



Pearson BTEC Nationals in Applied Science

Delivery Guide

Pearson BTEC Level 3 National Certificate in Applied Science

Pearson BTEC Level 3 National Diploma in Applied Science

Pearson BTEC Level 3 National Extended Certificate in Applied Science

Pearson BTEC Level 3 National Extended Diploma in Applied Science

Pearson BTEC Level 3 National Foundation Diploma in Applied Science

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Welcome to your BTEC National delivery guide

This delivery guide is a companion to your BTEC Level 3 National specifications, Authorised Assignment Briefs (AABs) and Sample Assessment Materials (SAMs). It contains ideas for teaching and learning, including practical activities, realistic scenarios, ways of involving employers in delivery, ways of managing independent learning and how to approach assessments. The aim of this guide is to show how the specification content might work in practice and to inspire you to start thinking about different ways to deliver your course.

The guidance has been put together by tutors who have been close to the development of the qualifications and so understand the challenges of finding new and engaging ways to deliver a BTEC programme in the context of the new qualifications from 2016.

Guidance around what you will need to consider as you plan the delivery of the qualification(s) has been provided. You will find information around the structure of your course, how you may wish to build the course for your learners, suggestions for how you could make contact with employers and information around the other support and resources available to you.

Unit-by-unit guidance has been provided and includes suggestions on how to approach the learning aims and unit content, as well as ideas for interesting and varied activities. You will also find coverage of assessments, including useful advice about external assessment, as well as tips and ideas around how to plan for and deliver your assignments.

You will also find a list of carefully selected resources for each unit. The lists include suggestions for books, websites and videos that you can either direct your learners to use or that you can use as a way to complement your delivery.

We hope you will find this guidance relevant and useful.

Enjoy your course!

What's new

The BTEC Level 3 Nationals 2016 are the result of more than three years' consultation with employers, higher education institutions, and many thousands of tutors and managers in colleges and schools. Our aim has been to ensure the BTEC Level 3 Nationals continue to allow a recognised and well-respected route into employment or higher education by meeting the needs of these key stakeholders, and that learners continue to enjoy a stimulating course of study and develop the skills and attributes that will enable them to progress.

As a result of this consultation, and on the advice of employers, higher education and most importantly of those of you who teach BTEC, some key changes have been made to the BTEC Level 3 Nationals. These are described through this delivery guide and include the following.

- **Updated content and a larger proportion of mandatory content** – both employers and universities said they wanted a greater consistency in coverage of the subject for BTEC learners. Employers wanted to see systematic coverage of core knowledge and skills for their sector, and for the Nationals to reflect up-to-date industry practice.
- **The re-introduction of external assessment** – employers were keen to see an element of rigour and consistency across the country in terms of assessment, while HEIs wanted learners to be better prepared for meeting

deadlines and preparing for formal exams, where appropriate. Both were keen to see learners applying their knowledge and skills to new contexts through synoptic projects and assessments.

- **A focus on employability skills** – the BTEC approach to learning, through projects, self-directed assignments, group work and work placements has always supported the development of employability skills, such as self-management. In the new Nationals the balance of cognitive and skills work has been carefully calibrated to ensure learners get a range of different opportunities across their course.
- **Broader assessment in internal units** – the assessment criteria for each unit are carefully structured to set a clear level of demand. Distinction criteria encourage and require depth of study, including demonstration of the application of knowledge and understanding as well as a synoptic element for the learning aim or unit.
- **Alignment with DfE criteria for performance measures for 16–19 year olds in England** – all new BTECs are designed as either Applied General qualifications or Tech Levels to fulfil criteria for inclusion in 2018 performance tables and funding for 16–19 year old and 19+ learners.

To support transition to the BTEC Level 3 Nationals 2016 we are providing an enhanced support programme with exemplar and practice materials available from the end of 2015 and training from April 2016. Please see the *Support and resources* section for details of the support and the link to sign up to training, which continues from 2016 and throughout the lifetime of the qualification.

Notes:

The specification tells you what must be taught and what must be assessed. This delivery guide gives suggestions about how the content could be delivered.

The suggestions given in this delivery guide link with the Authorised Assignment Briefs provided by Pearson but they are not compulsory. They are designed to get you started and to spark your imagination.



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1 BTEC LEVEL 3 NATIONALS

Introduction

With a track record built over 30 years of learner success, BTEC Level 3 Nationals are widely recognised by industry and higher education as the signature vocational qualification at Level 3, providing progression into the workplace either directly or via study at a higher level. Proof comes from YouGov research, which shows that 62% of large companies have recruited employees with BTEC qualifications. What's more, well over 100,000 BTEC students apply to UK universities every year and their BTEC Level 3 Nationals are accepted by over 150 UK universities and higher education institutes for relevant degree programmes either on their own or in combination with A levels.

Structures, purposes and progression

The Pearson BTEC Level 3 National Applied Science suite of qualifications has been designed for post-16 students wishing to continue their education through applied learning, and who aim to progress to higher education, an apprenticeship or employment. There are five qualifications in the suite; each is equivalent in size to a specific number of A levels.

The qualifications have been designed so that they can be delivered as full-time programmes over one or two academic years. Learners who wish to complete a Level 3 qualification will have successfully completed a Level 2 programme of learning. In addition to the applied science sector-specific content, the requirements of these qualifications give learners the opportunity to develop the transferable and higher-order skills that are highly regarded by higher education and employers.

There are five sizes of qualification available in the BTEC Level 3 National Applied Science suite, each with a distinct purpose

<https://qualifications.pearson.com/en/qualifications/btec-nationals/applied-science-2016.html>. The five qualifications in the suite each have a separate specification with information relevant to that specific qualification.

An 'at a glance' summary table of the structure of the qualifications has been provided below, but you should ensure that you use the full structure found in *Section 2* of the specification when planning your course:

Qualification	Size – Guided Learning Hours	Size – number of units	Equivalent in size to
Pearson BTEC Level 3 National Certificate in Applied Science	180	2 units	0.5 A level
Pearson BTEC Level 3 National Extended Certificate in Applied Science	360	4 units	1 A level



Pearson BTEC Level 3 National Foundation Diploma in Applied Science	510	6 units	1.5 A levels
Pearson BTEC Level 3 National Diploma in Applied Science	720	8 units	2 A levels
Pearson BTEC Level 3 National Extended Diploma in Applied Science	1080	13 units	3 A levels

Progression routes from a BTEC Level 3 National in Applied Science qualification are varied and depend on a learner’s choice of qualification size. This delivery guide will enable you to help learners to choose the best qualification size for their needs. For example, a learner wishing to progress to higher education to continue their study of applied science may be best advised to complete the Diploma or Extended Diploma qualification.

The four smaller sizes of the BTEC Applied Science Level 3 Nationals in Applied Science qualification suite enable learners to progress to a larger size of the qualification, if they so wish, without having to repeat units.

All BTEC Level 3 National Applied Science qualifications carry UCAS points according to their size and are recognised by higher education providers as meeting admission requirements to many relevant courses.

Making the right choice for your learners

It is expected that as part of their recruitment process, all schools and colleges offering these BTEC Level 3 Nationals in Applied Science will review each learner’s prior achievement and aspirations in order to advise on the most appropriate study programme. The range of sizes available means that the qualifications can either be delivered on their own or combined in a variety of ways with other qualifications. The table below highlights a few examples of learners and their potential entry grades or situation, and the examples of potential qualifications and study programmes that might be suitable for them. It also gives some examples of the progression routes available and where they may wish to progress. The number of opportunities are vast, so these are just limited examples.

16-year-old student choice		
Progression intention	Prior achievement	Potential BTEC National route
Applied Science-related subject in HE	Equivalent to five GCSEs at grade 4 or above, including English and Maths	BTEC Level 3 National Extended Diploma in Applied Science
HE, but uncertain of final subject to be studied	Equivalent to five GCSEs at grade 4 or above, including English and Maths	BTEC Level 3 National Extended Certificate in Applied Science with A levels in e.g. Mathematics, Geography, Psychology depending on interests



HE, but uncertain as to course	Equivalent to five GCSEs at grade 4 or above, including English and Maths	<p>Year 1: BTEC Level 3 National Foundation Diploma in Applied Science.</p> <p>Year 2: If firming up for an Applied Science-related subject in HE, then continue to a BTEC Level 3 National Extended Diploma in Applied Science. If starting to look in other directions, a second BTEC Level 3 National Foundation Diploma in e.g. Sport, or Health and Social Care</p>
Applied Science-related subject in HE	Equivalent to five GCSEs at grade 4 or above, but without English and/or Maths	<p>Year 1: BTEC Level 3 National Extended Certificate in Applied Science with GCSE English and/or Maths</p> <p>Year 2: BTEC Level 3 National Diploma in Applied Science</p>
Applied Science Apprenticeship	Less than equivalent to five GCSEs at grade 4, and without English and/or Maths	<p>Year 1: BTEC First Extended Certificate in Applied Science with GCSE English and/or Maths.</p> <p>Year 2: BTEC Level 3 National Extended Certificate in Applied Science, perhaps continuing with English and/or Maths</p>

19+ student choice		
Progression intention	Prior achievement	Potential BTEC National route
HE or Apprenticeship	One- or two-year programme: BTEC Level 3 National Foundation Diploma	BTEC Level 2 First Diploma in Applied Science



Making contact with employers

You may already be engaging with local, regional and/or national employers in several ways. However, for those centres or subject areas that wish to improve or expand their employer engagement opportunities, below are some areas you may wish to pursue.

- Contact your local Chamber of Commerce and ask for details of their employers. These employers are often actively engaged in the community and they are often keen to work with young people. Details of smaller employers are useful as they are a great resource for work experience opportunities and are often willing to help learners develop the employability skills that they hope to see in their future employees.
- Approach a local large employer via their human resources and training department and confer with them to create a mutually beneficial relationship for them and your learners.

Although employer engagement is not mandatory for Applied General qualifications, ideas for employer involvement can be found on the last page of most units.

2 PLANNING THE DELIVERY OF YOUR COURSE

How should the units be delivered for specific programmes?

We understand that each centre is different and that it is not possible to provide a 'one size fits all' strategy for delivering BTEC Level 3 Nationals. Indeed, one of the key features of these qualifications is that their delivery and, to a large extent, their assessment can be tailored to meet the constraints of individual centres in terms of curriculum time, availability of laboratory space, equipment and staff expertise and availability. There are, however, requirements that must be met in relation to assessment plans and teaching and learning preceding assessment that will be discussed in later sections of this guide.

Types of delivery

How units are delivered is the prerogative of the centre. Some centres opt for a 'long and thin' delivery with units(s) taking most of the year to complete. Other centres adopt a 'short and fat' approach delivering and assessing units within a limited number of weeks/lessons. A common approach adopted by centres is to mix both strategies, using a 'long thin' approach for some units and the 'short fat' approach for others. Availability of specialist staff and/or visits to vocational settings or from experienced vocational practitioners and employers may determine when and how some specialist units are delivered.

- **'Long and thin'** delivery can allow a prolonged period of development for skills, knowledge and understanding, and confidence but can lead to loss of momentum and learner interest. It may involve additional time prior to assessment for revision.
- **'Short and fat'** delivery allows learners (and tutors) summative achievement to show progression, and can help identify key areas for development and support required in future units. This approach means learners have less time to develop skills, knowledge and understanding, and a maturity of approach that may lead to more mature outcomes for assessment evidence.

Integration vs stand-alone delivery of units

Integration and co-delivery of units can avoid unnecessary repetition of relevant unit content and can help consolidate understanding and skills. It also allows learners to transfer skills, as well as subject knowledge, to new situations, providing them with the opportunity to demonstrate and improve problem-solving and time-management skills.

Carrying out practical activities associated with the unit content for one unit can help learners develop the skills that will be assessed in other units. For example, titrations are part of the unit content for different units, e.g. Unit 13. Having completed this learning in one of these units can help prepare learners for the assessment in Unit 2. Conversely, learners could be encouraged to access



completed work for units delivered early in the course, in preparation for assessment in units delivered later. For example, work completed in Unit 2 may be useful if learners have then gone on to study Unit 13. It is good practice to draw attention to the vocational context of unit content, and to the relationship between different units and the study pathway that they have chosen to follow.

Every opportunity should be taken to deliver content in a vocational context and to involve local employers/businesses where possible. Learners should be encouraged to consider how what they are learning could be applied in a real-world situation. Many learners may have part-time jobs and should be encouraged to consider these in relation to what they are studying. This will help learners develop higher-order thinking skills that will enable them to achieve well, particularly in Units 3, 6 and 7.

Induction

A period of induction, not necessarily prolonged, should be included to help learners understand the demands of the course they have opted to study and the BTEC ethos and methodology. Self-management skills in relation to accepting responsibility for their own actions and meeting deadlines must be stressed. Referencing skills need to be covered, forms of plagiarism discussed, and potential consequences made clear to learners.

A set of *Skills for Learning and Work* activities covering areas such as these have been provided for download, and could be used during your induction session.

Ensuring learners are aware of the structure of units and how to use assignment briefs to best advantage can be discussed. The level and depth of responses required to meet each level of achievement, pass, merit and distinction should also be covered with learners and command word definitions used in the assessment criteria should be made available to them. A similar induction for BTEC Level 3 tutors, especially those new to delivery and assessment of BTEC work is also recommended as part of standardisation training at the beginning of each academic year and when/if new staff join the team during the year.

Creating a course

The flexibility of different size programmes and pathways offered by the BTEC Level 3 Nationals in Applied Science, while providing choice for learner progression, can produce challenges for centres. This section offers some suggestions to help centres understand and resolve some of these potential challenges.

There are three types of assessment in the BTEC Level 3 National Applied Science qualifications:

- assignment, set and marked internally
- task, set and marked externally
- written assessment, set and marked externally.

BTEC Level 3 National Certificate

There are two mandatory units for the **BTEC Level 3 National Certificate**:

- Unit 1 is an externally set and marked written assessment.
- Unit 2 is an internally set and assessed assignment.

If the BTEC Level 3 National Certificate is delivered as a one-year programme, consideration should be given to delivering both Unit 1 and Unit 2 concurrently (long and thin) throughout the year. The internally assessed Unit 2 must be completed and available for Standards Verification by mid-May. This would allow time for revision for Unit 1 prior to the external assessment in May/June. Delivering the chemistry content in Unit 1 first would help learners consolidate knowledge and understanding that can be incorporated into their evidence for their Unit 2 assignments.

If these units are being delivered as part of a larger one-year programme, the chemistry content in Unit 1 could be delivered alongside the teaching and learning of Unit 2, while the biology and physics content from Unit 1 could be incorporated into the teaching and learning for relevant optional unit(s) as chosen by the centre. Each unit specification indicates links to other relevant units. Unit 1 could be delivered long and thin over the year while Unit 2 could be delivered short and fat within a few weeks.

BTEC Level 3 National Extended Certificate

Learners following the **BTEC Level 3 National Extended Certificate** may be enrolled on a one-year full-time course and be studying other Level 3 BTECs or A levels, possibly with Maths and/or English Level 2. Alternatively, the Extended Certificate may be delivered as a part-time stand-alone course.

There are three mandatory units for the Extended Certificate:

- Unit 1 is externally set and examined.
- Unit 2 is internally set and assessed.
- Unit 3 is externally set and assessed.

Depending on staff availability, it may be good practice to run all three mandatory units concurrently, i.e. long and thin. The chemistry content in Unit 1 could be included in teaching and learning for Unit 2.

Mandatory internally assessed unit	Delivery suggestions
Unit 2	<p>It may be suitable to run this unit concurrently with the mandatory externally assessed units. The practical work for Unit 2 will provide experience and support learner achievement for Unit 3 and the chemistry content in Unit 1 can be included in the teaching and learning content of this unit.</p> <p>It is essential that Unit 2 is completed in good time for submission to the Standards Verifier, no later than the end of May.</p>



Externally assessed mandatory units	Delivery suggestions
Unit 1 and Unit 3	<p>Assessment for Unit 3 is available during a three-week period timetabled by Pearson twice a year: Dec/Jan and between April and May Unit 3 has a two-week preparation period for Part A with assessment (Part B) occurring at a single sitting during the third week.</p> <p>It may be suitable to run this Unit 3 concurrently with the mandatory, internally assessed unit. The practical work for Unit 2 will provide experience and support learner achievement for Unit 3 and the chemistry content in Unit 1 can be included in the teaching and learning content of Unit 2.</p> <p>Unit 3 requires learners to have experience and skills in planning, carrying out, collecting, processing, and evaluating data and experimental design across investigations in all three scientific disciplines. All the Unit 3 content needs to be delivered in preparation for assessment. It is recommended that learners are offered as much opportunity as possible to cover the content in a practical context. Learners must be encouraged to develop a hypothesis for an investigation(s) and design investigations even if they are not going to carry them out.</p> <p>Data can be provided to learners for processing, analysis and evaluation without an investigation having been carried out. Learners with weaker mathematical skills should be provided with additional support and time may be required to develop them to meet the demands of this Level 3 unit. This could possibly be incorporated into maths lessons.</p> <p>If undertaking practical work on plant growth and/or distribution, you will need to consider the practical element of ensuring it is delivered at an appropriate time of year.</p> <p>Health and safety must be discussed, and risks and hazards understood and taken into consideration when investigations are planned.</p>
Optional internally assessed units	Delivery suggestions
One optional unit from Units 8–16 must be delivered and assessed	Optional Units 8, 9, 10 and 11 will link with aspects of the Unit 3 content. Unit 15 will provide links to the electrical circuits content found in Unit 3. The centre can choose to deliver the optional units long and thin or short and fat but arrangements for the units to be available for Standards Verification must be considered when the centre assessment plan is being developed.

Completing only Units 1 and 2 in the year would allow the BTEC Level 3 National Certificate to be claimed as a fallback.

BTEC Level 3 National Foundation Diploma

The **BTEC Level 3 National Foundation Diploma** is designed as a one-year, full-time course or as part of a two-year, full-time programme with opportunity for inclusion of other BTEC National Level 3 courses or A levels. It consists of four mandatory and two optional units to be selected from Units 8–19.

Mandatory internally assessed units	Delivery suggestions
Units 2–4	The mandatory internally assessed Unit 2 could be delivered as indicated for the Extended Certificate. Unit 4 needs to be available for Standards Verification by the end of May. Unit 4 links with mandatory Units 2 and 3, and optional Units 18 and 19. It is probably good practice to deliver Unit 4 in a 'short and fat' delivery.
Externally assessed mandatory units	Delivery suggestions
Unit 1 and Unit 3	The mandatory externally assessed Units 1 and 3 could be delivered as indicated for the Extended Certificate delivery.
Optional internally assessed units	Delivery suggestions
Two optional units from Units 8–19 must be delivered and assessed	The optional units would probably be better delivered 'short and fat' in the Autumn/Spring terms. This would help ensure they were available for Standards Verification in a timely manner. The need to include as much practical experience as possible to support Unit 3 cannot be overemphasised.

If only Units 1 and 2 are completed in year 1, learners can claim the BTEC Level 3 National Certificate as a fallback. If only Units 1, 2 and 3 and one optional unit are completed in year 1, learners can claim the BTEC Level 3 National Extended Certificate as a fallback.

BTEC Level 3 National Diploma

The **BTEC Level 3 National Diploma** is likely to be delivered full time, over two years, possibly alongside another BTEC National (Certificate/Extended Certificate) in a different subject or an A level in a complimentary or contrasting subject.

There are six mandatory and two optional units. Mandatory Units 1, 2, 3 and 4 are the same as for the smaller Foundation Diploma programme.



Mandatory internally assessed units	Delivery suggestions
Units 2, 4 and 6	<p>Delivering and assessing internally assessed Unit 2 'long and thin' in year 1 will allow content from Unit 1 to be integrated into the teaching and learning. This will support learners in completing the internally assessed practical work. It would be good practice to have the unit ready for Standards Verification by mid-May at the latest.</p> <p>Internally set and assessed Unit 4 can be delivered and assessed in year 1 and, if possible, should be completed and available for Standards Verification by mid-May. It should be possible to deliver and assess Unit 4 in year 1 or year 2 in conjunction with other optional chemistry units, if chosen.</p> <p>Unit 6 is internally set and assessed and provides the opportunity for learners to carry out an investigative project. This will build on the skills developed and assessed for Unit 3. Careful consideration will need to be given to the timing of this unit. It should be completed by mid-May in year 2, in time for Standards Verification. The unit specification is very open-ended and learners could choose to extend practical work from another unit, e.g. breeding of drosophila from Unit 11 or growth factors/requirements of plants/bacteria from Unit 10 and Unit 17 respectively.</p>
Externally assessed mandatory units	Delivery suggestions
Units 1 and 5, Unit 3	<p>Delivering externally set and assessed Units 1 and 3 'long and thin' in year 1 will allow assessment in summer of year 1 and a resit opportunity for learners in year 2, if required. (See information for Extended Certificate, Foundation Diploma and Extended Diploma about links with optional units.)</p> <p>If the externally assessed Unit 5 is delivered in summer of year 1 and during the autumn term of year 2, it would be completed for the first assessment opportunity in January of year 2. A resit opportunity would be available in the summer of year 2.</p>
Optional internally assessed units	Delivery suggestions
Two optional units must be selected from Units 8–23.	These will probably need to be delivered in year 2 but should be completed by mid-May in time for Standards Verification. Whether they are delivered 'short and fat' or 'long and thin' will depend on the units selected and tutor availability.

If only Units 1 and 2 are completed in year 1, learners can claim the BTEC Level 3 National Certificate as a fallback. If only Units 1, 2 and 3 and one optional unit are completed in year 1, learners can claim the Level 3 Extended Certificate as a fallback. If only Units 1, 2, 3 and 4 and two optional units are completed, learners can claim the Level 3 Foundation Diploma as a fallback.

BTEC Level 3 National Extended Diploma

BTEC Level 3 National Extended Diploma is designed as a two-year full-time programme. All the mandatory Units 1–7 must be completed plus six optional units. The choice of optional units provides additional flexibility for learners to choose options relating to specific career choices, or to ‘keep their options open’ if they do not have a specific preference at this stage. See the table below.

As with all BTEC programmes, when and how units will be delivered is the prerogative of the centre but the following points may need to be considered.

Mandatory internally assessed units	Delivery suggestions
Unit 2, Unit 4, Unit 6	<p>Unit 4 is internally set and assessed and is largely practical based. If delivered in year 1 this would provide further opportunities for development of practical skills to help prepare for Unit 3.</p> <p>Unit 6 is internally set and assessed and provides the opportunity for learners to carry out an investigative project. This will build on the skills developed and assessed for Unit 3. Careful consideration will need to be given to the timing of this unit. It should be completed by mid-May in year 2, in time for Standards Verification. The unit specification is very open-ended and learners could choose to extend practical work from another unit, e.g. breeding of drosophila from Unit 11 or growth factors/requirements of plants/bacteria from Unit 10 and Unit 17 respectively, chemistry of combustion from Unit 25, or velocity and friction from Unit 26.</p> <p>It is important to remember that internally assessed units need to be available for Standards Verification as soon as possible and the process must have been completed and certification claims, if relevant, made by the middle of July for issue of results in the summer results series. Completing internally set and assessed units by mid-May (three or four units should be completed in year 1) will allow time for preparation for the external task and assessment for Unit 3 and for revision of Unit 1 for June.</p>
Externally assessed mandatory units	Delivery suggestions
Unit 1, Unit 3, Unit 5, Unit 7	<p>Units 1 and 5 underpin scientific knowledge and understanding for many of the other units. It may well be good practice to deliver these long and thin to allow content to be correlated with other units that are being delivered. Many centres may wish to allow learners to have an opportunity to resit these externally examined units. Unit 1 will need to be completed for June 2017 with a resit opportunity in January or June 2018. Unit 5 could be partly delivered starting later in the first year of the programme,</p>



	<p>e.g. in the summer term, and be completed in the first term of year 2. This would allow for first entry in January 2018, with a resit opportunity in June 2018.</p> <p>Assessment for Units 3 and 7 are available during a three-week period timetabled by Pearson twice a year: Dec/Jan and between April and May Each unit has a two-week preparation period for Part A with assessment (Part B) occurring at a single sitting during the third week.</p> <p>Unit 3 is designed to assess learners' ability to plan, record, process, analyse and evaluate scientific findings, using primary and secondary information/data. The first assessment will be available between April and May 2017 and most centres may want to allow an opportunity for assessment at this point. Learners will need to have had a lot of experience of practical work if they are to achieve at a high level in this unit. This may influence the optional units that you choose to deliver in year 1 of the programme. For instance, Unit 11 allows learners access to a number of the statistical tests for calculations and evaluation of data listed in Unit 3 content.</p> <p>Once the external assessment of Unit 3 is completed, Unit 5 delivery and the introduction of at least one more optional unit should be considered.</p> <p>Learners would be able to resit Unit 3 in 2018. This may overlap with a similar assessment period for Unit 7. It is always good practice to encourage learners to aim high on the first attempt and not to rely on a resit.</p> <p>Unit 7 is externally set and assessed over a three-week period between April and May. Learners are required to demonstrate their skills and understanding in evaluating the impact of contemporary scientific issues and how they are discussed in publications. Part A involves learners researching and understanding three articles supplied by Pearson during a two-week timetabled period. In week three, learners will have a maximum of two and a half hours, in one sitting, to complete Part B, a written task to be submitted to Pearson for assessment. To achieve well in this unit, learners need to have experience of contemporary issues and how they are discussed in different types of media, and have experiences of discussing, analysing and evaluating them. To support learners for this unit, centres need to encourage reading and debate around contemporary issues. This can be linked to each unit they are studying during the programme.</p> <p>Completing the internally assessed Unit 2 early in year 1 would be good practice. Teaching and learning can be linked to the chemistry section of Unit 1 and possibly Unit 5. The practical work, analysis and evaluation of results undertaken by learners will help develop and consolidate skills to support Unit 3.</p>
<p>Optional internally assessed units</p>	<p>Delivery suggestions</p>
<p>Six optional units must be selected from Units 8–</p>	<p>When choosing the optional units you should ensure that opportunities for learners to select specialist pathways from</p>

26.	<p>the Extended Diploma are not compromised (see more information below). It is also worthwhile considering that Units 2 and 4 contain a substantial amount of chemistry content and that content in Unit 3 also requires learners to have experience of other scientific disciplines.</p> <p>Introducing another optional unit requiring a significant amount of practical work in year 1 would be useful in supporting Unit 3.</p>
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Completing Units 1 and 2 will allow a fallback Level 3 BTEC National Certificate to be claimed should the learner decide to leave after year 1. Delivering and assessing another optional internally assessed unit from 8–19 will provide a fallback for claiming the Level 3 BTEC National Foundation Diploma at the end of year 1.

BTEC Level 3 National Extended Diploma general route and specialist pathways

The **BTEC Level 3 Extended Diploma** has an applied science general route and three specialist pathways available within the programme and the optional units are grouped accordingly (see the table below):

- **Applied Science:** select a maximum of three units from each group OS 1, OS 2 and OS 3.
- **Biomedical Science:** select a minimum of four units from OS 4 and a maximum of two units from OS 5
- **Analytical and Forensic Science:** select a minimum of four units from OS 6 and maximum of two units from OS 7
- **Physical Science:** select a minimum of four units from OS 8 and a maximum of two units from OS 9.

Six units from:	Applied Science			Biomedical Science		Analytical and Forensic Science		Physical Science	
	OS1	OS2	OS3	OS 4	OS 5	OS 6	OS 7	OS 8	OS 9
8 Physiology and Human Body Systems	Y			Y			Y		Y
9 Human Regulation and Reproduction	Y			Y			Y		Y
10 Biological Molecules and Metabolic Pathways	Y			Y			Y		Y
11 Genetics and Genetic Engineering	Y			Y		Y			Y
12 Diseases and Infections	Y			Y			Y		Y
13 Applications of Inorganic Chemistry			Y		Y	Y		Y	
14 Applications of Organic Chemistry		Y			Y	Y			Y
15 Electrical Circuits and			Y		Y		Y	Y	



their Application									
16 Astronomy and Space Science			Y		Y		Y	Y	
17 Microbiology and Microbiological Techniques	Y			Y			Y		Y
18 Industrial Chemical Reactions			Y		Y		Y	Y	
19 Practical Chemical Analysis		Y			Y	Y		Y	
20 Biomedical Science	Y			Y			Y		Y
21 Medical Physics Applications			Y	Y			Y	Y	
22 Materials Science		Y			Y	Y		Y	
23 Forensic Evidence, Collection and Analysis		Y			Y	Y			Y
24 Cryogenics and Vacuum Technology			Y		Y		Y	Y	
25 Forensic Fire Investigation		Y			Y	Y			Y
26 Forensic Traffic Accident Investigation		Y			Y	Y			Y
	3 MAX	3 MAX	3 MAX	4 MIN	2 MAX	4 MIN	2 MAX	4 MIN	2 MAX

When making optional unit choices, you should avoid limiting learners' options in the future, should they decide to change their specialist pathway.

- For instance, if a learner had completed Units 8, 9 and 10, it would mean that they could not easily transfer to Analytical and Forensic Science or Physical Science as they would have more than the maximum number of units allowed from OS 7 (Analytical and Forensic Science) or OS 9 (Physical Science.)
- Similarly, if a learner had completed Units 18, 21 and 24, they could not easily transfer to Analytical and Forensic Science. The maximum number of units for OS 7 has been exceeded.
- If a learner had completed Units 22, 23 and 25, it would be difficult for them to transfer to Biomedical Science, as the maximum number of units for OS 5 has been exceeded.

3 EMPLOYABILITY

Employability skills

Helping learners to progress into employment has always been a cornerstone of BTEC qualifications. Equipping learners with the skills they will use in the workplace is at the very heart of BTEC and remains an important driver in determining the content of each qualification. When developing our qualifications we work closely with employers to understand the skills they are looking for in new entrants to their industries. Employers are often looking not only for technical skills, knowledge and understanding but also for those attributes that can be termed **employability skills**. These are the skills which underpin the different tasks and duties which a person can be expected to undertake in their role and which are applicable across sectors.

Unlike technical skills, which may become outdated over time, employability skills enable learners to adapt to the ever-changing roles needed to survive in the global economy.

The Confederation of British Industry (CBI) definition of employability skills is based on a positive attitude (readiness to take part, openness to new ideas and activities, desire to achieve) which underpins seven characteristics:

- 1 **Self-management:** readiness to accept responsibility, flexibility, time management, readiness to improve own performance.
- 2 **Teamworking:** respecting others, co-operating, negotiating/persuading, contributing to discussions.
- 3 **Applied Science and customer awareness:** basic understanding of the key drivers for Applied Science success and the need to provide customer satisfaction.
- 4 **Problem solving:** analysing facts and circumstances and applying creative thinking to develop appropriate solutions.
- 5 **Communication and literacy:** application of literacy, ability to produce clear, structured written work, and oral literacy (including listening and questioning).
- 6 **Application of numeracy:** manipulation of numbers, general mathematical awareness and its application in practical contexts.
- 7 **Application of information technology:** basic IT skills including familiarity with word processing, spreadsheets, file management and use of internet search engines.

In the annual CBI/Pearson education and skills survey, *Inspiring Growth 2015*, it was noted that employers (+65 per cent) expect to need more employees with higher skills. They also report that there needs to be more done around skills in basic literacy (50 per cent), numeracy (50 per cent) and IT skills (46 per cent).

The development of employability skills has been considered during the creation of this BTEC Applied Science suite of qualifications. The table below shows some of the instances where employability skills have been embedded in the mandatory units.



4 MYBTEC

myBTEC is an online tool designed to support the administration of delivering BTEC courses. This service will be available free to centres offering supported qualifications.

Control all your BTEC provision from one place

Complete visibility of all courses, assessment, internal verification and results at your centre.

- See the complete assessment schedule for every course at your centre.
- See all assessment decisions and verification processes.
- Track the progress of every learner throughout their course.
- 90% of BTEC Firsts (next generation) and Nationals (QCF) supported.

Built by Pearson, for BTEC

Designed specifically for BTEC qualifications, so you know you're doing it right.

- Designed to help you meet all requirements of BTEC assessment and awarding, including next generation.
- Courses automatically checked against rules of combination.
- Design your own assignments, or use the pre-loaded Authorised Assignment Briefs.
- Calculates scores and predicted grades automatically.

Access for the full team

Full access for the entire delivery team, whatever their department or role.

- Access for the full team, whatever their role, in as many BTEC subjects as they deliver.
- Login with your Edexcel Online password.
- Quality Nominee has ultimate control over access.

Saves you time

Enter your information once; download and export at will.

- Automatically generates the documents and tracking screens you need.
- Export and download data and documents or data whenever you need to – no need to copy it out again.

Easy to use and fully supported

Step-by-step wizards for the key tasks; walkthrough videos and other resources available on-demand.

- Browser based, so it works from anywhere.
- Step-by-step wizards for the key tasks.
- Walkthrough videos and help content on our website and in the platform.

To get started, all you need is an Edexcel Online account (your centre's Exams Officer can set one up) and for the myBTEC profile box to be ticked.

To log in to the service, go to: mybtec.pearson.com

For help, support and user guides, or to sign-up for a free online training event, go to: quals.pearson.com/mybtec

5 SUPPORT AND RESOURCES

There are a wealth of resources available to ensure you feel confident delivering your BTEC National qualification throughout your entire course. Refer to the Pearson website for a full list of resources available:

<http://qualifications.pearson.com/en/qualifications/btec-nationals/applied-science-2016.html>

As well as the free resources supporting the qualification, provided by Pearson as an Awarding Organisation, Pearson Learning Services ('Publisher' in the tables below) provides a range of engaging resources to support BTEC Level 3 Nationals, including:

- textbooks in e-book and print formats
- revision guides and revision workbooks in e-book and print formats
- teaching and assessment packs, including e-learning materials via the Active Learn Digital Service.

	Plan	Teach	Track and assess	Develop
	Support to help you get ready to teach and plan	Resources to support your impact on learner outcomes	Support to track progress and help you prepare for assessment	Professional development to support great teaching
AWARDING ORGANISATION	<ul style="list-style-type: none"> • Get to know your course: Specification, SAMs, Delivery Guide • Recruit and prepare learners: Learner profiles, Skills for Learning and Work Activity Sheets • Expert help and support: Subject Advisors • Course planning: myBTEC, Delivery Plans, Curriculum Models, Authorised Assignment Briefs, Get Ready to Teach events 	<ul style="list-style-type: none"> • Resources for teaching: Delivery Guides, Schemes of Work, Skills for Learning and Work Activity Sheets • Training: face-to-face training events with focus on troubleshooting eg delivery of externally-assessed units 	<ul style="list-style-type: none"> • Guidance: Quality Assurance Guides, Standards Verifier and Quality Review visit, Standardisation training, Authorised Assignment Briefs • Examples of the standard: past papers, specimen papers and tasks for practice, sample marked learner work • Templates and tools: myBTEC progress tracking • Reports and feedback: PSV reports, examiner reports 	<ul style="list-style-type: none"> • Training: Launch events, Get Ready to Teach events • Collaborative networks to support centres with employer involvement
PUBLISHER		<ul style="list-style-type: none"> • Student Book • Revision Guides and Revision Workbooks 	<ul style="list-style-type: none"> • Student Book with assessment tips and self assessment activities • Revision Guides/Workbks 	<ul style="list-style-type: none"> • Professional Development courses

In addition to the 'publisher' resources listed above, other publishers in addition to Pearson may produce textbooks that are endorsed for BTEC. Check the Pearson website (<http://qualifications.pearson.com/en/support/published-resources.html>) for more information as titles achieve endorsement.



Plan

Support to help you get ready to teach and plan

AWARDING ORGANISATION

- Get to know your course: Specification, SAMs, Delivery Guide
- Recruit and prepare learners: Learner profiles, Skills for Learning and Work Activity Sheets
- Expert help and support: Subject Advisors
- Course planning: myBTEC, Delivery Plans, Curriculum Models, Authorised Assignment Briefs, Get Ready to Teach events

Sample Assessment Materials: sample assessments, complete with mark schemes, to help you plan how to prepare learners for the external assessments.

Delivery Guides: an example of how you could structure your course at different sizes of qualification over one or two years, with details of which units would suit teaching together and highlighting key dates.

Authorised Assignment Briefs: briefs approved by Pearson Standards Verifiers (remember that they must still be verified at every use) available through the Pearson website and on myBTEC.

Mapping documents: will provide a resource as to where the new 2016 qualification retains the same or similar content as the 2010 qualification.

Teach

Resources to support your impact on learner outcomes

AWARDING ORGANISATION

- Resources for teaching: Delivery Guides, Schemes of Work, Skills for Learning and Work Activity Sheets
- Training: face-to-face training events with focus on troubleshooting eg delivery of externally-assessed units

PUBLISHER

- Student Book
- Revision Guides and Revision Workbooks

Schemes of Work: available as customisable Word™ files for all mandatory units in each sector; to provide ideas for teaching and learning activities.

Skills for Learning and Work: activity sheets to be used during the induction process, introducing learners to their BTEC course and helping them think about learning strategies and how best to approach their work.

Track and assess

Support to track progress and help you prepare for assessment

AWARDING ORGANISATION

- Guidance: Quality Assurance Guides, Standards Verifier and Quality Review visit, Standardisation training, Authorised Assignment Briefs
- Examples of the standard: past papers, specimen papers and tasks for practice, sample marked learner work
- Templates and tools: myBTEC progress tracking
- Reports and feedback: PSV reports, examiner reports

PUBLISHER

- Student Book with assessment tips and self assessment activities
- Revision Guides/Workbks

Sample Marked Learner Work: exemplar marked learner work for selected internal and external units to help you understand the expectations of the standard for each grade.

Sample Assessment Materials: additional sample papers will be available from September 2016 for units that are first assessed in Summer 2017. For units first assessed in 2018, additional SAMs will be available from 2017. Past papers will be published following each assessment, complete with mark schemes, on or before results day for that series. Examiners' reports will also be available from 2017. Further assessment materials will be made available as the course progresses. These materials can be found on Edexcel online.

Training: we have a range of events to help you in every aspect of planning, teaching and assessing your BTEC. To make it as easy as possible for you to benefit from our training, many of our face-to-face events are available as online sessions, and you can request for any of our events to be delivered in your centre.

Develop

Professional development to support great teaching

AWARDING ORGANISATION

- Training: Launch events Get Ready to Teach events
- Collaborative networks to support centres with employer involvement

PUBLISHER

- Professional Development courses



There are also a number of people who are available for you to speak to:

Subject Advisor

Stephen Nugus

UK: 020 7010 2190

Intl: + 44 (0)20 7010

TeachingScience@pearson.com

[Join Stephen on Facebook](#)

□

- **Standards Verifiers** – they can support you with preparing your assignments, ensuring that your assessment plan is set up correctly, and support you in preparing learner work and providing quality assurance through sampling.
- **Curriculum Development Managers (CDMs)** – they are regionally based and have a full overview of the BTEC qualifications and of the support and resources that Pearson provides. CDMs often run network events.
- **Customer Services** – the 'Support for You' section of our website gives the different ways in which you can contact us for general queries. For specific queries, our service operators can direct you to the relevant person or department.

Training for the new BTEC Level 3 Nationals can be found on the Pearson website here: □

<http://qualifications.pearson.com/en/support/training-from-pearson-uk.html>

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qualifications.pearson.com

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Unit 1: Principles and Applications of Science I

Delivery guidance

Approaching the unit


This is an externally assessed unit that gives your learners the knowledge and understanding that underpins progression in the science sector and on to science higher nationals and degrees.

Delivering the topics

For **topic A**, a good starting point would be to give learners a copy of the Periodic Table of the elements and exploring what information can be obtained from it (that is, arrangement of the elements, atomic and mass numbers, relative atomic masses, and the relationship between group and period position to the electronic structure of atoms). You could use demonstrations of elements' properties and reactions to illustrate points (for example, group 1 metals with water, group 7 displacement reactions). You could then give problems to learners to draw simple electron configurations for atoms and then you can discuss with learners the limitations and anomalies of the Bohr model. You can build on this by introducing the concepts of electronic orbitals, the Aufbau principle and s, p and d block elements and s, p, d notation. Learners could then revisit their problems with this new information. Subsequent sessions should move on to include compounds, their bonding (ionic, covalent or metallic) and structure. This would be linked to practical work where learners could investigate the properties of unknown substances (such as conductivity, solubility and relative melting and boiling points), and attempt to classify the type of bonding and structure. Underpinning theoretical work will include drawing dot and cross diagrams and structural cross-sections, explaining the nature of the bonding and its influence upon a substance's physical properties. Factors such as bond strength and length, lattices and molecular shape, and the role of intermolecular forces (van der Waals, dipole-dipole and hydrogen bonding) must also be included in the explanations.

Learners should then move on to look at periodicity of the elements by considering physical and chemical properties. They could research data for physical properties for atoms of elements and explain trends in properties across periods and down groups in terms of atomic and electronic structure. Explanation of changes in macroscopic physical properties, such as conductivity, melting and boiling point, need to be explained in terms of changes in bonding and structure for the elements. You should give learners practical investigations or get them to observe demonstrations for e.g. reactions of elements in periods 2 and 3 with oxygen; metals with oxygen, water and acids; and displacement reactions for metals and halogens. They will need to describe and explain trends in reactivity observed and identify oxidation and reduction. For the reactions, learners must construct chemical equations and name products formed.

You could give learners quantitative practicals such as gravimetric analysis of solids, preparation of standard solutions and titration of acids and alkalis to



determine concentrations, percentage yields, reacting quantities and balance equations.

You can give opportunities throughout the delivery and learning of this topic for learners to present their own research on substances and their applications to the group.

For **topic B**, learners need to complete practical work and assessors will assess and validate this. Centres must ensure they comply with all health and safety guidance and regulations. Learners must be encouraged to risk assess practical work to help ensure they are aware of the safety issues and follow the relevant procedures and guidelines.

Use of simulation and animations of cells and cell organelles using both optical microscopes and electron micrographs could offer stimulus material to aid recall of knowledge from level 2 and allow learners to extend their understanding of the structure and functions of cells. Model making using paper shapes or jelly cells with sweets to simulate cell organelles can be useful to help some learners understand the concept and also to distinguish between plant and animal cells. The production of biological diagrams is essential in terms of understanding the structures and the ability to complete magnification calculations is imperative. You should ensure that learners are able to identify prepared slides showing gram-positive and gram-negative bacteria and understand their use in antibiotic preparation.

In preparation for assessment, learners will need to have had the opportunity to prepare and stain microscope slides for examination. Learners may need to revise handling and use of microscopes. You need to demonstrate good biological drawing technique. You should give learners opportunities for practice prior to assessment using, for instance, purchased prepared microscope slides of material other than that to be assessed. Photomicrographs, simulations from the internet and textbooks should be available, in conjunction with purchased slides showing specialised cell structures. Kinaesthetic learners may benefit from the opportunity to model the sperm and ovum in order to understand fully the size and structure of these specialised cells.

Once again, you will need prepared slides in order to compare the epithelial tissues. Demonstration of an animal pluck will allow the learners to relate the micro to the macro structure of the lungs to understand the hierarchy of cells, tissue and organs. Written lab reports of the practical investigation into the relative strength of arteries and veins should be written and evaluated. You could organise visits to hospitals to see ECG traces and understand how to interpret these. Presentation of personal research into neurotransmitters and naturally occurring brain chemicals to the assessor and other learners will further reinforce the learning. Scientific articles in magazines can reinforce understanding of new developments into the treatment of depression and Parkinson's disease as this is an exciting area of development.

For **topic C**, learners must develop an understanding of the theory of both transverse and longitudinal waves and be able to use this theory to understand and explain the importance of waves in a variety of applications. Learners need to see superposition effects to understand this concept. You can best do this through practical demonstrations or the use of online resources. Learners should have the opportunity to use diffraction gratings to produce spectra and be able to take measurements from vibrating strings and air columns to study the characteristics of notes produced by musical instruments. Refraction of light and the measurement of critical angles is another practical activity that learners can carry out. You can then apply these concepts to optical fibres and their uses in medicine and communication. Learners also need to appreciate the difference between analogue and digital signals, and the importance of the regions of the



electromagnetic spectrum in producing the high-quality signals needed for modern day communication systems.

As concepts in physics are expressed mathematically, this topic requires that learners need to be able to use the relevant equations and are able to apply mathematical skills to problems in physics. Learners need to be able to transform equations, use standard form and trigonometric functions. They must also be familiar with the accepted symbols that are used for quantities given in equations, give units in standard form and know the standard prefixes to indicate multiples or fractions of a unit. Throughout the course, you should stress accurate use of symbols and units as well as always showing the working for calculations. Prior to the examination learners should be given a suitable time for revision, which the assessor will lead. This should include a discussion of examination technique, review of the examination command words as well as completion of exemplar material.

Assessment guidance

This unit will be assessed through a 120-minute written exam worth 90 marks. The paper is split into three sections, and each section (biology, chemistry and physics) is worth 30 marks. The exam will be set and marked by Pearson.

The paper will include a range of question types. These include:

- multiple choice
- calculations
- short answer
- open response.

These question types are intended to assess learners' discrete knowledge and understanding of the content in this unit.

Sample assessment materials will be available to help centres prepare learners. You should also give learners the table of command words found in the specification and talk through the words.

Getting started

This gives you a starting place for one way of delivering the unit. Activities are supplied in preparation for the external assessment.

Unit 1: Principles and Applications of Science I

Topic A – Periodicity and properties of elements

A1 Structure and bonding in applications in science

A2 Production and uses of substances in relation to properties

- Learners can discuss what they already know about the periodic table of elements, its value to chemists and information that they can take from it, as a means to get everyone to the same starting point. Tutor input can then fill gaps in knowledge and extend understanding of the atomic model further into orbitals and s, p and d notation.
- Theoretical sessions should be regularly interspersed with practical activity sessions such as the decomposition of a group 2 carbonate, the preparation of a standard solution, and acid-base and redox titrations. You can link this to the use of the Periodic Table to undertake mass, volume and molar calculations, and the writing of balanced equations.
- Learners can move on to compounds and use the periodic table to solve problems involving the deduction of formulae and drawing diagrams to represent the bonding between atoms. The theory can again be interspersed with practical investigations so that learners can determine the differences in properties between metals, ionic and covalent compounds, such as solubility, electrical conductivity and melting points.
- You can give a project to learners to look at different substances and their everyday use or application. Learners can then present their findings back to the group, giving explanations of the substance's properties and justification of its use rather than alternative substances.
- Learners will then look at trends in physical properties across periods and down groups by being set a research-based task to find data relating to first ionisation energy, electron affinity, electronegativity and atomic and ionic radius. Learners could tabulate the data or present it in graphical form, and supplement it with an explanation.
- Practical work or tutor demonstrations should form the basis of the learners' understanding of the chemical properties of the elements. Practical activities should include period 2 and 3 elements burning in oxygen, the reaction of metals with water and acids, and displacement/redox reactions, so that learners can observe relative reactivity down groups and across periods. You should give them the opportunity to explain their observations, write equations and carry out quantitative calculations.

Topic B – Structure and function of cells and tissues

B1 Cell structure and function

- Learners should carry out practical work to practise preparation of microscope slides and use microscopes. Your input about good drawing technique and opportunity to practise skills will be required.



Unit 1: Principles and Applications of Science I

- Use optical microscopes to observe slides of various types of bacterial cells to distinguish prokaryotes and compare these to electron micrographs of subcellular structures.
- Calculate the size of cells using 'I AM' calculations from direct viewing using an optical microscope or images from electron micrographs.
- Ask learners to label subcellular structures using electron micrographs in prokaryotic and eukaryotic cells.
- Make jelly cells to illustrate subcellular structures of eukaryotic cells using sweets as organelles for both plant and animal cells to distinguish specific structures.
- Arrange an assessor-led discussion showing three-dimensional views of cells to enable further understanding of these structures.
- Individual research into one subcellular structure to be presented to the class.
- Ask learners to carry out a research task into Hans Christian Gram to discover the difference between the staining of gram-positive and gram-negative bacteria. This task could also be extended to look at the uses of these bacteria in everything from medical treatment to Swiss cheese manufacture.

B2 Cell specialisation

- Optical microscopy will enable learners to look at specialised cells and drawing of biological structures in order to understand their complexity and structure function relationship.
- Model sex cells using modelling clay, paper and string to show size and major structures.
- Preparation and viewing of root hair cells from cress seeds works particularly well.
- View prepared blood smears to distinguish the various components of the blood.
- Production of cartoon strip on the action of the different white blood cells when encountering foreign pathogens.

B3 Tissue structure and function

- Allow learners to observe squamous and columnar epithelial tissue under optical microscopes and drawing of biological diagrams to reflect the differences and similarities.
- Demonstrate a pluck to illustrate the macro structure of the lungs including inflation of the lung to show the action of ventilation.
- Ask learners to carry out an investigation into the strength of arteries and veins to understand the differences between the different vessels.
- Learners should undertake research into respiratory and cardiovascular diseases due to smoking tobacco. Learners should research and present their findings back to the class in five-minute presentations.
- Assessor-led discussion about sliding filament theory with animation of the action of fast and slow twitch muscle fibres.
- Interpret ECG traces that can be sourced from local hospitals.
- Compare graphs of myelinated and non-myelinated neurones, comparing size and speed of action.
- Learners should research the action of neurotransmitters at the synapse.
- Use NASA's 'the brain in space' learning activity II to model axons.

**Unit 1: Principles and Applications of Science I**

- Learners could carry out a research task for feedback to groups into the action of dopamine and serotonin on the brain.

Topic C – Waves in communication

This topic will give learners the opportunity to study different types of waves and appreciate the importance of waves to many aspects of their lives. Most of the theory delivered is supported by practical experiments that encourage critical thinking, problem solving and team working. Learners will also learn to apply mathematical relationships to wave forms and develop communication skills by giving their own presentations. This, with time dedicated to revision, will give a good basis for success in the examination.

C1 Working with waves

- You should define the features of both longitudinal and transverse waves, carrying out experiments and demonstrations to support the understanding of wave motion.
- Light waves are applied to diffraction gratings and sound waves to musical instruments. Learners research further applications, select relevant information and make short presentations. The equations are given and verified by experiment. This tests problem solving, critical thinking and develops mathematical understanding.

C2 Waves in communication

- Learners need to understand the transmission of light through fibre optic cables and the uses of fibre optics in medicine and communication. Learners should carry out experimental work to show refraction and total internal reflection, and from the results they can calculate values of refractive index. This requires learners to work accurately, as they can compare their results with known values of refractive index.

C3 Use of electromagnetic waves in communication

- Learners will study the waves of the electromagnetic spectrum as a whole and the mathematical link between intensity and distance from the source of a wave should be established through experiment and then applied to the equation. Applications of various waves in the electromagnetic spectrum to modern day communication can then be researched and a short presentation given.
- Preparation of a revision timetable, time management of revision and tutor-led revision exercises will help prepare learners to attempt the sample examination material. This then gives a basis for tutor-led discussion and more focused revision prior to learners taking the examination.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit, alongside *Unit 5: Principles and Applications of Science II*, covers some of the fundamental core science concepts in biology, chemistry and physics.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/en/support/published-resources.html>) for more information as titles achieve endorsement.

Textbooks

Annets, F., *Applied Science L3 BTEC National*, Pearson Education, 2010 (ISBN: 978-1846906800).

The chapter on cells and tissue structure supports the unit content and has activities suitable for learners to access practice skills and acquire knowledge and understanding prior to assessment. Chapter 1 supports understanding of atomic structure, bonding and quantitative chemistry and Chapters 4 and 22 support an understanding of practical and analytical skills needed.

Chapman, B., Beavon, R. and Jarvis, A., *Structure, Bonding and Main Group Chemistry*, Nelson Thornes, 2003 (ISBN: 978-0748776559).

Good overview of the main features of the periodic table, groups, bonding and structure.

Clark, J., *Calculations in AS/A Level Chemistry*, Longman, 2000 (ISBN: 978-0582411270).

This book has many relevant calculations and worked examples.

Duncan, T., *Advanced Physics*, 5th edition, John Murray, 2000 (ISBN: 978-0719576690).

Has clear references to standard experimental activities and challenging problems.

Fullick, A. and McDuell, B., *Edexcel AS Chemistry Students' Book*, 1st edition, Longman, 2008 (ISBN: 978-1405896351).

Various chapters support understanding of periodicity, group 1 and 7 properties and reactivity.

Ramsden, E.N., *A-level Chemistry*, 4th edition, Nelson Thornes, 2000 (ISBN: 978-0748752997).

In-depth look at atomic theory, bonding and periodicity.

Ramsden, E., *Calculations for A-Level Chemistry*, Nelson Thornes, 2001 (ISBN: 978-0748758399).

This book has many relevant calculations and worked examples.

Journals

Chemistry World

www.rsc.org/chemistryworld

Education in Chemistry

www.rsc.org/Education/EiC

Guardian Science

www.guardian.co.uk/science

Nature

www.nature.com

New Scientist

www.newscientist.com

Scientific American

<http://www.scientificamerican.com>

Technical journals requiring high-level reading skills and ability to use and understand technical terms. They contain articles and latest news and research into related topics.

Videos

<https://www.youtube.com/watch?v=gFuEo2ccTPA>

An introduction to cells (2.55 mins).

<https://www.youtube.com/watch?v=4OpBylwH9DU>

History of cell theory TED ED.

Websites

www.cellsalive.com

This gives an overview of both prokaryotic and Eukaryotic cells and specialised cells including interactive cells and videos on microscopy.

<http://chemistry.about.com>

About Chemistry website – engaging chemistry practical demonstrations and videos.

www.cleapss.org.uk

Health and safety information when handling chemicals and performing experiments.

www.ibiblio.org/virtualcell

This shows a virtual cell and is an online textbook on cell structure.

www.mananatomy.com

A useful website for research into tissues and organs.

www.nasa.gov

Activities on the brain in space to model the axons.

www.nationalstemcentre.org.uk

National STEM (Science Technology Engineering and Mathematics) Centre website – resources for supporting delivery and learning, links with employers and industry.

www.nuffieldfoundation.org/practical-chemistry

Nuffield Foundation website – a good range of practical chemistry experiments.

www.physicsclassroom.com/gallery/waves

Photos of different types of waves.

www.rsc.org

Royal Society of Chemistry website – resources and videos to support the delivery of chemistry.



www.schoolscience.co.uk

Association of Science Education website – links to resources, activities, events and research.

http://spiff.rit.edu/classes/phys312/workshops/w10b/spectra/mystery_spectra.html

Using diffraction gratings to produce line spectra of elements.

www.youtube.com/watch?v=0MwMkBET_5I

Fibre optic cables.

www.youtube.com/watch?v=8VZHym6HqVU

TRI for semi-circular glass block.

www.youtube.com/watch?v=9LkLj8TS9VI

Different types of waves.

www.youtube.com/watch?v=BE827gwnnk4

Resonance in a wine glass.

www.youtube.com/watch?v=eAXVa_XWZ8

Millennium bridge.

www.youtube.com/watch?v=egRFqSKFmWQ

Diffraction single and double slit MIT.

www.youtube.com/watch?v=HPcAWNIVI-8

NASA tour of the electromagnetic spectrum.

www.youtube.com/watch?v=j-zczJXSxnw

Tacoma Narrows bridge.

www.youtube.com/watch?v=NpEevfOU4Z8

Standing water waves.

www.youtube.com/watch?v=RIx8jdhtngs

Resonance tube, pipe closed at one end (closed pipe).

www.youtube.com/watch?v=VE520z_ugcU

Wave machine demonstration.

www.youtube.com/watch?v=w2s2fZr8sqQ

Different types of waves.



Unit 2: Practical Scientific Procedures and Techniques

Delivery guidance

Approaching the unit

Your learners should be engaged in carrying out practical work, discussing the quality of their results and presenting their findings during almost every teaching session. Encourage learners to follow standard procedures and methods, and train them in the correct way to carry out techniques. Stress the importance of calibration and using equipment that is accurate enough for the task. Ensure that learners know these rules are vital to carrying out analysis accurately in an industrial laboratory.

Wherever possible, you should ensure that learners carry out practical activities on an individual basis so that every learner has the opportunity to become proficient in the practical techniques. You should arrange teaching and learning sessions for learners to practise the skills required before they carry out the assessment exercises. Merit-level learners must perform the assessment tasks with minimal supervision and perform to a high degree of accuracy and precision. You should allow enough time for all the learners to complete the assignment tasks at their own pace.

If some learners are ready for assessment sooner than others, they can be supported and directed to carry out additional research, prior to the assessment date. This could be in relation to developments and use of the techniques in industry that will afford them a better opportunity to address the higher criteria for learning aims where techniques need evaluating and suggestions for improvement are required. The time for additional research will be particularly useful for learning aim D, where opportunities for potential future development need to be considered.

Encourage learners to reflect on their work and to compare results with each other and with the correct values. Learners must learn to identify which measurements need to be exceptionally accurate and to justify their conclusions about the main sources of error in all the practical work undertaken, in a way that is specific to the task. You should give learners the chance to discuss their own personal practical performance with you and with others. Learners will collect evidence for the learning aim D (reflection on skills) assignment while undertaking the other learning aims.

Delivering the learning aims

Learning aim A introduces accurate measurement of mass and volume, which then allows learners to carry out acid-base titrations and colorimetry. You should plan a series of activities that will allow learners to gain confidence in the techniques that will be part of the assessment. These include:

- checking calibration of balances
- checking calibration of volumetric glassware by using the accurate density of water as a standard

- calibrating a pH meter and measuring pH
- making up solutions accurately
- carrying out acid-base titrations using indicators and a pH meter
- performing colorimetry
- processing results
- keeping records of calibration.

You should encourage learners to compare their results to other learners so they can reflect on their own level of competence. Once all the learners are confident in carrying out the techniques, they should attempt the assignment.

Learning aim B has the aim of measuring cooling curves as accurately as possible. This is not a standard laboratory technique in the same way as titration. Constructing and interpreting a cooling curve is an activity that should give all learners the opportunity to investigate how to collect and analyse their data in the most reliable way. You will give learners a basic and safe method of heating a solid to a temperature above its melting point so that they can gather temperature data as a function of time. You should allow learners to consider the variables involved in this simple experiment, such as:

- the time intervals
- the starting temperature
- the quantity of material to use
- the vessel to use
- how to mount the thermometer
- whether to cool the material in air or in a fluid such as water or oil
- how to plot the temperature/time graph
- how to draw accurate tangents and calculate cooling rate
- how to interpret the shape of the curve.

You should give learners the opportunity to compare the accuracy of different thermometers over a range of temperatures and to devise a convenient way of checking their calibration, e.g. comparison with an accurate thermometer or checking the freezing point of water and the boiling point of water.

Learning aim C introduces the technique of chromatography. It is important to use the correct terminology (e.g. 'mobile phase', 'stationary phase', 'solvent front', 'locating agent', 'polarity'). You should give learners the opportunity to devise a way of preparing a dark, concentrated extract of pigment from fresh leaves or from dried herbs by grinding with sand, extraction with a suitable solvent, filtration and concentration by evaporation. Learners will carry out paper chromatography and thin layer chromatography (TLC) of plant pigments. You could allow learners to explore the effect of varying the polarity of the solvent, using the extremes of 100% petroleum ether (not polar enough) and 100% propanone (too polar) as well as optimum mixtures (9:1 ratio of petroleum ether to propanone for paper and 7:3 ratio of petroleum ether to propanone for TLC). Ensure learners have the opportunity to explore the effects of changing the size and concentration of the spot on the final chromatogram. You should encourage learners to establish what a good separation of components looks like. Learners have the opportunity to use a locating agent (ninhydrin) when carrying out the paper chromatography of amino acids. You should give learners the opportunity



of applying the locating agent by even spraying. This experiment allows learners to measure the R_f values of the amino acids and to determine the amino acids present in a mixture. Learners must have the chance to discuss what went wrong when chromatograms do not have the expected appearance. Learners should undertake the assignment once they are confident in using the techniques.

Learning aim D is based on the work from the other three learning aims. From the start of the practical programme, ensure that learners keep a diary or a log of the skills that they are developing in each practical session, including those that are associated with assignments. The skills may be practical skills (e.g. the ability to weigh accurately) or interpretative (e.g. the ability to draw an accurate tangent to a cooling curve), or the personal competences identified in the unit content (e.g. communication or the ability to recognise problems and apply appropriate scientific methods to identify causes and achieve solutions). You should encourage learners to identify when they have used or improved skills, and where they may have missed an opportunity to develop their skills. Once learners have completed the assignments for learning aims A, B and C, they should be able to attempt the assignment for learning aim D.

It would be useful for learners to visit a local laboratory or to have a talk from someone working in one. The visit/talk could focus on safety, the importance of calibration and how technicians carry out calibration, the need to follow standard procedures and how the appraisal process may use reflection in order to identify individuals' strengths or areas for improvement. It would be interesting to highlight where a local laboratory may use the techniques that the learners have used in this unit. Throughout the unit, you should highlight the importance of carrying out procedures safely.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Undertake titration and colorimetry to determine the concentration of solutions	<p>A1 Laboratory equipment and its calibration</p> <p>A2 Preparation and standardisation of solutions using titration</p> <p>A3 Colorimetry</p>	<p>Pro formas of results for checking the calibration of a pipette and balance(s) and calibration of a pH meter.</p> <p>Report on the use of Na_2CO_3 to standardise HCl, used in turn to standardise NaOH. pH curve from the titration plus a differential plot.</p> <p>Results, calculations and calibration graph for the determination of the concentration of a coloured solution using colorimetry.</p> <p>Explanations of how the accuracy, precision and safety of the quantitative techniques may be optimised.</p> <p>Observation checklist, completed by the tutor,</p>



		including safety.
B Undertake calorimetry to study cooling curves	B1 Thermometers B2 Cooling curves	<p>Results from checking the calibration of at least two types of thermometer.</p> <p>A table of time/temperature data and a graph of temperature against time for a substance cooling.</p> <p>Calculations of the rate of cooling at points on the graph.</p> <p>An analysis of how the rate of cooling is related to intermolecular forces and the state of the substance.</p> <p>A report evaluating the accuracy of the cooling curve experiment.</p> <p>An observation report with a checklist, completed by the tutor, including safety.</p>
C Undertake chromatographic techniques to identify components in mixtures	C1 Chromatographic techniques C2 Application of chromatography C3 Interpretation of a chromatogram	<p>Results from the paper chromatography and TLC of extracted plant pigments from paper chromatography of amino acids.</p> <p>An explanation of the principles behind the chromatographic separations.</p> <p>Suggestions for improvements to the chromatographic procedures carried out and full justification of these suggestions.</p> <p>An observation report with a checklist, completed by the tutor, including safety.</p>
D Review personal development of scientific skills for laboratory work	D1 Personal responsibility D2 Interpersonal skills D3 Professional practice	<p>A presentation or report that focuses on the evaluation of learners' performance and skill development across all scientific procedures and techniques carried out in learning aims A, B and C.</p>



Assessment guidance

The unit will be assessed using four assignments, one per learning aim. Learning aims A, B and C involve practical work. You should write observation reports for the learners, or provide types of evidence that shows the learners undertaking the practical assessments. Learners should have carried out sufficient practice exercises during their teaching and learning to enable them to tackle the assessment activities. Learners should work at their own pace. Each assignment is likely to be spread over several teaching sessions. When completing the assignment for learning aim D, learners will need access to their skills diary/logbook and to their assignments for learning aims A, B and C.

For learning aims A, B and C, pass-level learners will carry out procedures competently and interpret their results. Merit-level learners must work with greater autonomy and confidence. They should automatically repeat practical work when they realise that they have made an error. They will be able to gain more information from interpretation of results. Distinction-level learners will interpret outcomes of their quantitative analytical procedures and techniques to make sound judgements on the accuracy of these. For learning aim D, learners will draw upon all areas of practical work carried out to critically reflect on strengths and weaknesses of their own performance and skill development drawing on feedback.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 2: Practical Scientific Procedures and Techniques

Introduction

Introduce the unit in the context of preparing the learner for working in a scientific laboratory or progressing to higher education in a scientific discipline by presenting case studies of learners who have progressed in those ways. Use the case studies to illustrate the importance of the four learning aims.

In the practical work leading up to the summative assessment for each of the learning aims A, B and C, learners can work collaboratively by comparing and discussing the results they obtain as individuals. They will share investigative tasks within a group and pool results in order to draw conclusions, and develop autonomy and a sense of responsibility for their own results. These are useful employability skills. They are also skills that will be useful when undertaking further study.

The reflection that will take place for learning aim D will allow learners to assess the skills that they have gained.

Learning aim A – Undertake titration and colorimetry to determine the concentration of solutions

- Introduce learning aim A by asking pairs of learners to weigh 25 cm³ of water from a measuring cylinder, small beaker, burette and pipette.
- Give learners the opportunity to discuss the relationship between mass and volume, the results that they obtain and the accuracy of the equipment.
- Introduce density and discuss with learners whether density is temperature-dependent before establishing the density of water at a given temperature as a standard for volumetric calibration.
- Allow learners to use the mass, volume and density relationship in calculations.
- Demonstrate the correct pipetting technique and introduce routine checks on the calibration of pipettes and balances following given instructions and using standard paperwork/pro formas. Explain that learners must carry out these activities routinely and as part of the assessment process.
- Demonstrate titrimetric technique and allow learners to practise this individually with different acid/base combinations, for which you have selected the appropriate indicator.
- Introduce pH measurement and calibration of pH meters.
- Demonstrate, and allow learners to practise, making up solutions and using them in titrations before carrying out the assessment activities.
- Introduce colorimetry by having a 1% and a 10% copper sulfate solution, and a solution of unknown concentration (between 1% and 10%). The same solution or concentration should not be used for assessment as for teaching and learning. Learners could comment on the intensity of the blue solution in relation to its concentration.
- Allow learners to discuss how they could find the concentration of the solution using a colorimeter or a visible spectrometer, and to deduce the need for the preparation of standards of known concentration.



Unit 2: Practical Scientific Procedures and Techniques

- Arrange a visit to a local laboratory or invite a visiting speaker to explain the importance of being trained to follow standard procedures, carrying out calibration checks and completing paperwork in a standard way.
- Once learners are confident in performing the techniques, they should attempt the assignment.

Learning aim B – Undertake calorimetry to study cooling curves

You could deliver learning aim B through a problem-solving approach, allowing learners to develop their skill sets.

- Learners could collect data that will allow them to construct a cooling curve, using a given method that lacks enough detail to give scope for discussion of the variables, e.g. amount of solid, container used, method of heating, maximum temperature, method of cooling, frequency of temperature readings.
- Learners could discuss the most appropriate scale to use for cooling curves and whether the time intervals used were appropriate.
- Learners could draw conclusions about the shape of the curve in relation to the state of the substance and the melting point of the substance.
- Encourage learners to identify ways to make the data more accurate, including calibration of thermometers.
- Give learners the opportunity to practise checking calibration of thermometers and completing standard record sheets for this activity.
- Encourage learners to deduce that the slope of the tangent to the curve is a measure of the rate of cooling at that point.
- Learners should discuss how to draw tangents and calculate their slopes as accurately as possible.
- Learners should discuss what may be happening in terms of the state of the substance and the intermolecular forces at various points of the cooling curve.
- Once learners are confident in performing the techniques, they should attempt the assignment.

Learning aim C – Undertake chromatographic techniques to identify components in mixtures

Chromatography resources (e.g. TLC plates, spotting tubes, equipment for spraying) are expensive. Individual chromatography runs take time. There is considerable scope for learners to compare their results with those obtained by other learners. For example, if one learner has a sharp, distinct pigment band when undertaking TLC of plant pigments while another learner has a chromatogram which lacks definition, these learners may compare what they did in order to establish best practice during teaching and learning.

- Introduce chromatography by demonstrating or having pairs of learners carry out the sort of simple experiment involving felt pens on filter paper that they are likely to have encountered at school.
- Learners should discuss the more sophisticated vocabulary that is necessary at this level, e.g. 'mobile phase', 'stationary phase'.
- Learners could investigate which one of a range of solvents (e.g. petroleum ether, ethyl ethanoate, propanone, ethanol and water) is best for extracting pigments from leaves or dried herbs. Different leaves should be used for teaching and

Unit 2: Practical Scientific Procedures and Techniques

learning than for assessment.

- Encourage learners to deduce the need to grind the plant material with sand in a mortar with a pestle, and to filter the extract. Because some learners will have used too much solvent, you will have scope to discuss the need to concentrate the extract by evaporation.
- Demonstrate good spotting technique. You should allow learners to use pure petroleum ether, pure propanone and the optimum mixture (9:1 petroleum ether: propanone for paper and 7:3 petroleum ether for TLC) as a mobile phase.
- Encourage learners to identify for themselves which chromatograms show good separation of pigments, and why.
- Because successful paper chromatography of amino acids requires good technique, it is best to demonstrate how to carry out the procedures, following the given method.
- Explain how to calculate the R_f value, using a real example so that the learners identify where the bulk of the material from the spot is located – rather than, say, the top of the spot.
- Once learners are confident in performing the techniques, they should attempt the assignment.

Learning aim D – Review personal development of scientific skills for laboratory work

In most professions, people need to maintain evidence of continuing professional development (CPD). Reflection is essential if people are to make the most of their learning experience. The work for learning aim D should lay the foundations for future CPD activities. To deliver this learning aim, you could:

- introduce a diary/logbook approach to record development of skills (practical, interpretative and personal), for learners to use at each practical session
- review how the diary/logbook entries are being made with each learner every two weeks.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

The practical work in this unit provides working practices and skills knowledge that will be useful for the work in *Unit 4: Laboratory Techniques and their Application* and in *Unit 19: Practical Chemical Analysis*. Skills in calculating concentrations from Unit 1 underpin learning aim A.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Bonner, PLR and Hargreaves, AJ *Basic Bioscience Laboratory Techniques: A Pocket Guide* (Wiley-Blackwell 2011) ISBN 9780470743096

This book deals with colorimetry, chromatography, weighing and making up solutions, and directs learners to further references.

Meah, MS and Kebede-Westhead, E *Essential Laboratory Skills for Biosciences* (John Wiley & Sons 2012) ISBN 0470686478

This book includes making up solutions, titrations, colorimetry and chromatography.

Videos

<https://www.youtube.com/watch?v=rLc148UCT2w>

Royal Society of Chemistry video introducing acid-base titration.

Websites

<http://www.chemguideforcie.co.uk>

Jim Clark's Chemguide material supports chemistry at level 3 and level 4. It is exceptionally useful.

<http://www.nuffieldfoundation.org/practical-chemistry>

The Nuffield Foundation website contains a range of practical chemistry exercises, some of which are relevant to the unit.



Unit 3: Science Investigation Skills

Delivery guidance

Approaching the unit

The way to approach this unit is to work through the five different topics (topics D to H in the unit specification) which are:

- enzymes in action
- diffusion of molecules
- plants and their environment
- energy content of fuels
- electrical circuits.

As well as conveying the content of each topic, you should incorporate all the content of the skills sections at relevant places throughout the unit.

Much of this unit involves practical work and in all topics it is essential that learners have the opportunity to carry out at least one scientific investigation.

You should visit each skill more than once so that learners become familiar with all the skills necessary to be able to complete the final assessment with confidence.

Each topic could include a revision session and a thirty-minute knowledge quiz to consolidate the key points in the topic.

The most important thing is that you give learners plenty of variety to keep them interested and focused. They should then look forward to the lessons and enjoy the learning experience.

The skills the learners acquire in this unit will help to prepare them for their future in the workplace.

Delivering the topics

For topic D – ‘Enzymes in action’ – you need to introduce learners to the structure and function of proteins as enzymes. Use of molecular model kits will make the topic much more visual and easier for learners to understand. Research skills can be developed early on by asking learners to find out information about protein structure and present their findings to the class.

You can then introduce learners to the skills required to plan an investigation so that they can plan an investigation and carry out the practical work. This is an early opportunity to introduce assessment outcome AO1.

The fermentation demonstration is an example of an enzyme-catalysed reaction which is very relevant in an industrial context; a visit to a brewery would provide an interesting and informative trip for the learners.

The enzyme-catalysed reaction of catalase on hydrogen peroxide solution could be the main scientific investigation in this topic and will enable you to introduce the skills involved in processing, analysing and evaluating data. Learners will

have been introduced to assessment outcomes AO1, AO3 and AO4 when they complete this investigation.

For topic E – ‘Diffusion of molecules’ – practical demonstrations could be used to capture the learners’ interest at the start of the topic. Demonstrations will also be a good introduction to the factors that affect the rate of diffusion.

Observing Brownian motion gives the opportunity for some paired practical work and is a good way of introducing the idea of random movement of molecules and kinetic theory.

A revision session will consolidate the theory behind this topic before the learners embark on the science investigation.

A diffusion of food dye practical could give the learners another opportunity to analyse and evaluate experimental results. This is also a good place for you to introduce the idea of precision of measuring equipment and for the learners to practice percentage error calculations. Learners then have the opportunity to search for secondary evidence related to this practical which they can evaluate in conjunction with the primary evidence they have collected.

For topic F – ‘Plants and their environment’ – you could start with a discussion of factors that can affect plant growth and distribution. This is a good topic for learners to research and practise their assignment-writing skills. Next move on to sampling techniques and introduce learners to a fieldwork investigation using quadrats. Having collected data, learners need to be taught how to analyse their data using statistics. You will need to give them worked examples of the various tests and plenty of practice at analysing data.

Some more fieldwork using the idea of transects will give learners a break from all the statistical analysis. This will give them a chance to think about the abiotic factors which may affect plant distribution.

You can then move learners on to the main science investigation in this topic. This could involve planning an investigation to study the populations of different species of plant in a lawn. They carry out the investigation, process and analyse the data, and evaluate the method. A discussion of the results and reasons for possible variations will round off this topic.

For topic G – ‘Energy content of fuels’ – a practical demonstration is a good way to introduce the unit. Learners can compare the ease of ignition, viscosity and smokiness of flame for the different fuels. This can lead to a discussion about the problems of incomplete combustion. There is an opportunity here for independent study as learners can find out about the properties of different fuels.

You then need to introduce units of energy and how heat energy supplied by a fuel can be calculated. The mathematical skills of the learners can be tested as they practise heat energy calculations.

The main science investigation for this topic involves finding heat energy produced when different foods burn. Learners will plan their investigation, discuss their plans, carry out the practical work, record their results, calculate the energy produced by each food in kJ kg^{-1} and compare their results with energy values on the food labels. This is a good opportunity to introduce learners to the problems with this type of practical. There are large differences in theoretical and actual energy values due to heat loss and incomplete combustion and learners can consider ways of overcoming these problems.

For topic H – ‘Electrical circuits’ – you need to start by finding out if learners know the electrical symbols for the components in the specification. The ‘Electricity Symbols Kung-Fu’ video (see Resources) is a fun way to help learners



remember these. They can then practise drawing circuit diagrams using the symbols. There are plenty of practicals to keep learners interested in this topic. The Ohm's law practical is a good way for learners to become familiar with building circuits and taking measurements. This practical then moves on to looking at resistors in series and parallel, giving an opportunity for learners to practise their mathematical skills as well as building circuits. Leading on from this, they can investigate bulbs and diodes which do not obey Ohm's law.

You next need to introduce the idea of power and energy; the energy usage of different appliances can be compared using a mains joule meter. This leads on to thinking about energy-saving devices, such as energy-saving light bulbs, and learners can look at electricity bills and learn how to work out the cost of electrical energy which is measured in kilowatt hours (kWh).

The main investigation in this topic involves your learners finding the specific heat capacity of a metal and tests many of their planning, analysing and evaluating skills. You will need to give them guidance on how to use their results to plot an appropriate graph and hence find the specific heat capacity of the metal.

A good way of rounding off this topic would be to organise a visit to a local power station so that you can show learners how electricity is generated.

You can change the order of the topics in this unit if necessary to suit the needs of the centre. Topic F, 'Plants and their environment', will need to be taught either late in the spring term or in the summer term in order for there to be enough species of plants in evidence for the fieldwork to be carried out successfully. Topic H follows on from topic G, so these two should be taught in sequence. You will need to revisit all the skills after the topics have been taught in preparation for the final assessment and you should ensure that the command words that will be used in the final assessment have been explained. It is strongly recommended that you use the sample assessment task as a trial assessment before learners embark on the final assessment.

Assessment guidance

The final assessment task for this unit focuses mainly on the skills in topics A to C. The task will be externally assessed and must be carried out under controlled supervision. Learners will have a two-week window in which to carry out the task. The first part of the task, part A, involves carrying out a practical investigation. A detailed method will be given to the learners and they will be able to carry out the practical in pairs. Tutor and technician notes will be given to centres in advance, so that any necessary resources may be purchased and the practical work trialed. An observation sheet is given to each learner in order for them to record their results and observations. You will need to collect in these sheets at the end of each practical session.

The second part of the task is a 90-minute written paper divided into two sections. The first section is related to the practical work and learners will need their observation sheets to complete this section, which will involve processing and analysing their results along with further secondary evidence. Learners should aim to complete this section in 60 minutes. The second section involves writing a plan for an investigation. This will not be related to the investigation carried out for the first section.

A sample assessment task has been written which you can use as a trial task so that learners know what will be expected of them.

Getting started

This gives you a starting place for one way of delivering the unit. Activities are given in preparation for the external assessment.

Unit 3: Science Investigation Skills

Introduction

This is essentially a skills-based unit in which learners will gain all the skills necessary to plan and carry out a scientific investigation, and to process and analyse the results. Learners will be able to recognise where there are weaknesses in the method and suggest improvements. They will also look at secondary evidence and evaluate the reliability of this evidence in conjunction with the primary evidence they have collected.

Topic D – Enzymes in action

- Initially learners need to know what an amino acid is and be familiar with the amine and carboxylic acid groups. They also need to understand how these groups join to form a peptide link with the elimination of a water molecule. A good way for them to get to grips with this concept is to use molecular model kits to build two amino acids and then to join them together so that they can clearly see how the peptide link is formed. The research project will increase the learners' depth of knowledge of protein structure and introduce them to independent learning. Giving a short presentation of their research will help increase their confidence.
- Learners need to appreciate that enzymes are protein molecules with an active site that attaches itself to a substrate molecule, and that anything which may destroy the three-dimensional structure of an enzyme or substrate will prevent the formation of an enzyme-substrate complex. Temperature and pH are factors which can denature protein molecules. Egg albumen is a protein which can be denatured. This is a good time for you to introduce the first science investigation. One of the skills required for the final assessment is to be able to write a plan for a science investigation. You need to discuss with the learners everything that they need to include in the plan, details of which can be found in section A of the specification: Planning a scientific investigation. Learners then write a plan to investigate the effect of pH and temperature on egg albumen. Following this they can carry out their practical, note their observations and write a conclusion.
- In order to understand why enzymes are considered as biological catalysts, learners need to know about rates of chemical reactions, collision theory and how catalysts work by lowering the activation energy. Particle diagrams showing how increasing concentration increases reaction rate, and energy profile diagrams showing how catalysts lower the activation energy, will help learners to understand the concepts. Fermentation is an example of a very relevant enzyme-catalysed reaction and setting up this demonstration will also give you an opportunity to discuss optimum conditions. A visit to a brewery or bakery would be a good follow-up to this demonstration.
- You can then introduce the main science investigation for this topic. Temperature, pH, substrate and enzyme concentration can all affect the rate of an enzyme-catalysed reaction. Learners are given a choice of investigating either the effect of temperature or of substrate concentration on the enzyme-catalysed reaction of catalase on hydrogen peroxide solution. The best way to approach this investigation would be to split it into stages. Learners will need some guidance on how to write a hypothesis and a plan for this investigation, as outlined in Section A of the specification. You should then look at the plans and suggest any changes which need to be made before learners carry out the practical work. Details of how to



Unit 3: Science Investigation Skills

collect and record their data should be discussed referring to relevant points from section B1 of the specification. The practical work will be a paired activity, but learners should record their results individually. When learners have recorded their results, you need to explain to them how to plot a suitable line graph of their results, as outlined in section B2 of the specification, and use this graph to write a conclusion. You need to explain to them what they need to do to analyse and evaluate the results referring to relevant points from the skills section of the specification. Learners can then analyse and evaluate their results, referring to relevant points from section C of the specification: Drawing conclusions and evaluation. As there are two different investigations here, the class need to discuss their findings so that they can summarise the conclusions to both investigations.

- Writing revision notes will help learners to consolidate the key points of this topic and the knowledge quiz will help both you and the learners to assess their progress.

Topic E – Diffusion of molecules

- You could start by setting up three demonstrations – bromine, potassium manganate(VII) and ammonia. The bromine demonstration, using two gas jars, should be carried out in a fume cupboard as the fumes are toxic. Also, soak the two pieces of cotton wool in the two solutions in the fume cupboard, as the fumes are unpleasant to breathe in, then place them in the long tube and seal the ends. You can then transfer the tube to the demonstration bench and clamp it horizontally. The manganate(VII) demonstration can be carried out on the demonstration bench. When setting up the long tube experiment, explain that the concentrated ammonia solution gives off ammonia gas and the concentrated hydrochloric acid solution gives off hydrogen chloride gas. When the two gases react they form a white solid of ammonium chloride. Ask your learners to find the molar masses of ammonia and hydrogen chloride. This should help them to appreciate why the white solid forms closer to the hydrochloric acid. A question and answer session can then lead into a discussion of factors which affect the rate of diffusion of molecules.
- The Brownian motion practical will give the learners a chance to practise using microscopes. If you have a microscope that links up to a data projector, you should be able to project the image from a smoke cell on to a screen so that all learners can see the results more clearly. Chance discoveries have played an important part in the development of scientific ideas and Brown's original experiments confirm this – learners should find it interesting to research the history of Brownian motion. This practical is also an excellent introduction to the idea of random movement of molecules and kinetic theory. Dynamic equilibrium is also an important factor when considering diffusion of molecules. You need to convey the idea that in the previous lesson's demonstration when the bromine had completely diffused to fill the two gas jars, the bromine molecules were still moving between the two gas jars but at equal rates, so overall there appeared to be no change.
- The diffusion of food dye through agar is the main scientific investigation for this topic. For this investigation, the learners do not need to write a plan and should be given a method for the practical. A suitable method can be found by referring to the Edexcel Biology GCSE 2015 B2 controlled assessment task. They can, however, write a hypothesis for the investigation, as outlined in section A1 of the specification. Each agar plate should have three wells, and the same volume and concentration of food dye solution should be placed in each well. Set up four more plates and use a different concentration of food dye in each plate. Leave the plates for 24 hours in order for a significant amount of diffusion to occur. If you are leaving them for over 24 hours, it would be advisable to keep them refrigerated. After 24 hours, learners can measure the diameters of the circles and find the average diameter for each plate. Learners can then plot a suitable line graph of the

Unit 3: Science Investigation Skills

results and write a conclusion. They can then evaluate the practical. This investigation gives a good opportunity for you to introduce the idea of precision of measuring instruments and teach learners how to calculate percentage errors on measuring equipment, as outlined in section B2 of the specification. The investigation also gives an opportunity for learners to look for secondary evidence and to comment on the reliability of all the primary and secondary evidence, as referred to in section C1 of the specification. The final assessment will involve comparing primary and secondary evidence, so learners will need to be familiar with this skill.

Topic F – Plants and their environment

You should teach this topic in either late spring or summer.

- Start with a discussion as to what factors may affect plant growth and distribution. Learners should be able to come up with most of the factors without much need for prompting. This is a good topic for learners to research. They can then write an essay explaining why each of the factors can affect the growth and distribution of plants.
- You should then introduce learners to the different sampling techniques and the need for collecting a large amount of data in order to make the results valid. Using open quadrats to count the number of daisies in different areas of a field is a good introduction to fieldwork. Each pair should place the quadrat in ten different places in the field in order to collect sufficient data for analysis. You then need to explain to learners how to analyse their data. They should calculate the mean number of daisies from their results, and the standard deviation, as referred to in section B2 of the specification. This would also be a good opportunity to introduce the idea of a null hypothesis, as outlined in section A1 of the specification. You should show learners how to use a chi-squared test to decide whether the null hypothesis is to be rejected or accepted in this case.
- From here, you can move on to introducing other statistical tests. Presentation software could be used and there are several available which you could adapt to suit your needs. You should show the learners some worked examples and then give them data to analyse. This could prove to be a difficult topic for the majority of learners, so take time and care to make sure they understand the techniques involved. These techniques are referred to in section B2 of the specification.
- The next fieldwork investigation involves transects. Choose a plant which is fairly abundant in a particular field or along the edge of a footpath. The learners can look at the different distributions of the plant along sections of the field or path. They can then draw conclusions as to why some areas are more densely populated than others, based on the different abiotic factors that can affect plant growth and distribution.
- From here, you can move on to the main science investigation for this topic, which involves looking for different species of plant in a field or lawn. There are identity cards available at www.saps.org.uk which can be downloaded and printed off to help learners identify the different species that are most likely to be present. Learners first write a plan of how they are going to carry out the investigation. They then collect the data and process and analyse the results. They can display their data in a bar chart to show the number of each different plant. They can also pool results together for the whole class and plot a further bar chart of the class results. Skills required here are outlined in section B of the specification: Data collection, processing and analysis/interpretation. This can lead on to a discussion as to why this is a better record of the plant numbers. Again, you can also discuss abiotic factors that affect the distribution of the plants.



Unit 3: Science Investigation Skills

Topic G – Energy content of fuels

- The simple demonstration of burning different fuels on watch glasses is a good introduction to this topic. Fuels such as ethanol, which has low viscosity, will ignite easily and burn with a clean blue flame. Butan-1-ol would be slightly more viscous, a bit harder to ignite, and burn with a more smoky flame. Cooking oil, which is a lot more viscous, would be very difficult to ignite. You need to explain that when a fuel burns in a plentiful supply of air, complete combustion occurs and the products are carbon dioxide and water. However if the air supply is insufficient, carbon (soot) and carbon monoxide can form. This is called incomplete combustion. The higher the ratio of carbon compared to hydrogen and oxygen in the fuel, the more likely it is that incomplete combustion will occur. Carbon monoxide is toxic and can combine with haemoglobin in the blood to stop it from carrying oxygen round the body. Carbon can cause respiratory problems, global dimming and other hazards associated with fuels, such as pollution from sulfur impurities. Learners can go on to research the properties of different fuels and whether they are formed from renewable or non-renewable energy sources. The learners can then discuss their findings and evaluate the pros and cons of using different fuels.
- Learners need to know about the units of energy and how to find the energy content of fuels. They should be familiar with calories from food labels but are unlikely to know what a calorie actually is. You should define a calorie as the energy needed to raise the temperature of 1 g of water by 1 °C. The energy information on food labels is given in kilocalories (kcal) and in kilojoules (kJ). In science, we use joules (J) and kJ more often than calories. In order to find the energy supplied by a fuel, the fuel is used to heat a known mass of water and the temperature rise measured. If we know the mass of fuel burnt, we can find the energy in kJ kg^{-1} . If the fuel is a pure chemical such as ethanol we can use kJ mol^{-1} . You need to explain the idea of specific heat capacity (shc) as the shc of water is needed to calculate the energy supplied in joules. You should then give some worked examples of how to calculate heat energy and this should be followed up by a worksheet of calculations for the learners to work through. These calculations will involve use and transposition of formulae and conversion of units, as referred to in section B2 of the specification.
- The main science investigation in this topic is to find the energy, in kJ kg^{-1} , supplied by a selection of different foods. You should introduce this practical by reminding learners of what needs to go into the plan for the investigation. Learners can then write their plans and when these have been reviewed they can complete the practical task. They can then calculate the energy supplied by each of the foods in kJ kg^{-1} , and plot the results on a bar chart. It would be a good idea to have various food labels available so learners can compare their results with the values on the labels. These values are normally given in kJ per 100 g, so multiplying the values by 10 will convert them to kJ kg^{-1} . The values calculated by the learners from their experiments are likely to be much lower than the values on the food labels. Learners can then think about why this is the case. They should come up with the ideas that combustion is not complete, as some ash will be left behind showing incomplete combustion, and that much of the heat is lost to the surroundings. Learners can then evaluate the practical and suggest improvements to minimise heat loss and incomplete combustion, using skills from section C2 of the specification. You may need to give them some help to come up with these ideas.

Topic H – Electrical circuits

- First, ask your learners if they know the electrical symbols for the different components. They should draw these symbols and some circuits which use them. Remind learners that ammeters are always placed in series in a circuit and

Unit 3: Science Investigation Skills

voltmeters in parallel. The 'Electricity Symbols Kung Fu' video will help them to remember the symbols. They do not need to write a plan for the Ohm's law practical but it will be a good introduction to building circuits. Warn learners that resistors become hot when the higher voltages are used, so tell them to take readings quickly and turn off the power pack after taking each reading. Recording results, plotting a graph of voltage against current, and finding the gradient to determine the resistance will also prove to be good practice for the final assessment, by revisiting skills from section B of the specification. You then need to introduce the equations for resistors in series and in parallel, and show the learners how to calculate the total resistance from these equations. Give them a table of examples of combinations of resistors in series and in parallel, and get them to calculate the total resistance of each combination. Having done this they can then set up the circuits, measure the resistances and compare them with the calculated values. It is simpler to use a digital meter to measure resistance directly for this practical. Repeating the first practical using a 12 V bulb and then a diode will give more learners more practice at graph plotting and show them that not all components in a circuit obey Ohm's law.

- Learners will have heard the term 'watts' in relation to light bulbs. Explain that a watt (W) is a unit for power and that power can be calculated in two ways: either by dividing the energy transferred by the time taken, or by multiplying the voltage by the current. If you have access to a mains joule meter, a good demonstration is to use the joule meter to find the number of joules per minute for various appliances including an energy-saving light bulb and a filament bulb of the same brightness. The power in watts can then be found for each appliance by dividing by 60 and the values can be compared with the actual power ratings of the appliances. This leads on to looking at fuse ratings for appliances, and by using the equation $P = VI$ learners can work out suitable fuse ratings for different appliances. You can also show them how to calculate the energy usage of the appliances in kilowatt hours and how the cost of electricity is worked out. Looking at actual electricity bills will help to make this topic more relevant to the learners. Some of the mathematical skills from section B2 will be used again here.
- From here, move on to the main science investigation for this topic, which is an investigation to find the specific heat capacity of a metal block. This investigation also links in with the energy content of fuels topic, as learners will need to use the equation: **heat energy = mass × shc × temperature rise** again. They will also need to measure current and voltage to calculate power, and multiply by time to find heat energy supplied. You will need to guide the learners through the planning of the investigation. They should include a list of hazards and risks, note what variables are to be controlled, write a method, draw a circuit diagram and have their circuits checked before they start the practical work. This investigation will revisit the skills in section A of the specification. A rheostat should be included in the circuit to keep the voltage and current constant. After they have taken readings you will need to guide them through the calculations. Learners should plot a graph of heat energy against temperature rise, which should be linear, and find the gradient of the graph which will be the shc × mass of the block, which is normally 1 kg. They can practise doing percentage error calculations on the equipment used, as outlined in section B2 of the specification. Learners then need to compare their results with data book values and try to account for any discrepancies. They should identify any anomalous results and attempt to explain why they may be anomalous, as outlined in section C2 of the specification. They should also evaluate the method, suggesting improvements, again using skills from section C2.
- A visit to a power station would be a good way to round off this topic, so that learners can find out how electricity is generated and how it reaches homes in the UK via the National Grid or its equivalent elsewhere in the world.



Preparation for the final assessment

After all the topics have been covered, learners will need to start revising and preparing themselves for the final assessment.

- They should make sure they are thoroughly familiar with the command words given in the unit specification.
- Learners should revise all the skills required in planning an investigation and then you should give them an investigation to plan. The investigation suggested in the Scheme of Work is the effect of temperature on the diffusion of potassium permanganate crystals in water.
- Next revise the skills needed to process, analyse and evaluate data. Give learners some data, including an anomalous result which they need to identify and account for. Learners then need to plot a suitable line graph of the data and write a conclusion. Now give them a method for an investigation which could be improved and ask learners to evaluate the method and suggest improvements to the method.
- Moving on, learners should revise the mathematical and statistical skills used in analysing data; give them some examples to work through.
- Before learners embark on the trial assessment task, review the table of command words found in the unit specification and revise examination skills, including reading the questions carefully, understanding the implications of mark allocation with time spent on a question, correct structuring of paragraphs for extended answers, and so on. Learners can then carry out the trial assessment. When you have marked the trial assessment, and discussed the mark scheme with the learners so that they can make the necessary corrections to their work, they should be ready for the final assessment.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

- *Unit 2: Practical Scientific Procedures and Technicians*
- *Unit 4: Laboratory Techniques and the Application*
- *Unit 5: Principles and Applications of Science II*
- *Unit 6: Investigative Project.*

This unit also links to a wide range of optional units available across the qualification, including:

- *Unit 10: Biological Molecules and Metabolic Pathways*
- *Unit 15: Electrical Circuits and their Application*
- *Unit 18: Industrial Chemical Reactions.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Fullick, A, *Edexcel AS/A Level Biology B Student Book*, Pearson, 2015 (ISBN: 9781447991144).

Information on protein structure and enzymes.

Johnson, K, *Physics for You*, Nelson Thornes, 1996 (ISBN: 9780748727612).
Ohm's Law and resistors in series and parallel explained.

Jones, M, *Biology 2 for OCR Student Book*, Cambridge University Press, 2008 (ISBN: 9780521732994).

Probability and chi-squared test explained.

Ryan, L, *Chemistry for You*, Nelson Thornes, 1996 (ISBN: 9780748723676).
Diffusion and Brownian motion demos explained. Information on combustion of fuels.

Sang, D, *Physics 2*, Cambridge University Press, 2001 (ISBN: 9780521797153).
Specific heat capacity practical explained.

Videos

Electricity Symbols Kung Fu www.youtube.com/watch?v=ex7xwaPha2I
To help learners remember symbols.

How diffusion works www.youtube.com/watch?v=VY0mZUDvbH4
A simple animation showing how diffusion occurs.

Propane tank explosion www.youtube.com/watch?v=Lr15rPHEmeQ
A spectacular video showing one of the hazards of using highly flammable fuels.

What's up buttercup? Population sampling techniques.
www.youtube.com/watch?v=nsMWvSuJm08



A Wellcome Trust video giving a good introduction to sampling techniques using quadrats.

Websites

www.nuffieldfoundation.org/practical-biology/biodiversity-your-backyard

Nuffield Foundation – Information on biology fieldwork

www.saps.org.uk

Science & Plants for Schools – Information and plant identity grids for biology fieldwork.

www.nuffieldfoundation.org/practical-physics

Nuffield Foundation – Information on experiments with electric circuits.



Unit 4: Laboratory Techniques and their Application

Delivery guidance

Approaching the unit

Organisations that employ laboratory technicians and science manufacturing technicians consider working safely, following standard methods, using communication and information systems and being an effective team member to be essential. They encourage their technicians to show an interest in the scientific processes and tests that they are carrying out because they will perform their roles much more competently as a result.

In this unit, you will be laying the foundations for a successful career in science. It is important for the learner to become familiar with different types of scientific organisations – for example, laboratories in hospitals and in university research departments, contact analysis laboratories, science manufacturing in the oil, coatings, polymer, food, life science and, in particular, the pharmaceutical and chemical sectors. Visits to as many types of organisation as possible and talks from industry representatives will help the learner to understand how the techniques learnt in this unit are carried out in industry. Collect a range of videos, photographs, case studies and good websites as a resource for your learners. Keep them motivated by facilitating links with industry and having relevant material for them to study.

Delivering the learning aims

Health and safety is the focus of **learning aim A**. Arrange a visit to an organisation which has a laboratory and which carries out scientific manufacturing. Learners should see first-hand the different sorts of precautions that people take to minimise risk from hazards when working in different parts of the organisation. If a visit to industry is not possible – for example, because of the location of your centre or because it is difficult to arrange a mutually convenient date – prepare a range of video clips. Input from an industrial speaker will confirm the specific legislation with which the organisation must comply and the procedures and practices – for example, risk assessment, following standard procedures, safety tours and audits, computer workstation assessments, use of PPE, and so on – adopted to ensure compliance. A laboratory in a school, college or university may give a useful contrast to an industrial laboratory when making comparisons of measures taken to ensure high standards of health and safety.

Learning aim B is intended to increase learners' dexterity in handling equipment. Learners must learn how to assemble Quickfit™ apparatus to enable them to prepare an organic liquid using the techniques of reflux and distillation. Ethyl ethanoate is one suitable liquid. You will have to develop learners' levels of competence in handling the equipment to prepare them for assessment. You will also have to give learners the opportunity to determine the purity of the liquid that they have made. The boiling point at the point of distillation will be useful. Learners may also use the Siwoloboff method for finding boiling point. Infrared spectroscopy is a useful technique and it should be possible to find a partner

organisation that would give spectra for learners. You should encourage learners to discuss how reliable boiling point is as a measure of purity.

It would be helpful to assist learners find information sources about the industrial manufacture and testing of an organic liquid.. Learners should focus on the scale of the industrial process. Learners will have had to control the rate of boiling for reflux and distillation in the laboratory and should therefore understand the importance of the rate of heating in the industrial context. They should look at how reflux and distillation compare in the lab and industry. Reaction vessels and distillation vessels are designed differently for industry. Learners should realise that using GC or HPLC will allow them to test the product quality more effectively.

Learning aim C is similar to learning aim B, except that it is the manufacturing and testing of an organic solid that are studied. Learners will become proficient in recrystallisation as a purification technique (including vacuum filtration) and use melting point and thin layer chromatography (TLC) (with a locating agent). Learners will undertake a series of developmental practicals before undertaking the assessment. For example, they should explore:

- the selection of a suitable recrystallisation solvent
- the amount of solvent needed for a good yield
- the effect of rapid cooling in ice and slow cooling on crystal size.

They should measure the melting point of pure substances and explore the technique of mixed melting point. They will practise using iodine as a locating agent for the thin layer chromatography of pharmaceuticals. In researching the industrial preparation and testing of the solid, direct the learners towards the different scale and design of equipment in industry – for example, large reaction vessels made of glass-lined steel with paddle stirrers, supply of reagents via pipework and valves, filtration using a rotating drum filter. Learners will have gained an understanding of how difficult it is to produce significant amounts of good quality crystals from their own laboratory work. Industrially, the size and quality of pharmaceutical crystals is very important to the organisation formulating the product for use – for example, making tablets. There has been a lot of research into using continuous rather than batch processes in order to produce crystals that meet the requirements of the customer. This involves the use of process analytical technology (PAT) to monitor crystallisation. Learners could explore how PAT may be used. Crystallisation vessels may require a more sophisticated design – for example, the continuous oscillatory baffled crystalliser (COBC) – which learners could explore.

For **learning aim D**, learners should only complete assignments once they have all the skills and knowledge that they will need to achieve these criteria.. They will need to use material from the teaching and learning sessions that prepare them for assessment. You could visit several working laboratories using informatics to generate case study material for your learners. Learner visits to working laboratories are useful to show laboratory information management systems (LIMS) in action. Speakers from laboratories could also give talks and show examples of paperwork that they complete or computer software that they use. Learners could investigate the many types of electronic laboratory notebooks whose trial versions are available free. A learner visit to an organisation or a talk from someone in an organisation that uses informatics should make the topic come to life.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the importance of health and safety in scientific organisations	A1 Application of health and safety legislation in scientific organisations A2 Hazards in scientific organisations	Report describing health and safety legislation relevant to an organisation, describing the hazards and discussing aspects of health and safety management.
B Explore manufacturing techniques and testing methods for an organic liquid	B1 Manufacturing techniques B2 Testing methods and techniques	A report containing: <ul style="list-style-type: none"> • notes and results from making and testing an organic liquid • a description of the principles behind the preparative methods and tests used • analysis of ways to improve yield and purity and the reliability of testing methods as a guide to purity • an explanation of the principles behind the industrial manufacture and testing of the liquid • an observation report by the tutor of making and testing the liquid safely.
C Explore manufacturing techniques and testing methods for an organic solid	C1 Manufacturing techniques C2 Industrial manufacturing techniques C3 Estimation of purity	A report containing: <ul style="list-style-type: none"> • notes and results from making and testing an organic solid • a description of the principles of preparative methods and tests used • analysis of ways to improve yield and purity and of the reliability of testing methods as a guide to purity • an explanation of the principles behind the industrial manufacture of a solid • an observation report



		by the tutor of making and testing the solid safely.
D Understand how scientific information may be stored and communicated in a workplace laboratory	D1 Systems for managing laboratory information D2 Communicating information in a scientific organisation D3 Use of informatics for storage and retrieval of scientific information	A report containing: <ul style="list-style-type: none">• a description of the information stored and used in the laboratory• a description of how useful information can be obtained from large data sets• analysis of the communication channels in the organisation• evaluation of the benefits and issues involved in making large volumes of data available to others.

Assessment guidance

The unit will be assessed using up to four assignments: one per learning aim.

Learning aim A will require learners to gather information on the importance of health and safety in scientific organisations and the potential hazards in different working environments.

Learning aims B and C involve practical work. Learners should have carried out sufficient practice exercises to ensure they are competent before they tackle the assessment activities. Learners should work independently and at their own pace. Each assignment is likely to be spread over several teaching sessions.

When completing the assignment for learning aim D, learners will need to gather information on how scientific information is stored in the workplace through either visits or their own research.

For learning aims B and C, pass-level learners will competently follow techniques and procedures, with some support given if necessary to assemble apparatus, to prepare and test the purity of their organic liquid/solid and be able to draw simple conclusions.

Merit-level learners must work with greater autonomy and confidence demonstrating skilful application of the techniques used in the preparation and testing the purity of the organic liquid/solid and comparing the laboratory and industrial manufacture and testing of the organic liquid/solid.

Learners should be able draw detailed scientific conclusions about the purity of their samples from the tests carried out and provide explanations on the principles behind the techniques to support their conclusions.

Distinction-level learners should be able to analyse the factors to give thorough explanations of how they affect the yield and purity of an organic liquid/solid and their relevance to industrial manufacture.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 4: Laboratory Techniques and their Application

Introduction

Introduce the unit by focusing on the benefits of the content to the learners when entering the job market. You could give a presentation involving photographs and videos of health and safety signage and precautions in an industrial environment. Outline the content of each of the learning aims by running a short simulated activity set in a chemical/pharmaceutical manufacturing plant. Learners should understand about the importance of health and safety, standard paperwork and data and manufacturing and testing procedures.

Learning aim A – Understand the importance of health and safety in scientific organisations

Give learners a timetable for this learning aim. You should stress the importance of taking notes and collecting real evidence from research and observations.

- Introduce hazard and risk and health and safety legislation:
 - Learners should identify the hazards in pictures and videos and discuss hazards in the laboratory.
 - Introduce sources of information.
 - Introduce the difference between hazard and risk.
 - Explain how to carry out a risk assessment.
 - Carry out a risk assessment for a practical activity that the learners have undertaken or will be undertaking – for example, making and testing ethyl ethanoate.
- Health and safety legislation:
 - Describe the main pieces of health and safety legislation with which the centre must comply. You should encourage the learners to access the Health and Safety Executive (HSE) website, to see where they may obtain more information. Learners will complete a worksheet using this information.
 - Learners could have a talk from the centre's health and safety manager or an industrial health and safety manager who will mention specific legislation that you have described and explain how they ensure compliance. (The health and safety manager need not be from a science-based industry.) The centre (or other) health and safety policy should be described.
- Health and safety study of laboratory area at the centre:
 - Learners should discuss the safety measures, of which they are aware and prepare questions for the technician and other members of staff.
 - Learners will ask questions of the technician and other relevant members of staff.
- Visit another area within the centre and prepare questions for an industrial visit:
 - Learners will make observations in another area of the centre (for example,

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engineering workshop, art and design).

- Learners will discuss what they have seen.
- Learners will prepare questions and a list of observations that they want to make during a visit to an industrial company, including how the company knows that the measures are effective.
- Investigating legislation relevant to an organisation to be visited:
 - You will give learners an outline of what the organisation does.
 - Learners will research and discuss relevant legislation.
 - Learners will modify the questions they wish to ask and observations they intend to make on their industrial visit.
- Visit to an industrial site:
 - Learners will make notes on all the precautions and safety measures that are observed in the laboratory and in another area – for example, production or warehousing.
 - Learners should ensure they have evidence of how effective the safety measures or health monitoring activities are.
 - If possible, learners should make observations about communication, IT and quality systems in the company that they visit.
- Different environments within companies:
 - You should show videos about precautions taken in different work environments, including COMAH sites.
- How effective are the centre's and others' health and safety measures?
 - Learners should discuss how they could assess that health and safety measures are effective – learners will deduce the key elements of an audit – records, interviews and observations.
 - Learners will evaluate the evidence that they have for effective health and safety practices and procedures in two environments and identify further research that they need to make. Learners could prepare questions for a second visit to a company or by a company representative.

Learning aim B – Explore manufacturing techniques and testing methods for an organic liquid

Explain to learners that they need to be practically proficient in a number of techniques before attempting the assessment activity. Learners should research and gather information about industrial practices. Learners should have an opportunity to make and test the purity of an organic liquid before they are assessed, to ensure that they have the confidence needed to perform practical procedures at merit level. Reflux and distillation of an organic liquid will require an appreciation of the need to minimise the amount of solvent vapour released.

- Reflux and distillation:
 - You must demonstrate how to set up reflux and distillation correctly.
 - Learners should set up reflux and distillation equipment using water as the solvent.
 - Learners could comment on each other's set up. Ensure that learners will be able to assemble the equipment correctly.



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- Industrial equipment and the reaction for making an organic liquid:
 - Describe and explain the reflux and distillation equipment that would be used on an industrial scale.
 - Deliver a presentation about making an organic liquid, and the likely impurities.
- Siwoloboff boiling point:
 - Learners should correctly measure the boiling point of a range of solvents using the Siwoloboff method, comparing their results to literature values.
- Infrared spectroscopy:
 - If possible, learners should run a drop of a liquid organic compound on an infrared spectrometer.
 - Explain that there are characteristic stretching and bending frequencies for the different bond types (for example, O-H, C-H, C=O, C-O etc.).
 - Give learners infrared spectra of ethanoic acid, ethanol and ethyl ethanoate. Learners should annotate the main peaks in the spectra.

Learning aim C – Explore manufacturing techniques and testing methods for an organic solid

Explain to learners that they need to be practically proficient in a number of techniques before attempting the assessment activity. Learners should research and gather information about industrial practices. Learners should have an opportunity to make and test the purity of an organic solid before they are assessed, to ensure that they have the confidence needed to perform practical procedures at merit level.

- Measurement of melting point:
 - Demonstrate how to fill a melting point tube and how to use melting point apparatus.
 - Learners find the melting point of three solids and compare their results to literature values and to each other's results.
- Mixed melting point:
 - Introduce learners to the lowering of melting point by the presence of an impurity and get the learners to deduce how the technique of mixed melting point will work.
 - Find the identity of an unknown solid, using the technique of mixed melting point.
 - Explain how melting point apparatus may differ in the industrial context.
- Choosing a solvent for recrystallisation:
 - Deliver a presentation about the technique of recrystallisation and the need to find a solvent, in which the solid dissolves in hot solvent but not cold solvent.
 - Learners choice of solvent for recrystallisation – hot and cold solvents – and draw conclusions about the best solvent to use for recrystallisation.
 - Describe the importance of understanding recrystallisation in the context of an industrial process.
- Recrystallisation of benzoic acid:

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- Explain how to carry out recrystallisation. Learners should recrystallise benzoic acid from water individually.
- Learners should cool the recrystallisation mixture slowly and in ice to recover the crystals in order to explore the effect of rapid cooling.
- Learners should filter off the crystals using vacuum filtration and should wash the crystals with chilled water (to learn that they should turn off the vacuum when adding the water to ensure even mixing).
- Recrystallisation using hot filtration:
 - Explain the technique of hot filtration to remove insoluble impurities. How this is carried out depends on the particular resources of the centre. One way is to have filter funnels containing a plug of cotton wool in an oven at 105°C. Learners may remove the funnel and place it in a test tube rack above the vessel (for example, a beaker) in which crystallisation is to take place. Learners may heat their solid plus solvent in a flask, by holding the neck of the flask in a peg-style test tube holder. It is then straightforward to pour the recently boiled solution plus impurities through the hot funnel.
 - Describe how recrystallisation and filtration are carried out in industry.
- Extraction of a drug from a tablet:
 - Learners should research typical pharmaceutical formulations. This could include looking at leaflets from commercial drugs (aspirin/paracetamol).
 - Lead learners to deduce how the drug may be extracted from excipients by using a suitable solvent and filtering. You could compare this to separating the salt from a road grit mixture by adding water.
 - Learners should be able to plan the extraction for themselves and should be able to carry out the extraction, using filter paper and leaving a solution – for example, in propanone – to evaporate in a crystallisation dish. Explain how rotary evaporation may be used instead of leaving the solution to evaporate.
 - Learners should revise how to carry out TLC and how to select a suitable mobile phase.
- TLC of pharmaceutical products:
 - Learners should follow a given method to separate a mixture of pharmaceuticals – for example, aspirin, paracetamol and caffeine – with pure products as reference, using TLC and locate the spots with iodine or other suitable locating agent. Learners should calculate R_f value for each substance. (They should use concentrated solutions of drugs so that it is not necessary to spot the origin several times.)
 - Explain how HPLC and GC may be used in the pharmaceutical industry.

Learning aim D – Understand how scientific information may be stored and communicated in a workplace laboratory

This learning aim concerns communication, storage and retrieval of laboratory information and how some information is recorded as part of a large data set, made available to third parties (informatics). Try to arrange as many visits or talks from visiting speakers as possible. Learners should be encouraged to investigate various free electronic notebooks.

- Visit a laboratory with learners. Analysts or research technicians should explain what they do, who their 'customer' is and the sort of information that they must



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give. They will also explain what information is recorded in relation to particular samples or experiments, how that is recorded and made available and how traceability is ensured.

- Ideally, learners should visit a second laboratory or have a visit from someone working in another laboratory who will explain the systems in operation.
- Visit different laboratories. Present the learners with three or four laboratory scenarios (laboratories that you have visited) – different types of laboratory. Learners, working in groups, could describe the sorts of information that they believe would be recorded, collected, stored and retrieved. They may discuss this in relation to the actual practice.
- Explain at least one bioinformatics application – use of a large database that will enthuse learners – for example, DNA sequencing. Write a worksheet that will lead learners through another description of an application. Learners will work through the worksheet. Learners should discuss the advantages and disadvantages of informatics and issues associated with making large amounts of data available, using case studies.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 18: Industrial Chemical Reactions*
- *Unit 19: Practical Chemical Analysis.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Choudhuri, S., *Bioinformatics for Beginners*, Elsevier Inc., 2014 (ISBN: 9780124194716).

This resource gives an introduction to bioinformatics.

Leonard, J., Lygo, B., Procter, G., *Advanced Practical Organic Chemistry*, 3rd edition, 2013 (ISBN: 9781439860977).

This book contains details of preparative techniques used in organic chemistry in addition to information about health and safety, recording laboratory data and retrieval of information in chemistry.

Videos

<http://www.ineos.com/intv>

This is a series of videos about the operation of a company heavily involved in the chemical industry. Learners will get the chance to see the chemical plant that is featured in these videos.

<http://saltendchemicalspark.co.uk/visiting-the-site>

This is an induction video to the Saltend Industrial complex in Hull. It includes health and safety guidance.

<http://www.abpischools.org.uk/page/modules/labpilotplant/index.cfm>

Virtual tours of laboratories – learners are able to navigate around laboratory areas in a pharmaceutical company and click on points of interest for more information.

Websites

<http://www.sciencethrillers.com/2014/bioinformatics-science-project-for-grades-7-9>

Amy Rogers: instructions about using some bioinformatics data.

<http://www.abpischools.org.uk/page/modules/labpilotplant/index.cfm>

Association of the British Pharmaceutical Industry (ABPI), Resources for Schools: virtual tours of laboratories – learners are able to navigate around laboratory areas in a pharmaceutical company and click on points of interest for more information.



<http://www.usetute.com.au/aspirin.html>

AUS-e-TUTE – science education website: tutorial on making aspirin in the laboratory.

<http://www.chemguide.co.uk>

Chemguide: Jim Clark. Although this website is aimed at AS and A level learners, it contains explanations of the topics that are broader than required for particular syllabi and thus targets the BTEC content effectively.

<http://www.essentialchemicalindustry.org/index.php?start=1>

CIEC, Chemistry Department, University of York: the central resource is a book about the chemical industry which is updated and is available online. This link explains how the material may be used and gives links to all the chapters (Introduction, Industrial Processes, Materials and Applications, Basic Chemicals, Polymers, Metals). It contains a great deal of material which learners will find relevant to the research for their assignments.

www.cleapss.org.uk

CLEAPSS: information on practical work and health and safety.

<http://www.youtube.com/user/CogentSkills>

Cogent Skills: links to case studies about apprentices, science organisations and process safety. There are links to other useful sites.

<http://www.contentextra.com/lifesciences/unit12/unit12home.aspx>

Cogent/Pearson: a chapter on bioinformatics, aimed at level 4/5 learners, which may give background information for tutors.

http://www.industrialsustainability.org/media/45288-CMAC-Alastair_Florence.pdf

Engineering and Physical Sciences Research Council (EPSRC): presentation on continuous crystallisation and its monitoring and the need to control the size/shape of crystals for formulation.

<http://www.hse.gov.uk>

Health and Safety Executive (HSE): information and guidance on health and safety law and its implementation, including risk assessment and hazard pictograms. Documents may be downloaded free of charge.

<http://www.hse.gov.uk/pubns/hsc13.pdf>

Health and Safety Executive (HSE): explanation of how UK health and safety legislation is structured.

<http://www.hse.gov.uk/pubns/indg163.pdf>

Health and Safety Executive (HSE): 'Risk assessment – a brief guide to controlling risks in the workplace' – an explanation of how workplace risk assessment may be carried out.

<http://www.ilocis.org/documents/chpt79e.htm>

International Labour Office: chapter about the pharmaceutical industry. Contains a process diagram for aspirin manufacture, including a diagram of a reactor and a picture of a rotary dryer. Explains about how pharmaceutical products are manufactured for consumer use.

<http://www.rsc.org/learn-chemistry>

Learn Chemistry: Royal Society of Chemistry – links to resources relevant to the topics in the unit.

<http://davisson.nat.uni-magdeburg.de/Downloads/TC-4.pdf>

Magdeburg University: contains an outline of how aspirin is made industrially.

<http://files.rushim.ru/books/praktikum/Mann.pdf>

Textbook of practical organic chemistry by F.G. Mann and B.C. Saunders. An old book that is still useful.

https://www.fishersci.com/content/dam/fishersci/en_US/documents/programs/scientific/brochures-and-catalogs/brochures/mettler-toledo-mp50-melting-point-systems-brochure.pdf

Mettler-Toledo, part of Fisher Scientific: sales brochure which outlines the use of melting point measurement in the pharmaceutical industry.

<http://www.nuffieldfoundation.org/practical-chemistry/organic-chemistry>

Nuffield Foundation: collection of practical resources for organic chemistry.

<http://nitechsolutions.co.uk/wp-content/uploads/2012/04/AZ.pdf>

Organic Process Research and Development: paper that describes factors affecting crystallisation of pharmaceuticals and compares batch and continuous processes.

<http://preparatorychemistry.com>

Preparatory Chemistry: An Introduction to Chemistry by Mark Bishop. This contains a link to an eBook chapter on solubility and supersaturation.

<http://www.ploscollections.org/article/browseIssue.action?issue=info%3Adoi%2F10.1371%2Fissue.pcol.v03.i09>

Public Library of Science (PLOS): links to articles about using bioinformatics with secondary school learners.

<http://www.rsc.org/learn-chemistry/content/filerepository/CMP/00/000/045/Aspirin.pdf>

Royal Society of Chemistry: resource on the preparation and testing of aspirin in the laboratory.

http://www.rsc.org/learn-chemistry/content/filerepository/CMP/00/000/047/Paracetamol_web.pdf

Royal Society of Chemistry: resource on the preparation and testing of paracetamol in the laboratory.

http://www.thinksrs.com/downloads/PDFs/ApplicationNotes/MP_Protocols.pdf

Stanford Research Systems (SRS): an outline of how melting point measurement is used in the pharmaceutical industry.

<http://inpact.inp-toulouse.fr/GPE2007/textes/text272.pdf>

State University of Campinas: paper describing how production of ethyl ethanoate by reactive distillation may be improved.

<http://www.slideshare.net/sunandobasu10/good-laboratory-practice-documentation>

Sunando Basu, Vivo Bio, Hyderabad: presentation explaining documentation and why it is necessary, at a level accessible to learners.

<http://encyclopedia.che.engin.umich.edu>

University of Michigan: encyclopaedia of chemical engineering equipment. Describes several pieces of equipment that are used in the chemical/pharmaceutical industries.

<https://ia700403.us.archive.org/26/items/TextbookOfPracticalOrganicChemistry5thEd/VogelPracticalOrganicChemistry5thEditionnewfoundV.pdf>

Vogel's Textbook of Practical Organic Chemistry 5th edition.

<https://www.sanger.ac.uk/research/areas/bioinformatics>

Wellcome Trust Sanger Institute: description of research projects which involve bioinformatics with links to resources.



Unit 5: Principles and Applications of Science II

Delivery guidance

Approaching the unit

This is an externally assessed unit, which gives your learners the knowledge and understanding that underpins progression in the science sector and on to science higher nationals and degrees.

Delivering the topics

For **topic A**, a good starting point for the properties and uses of substances would be to have learners carry out an investigation into the acid-base nature of oxides and focus upon the amphoteric nature of aluminium oxide, which would then lead into the extraction of alumina and aluminium. Revisiting the reactivity series of metals and electrolysis through practical work will offer platforms for learners to look at case studies for the extraction of titanium and the useful products from the electrolysis of brine. Research and presentation of substances, their uses and their methods of manufacture will give learners a better understanding of the processes and considerations involved.

Learners will then move on to consider organic compounds, specifically hydrocarbons, and their commercial importance. This will be a relatively new topic for many learners and there is a substantial amount of knowledge initially. You should give learners opportunities to apply this knowledge through problem solving and use of molecular models to visualise compounds in order to name and draw molecular formulae. You can explain the physical properties and trends of organic compounds through data and graphical analysis. Learners can explore the chemical reactivity of different hydrocarbons through practical work and commercially useful products can be synthesised in the laboratory. Learners can present their own research on organic compounds and their applications to the group.

Finally, learners need to consider the energy requirements in the industrial manufacture of substances. You can present calculations to learners to solve and to consider whether chemical reactions are exothermic or endothermic in nature, and the feasibility. Practical work, including combustion and formation of substances, will give learners temperature change data upon which they can calculate enthalpy change.

For **topic B**, learners need to undertake practical work; this will be assessed and validated by assessors for this unit. Centres must ensure they comply with all health and safety guidance and regulations. Learners must be encouraged to risk assess practical work to help ensure they are aware of the safety issues and follow the relevant procedures and guidelines.

Understand the structure and function of the heart by looking at a lamb's heart and dissecting this to show the chambers and the major blood vessels entering and leaving the heart. Learners can carry out further practical work for the identification of ABO blood groups using one of the many kits available from most scientific suppliers. In addition to this, optical microscopes can be used to



see the effect of caffeine on the heart rate of the water flea *Daphnia*. Care must be taken during this investigation to not stress the *Daphnia* and ensure that the organisms are treated humanely. A visit to a cardiothoracic ward in a hospital in order to see the use of ECG traces as diagnostic tools is helpful.

In order to truly understand the structure of the lungs, it is possible to obtain a pluck from a butcher which will have the trachea, lungs and possibly heart connected to see these structures and to cut through the lung to see the bronchioles and alveoli membranes. The making of a model lung will suit those kinaesthetic learners as will the acting out of the ventilation process. In order to understand the pressure differences, you can use the collapsing can demonstration. Looking at spirometer traces either in an exercise physiology laboratory or a hospital can put this topic into a real-life situation. This practical work is further enhanced by research topics, which can then be presented back to other learners. It is particularly useful if you can divide up research topic areas so each learner has a unique research task.

Dissection of a lamb's kidney allows learners to see the structures inside the kidney but the nephron is too small actually to observe directly so a model can be made of this to show the flow of fluid through the kidney. If possible a visit to a nephrology department within a hospital is very useful here especially in understanding the process of kidney dialysis and how it impacts on people's lives. Research also enhances the delivery of this topic and specific research into mammals such as the kangaroo rat, which has slightly different morphology, can lead to stimulating and informative discussions.

The practical work on diffusion and osmosis can also be used to inform students about how surface to volume ratio impacts on diffusion into and out of cells. A written record of these investigations is essential in order to prepare effectively for assessment. The production and labelling of a poster showing the fluid mosaic model helps with the understanding of the structure of the cell membrane. Further research tasks help with the understanding of active transport including endocytosis and exocytosis.

In **topic C**, learners must develop an understanding of conservation of energy, energy transfer and efficiency and be able to apply this to ideal gases, heat engines, heat pumps and changes in state. The first and second laws of thermodynamics and the ideal gas equation are used to give a theoretical basis to the practical applications. Heat transfer and changes in state give learners the opportunity to make practical determinations of specific heat capacities. The properties of materials are studied with reference to Hooke's Law, Young's Modulus and density. Learners can experimentally verify Hooke's Law for springs, determine values for Young's modulus for metals in the form of a wire and find out what happens when the elastic limit is exceeded. These concepts can then be used to analyse the design products used in industry and the home. Learners also need to understand the variation in viscosity of fluids and how Bernoulli's principle links the rate of flow of a fluid to the pressure that the fluid exerts.

As concepts in physics are expressed mathematically and tested experimentally the topic requires that learners are able to use the relevant equations and apply mathematical skills to problems in physics. Learners need to be able to transform equations and use standard form. They must also be familiar with the accepted symbols that are used for quantities given in equations, give units in standard form and know the standard prefixes to indicate multiples or fractions of a unit. Accurate use of symbols and units as well as always showing the working for calculations should be stressed throughout the course. To gain the most from experimental work learners need to be able to express results in a form that shows the relationship between quantities. Prior to the examination



learners should be given a suitable time for revision which is led by the assessor. This should include a discussion of examination technique, review of the examination command words and also the completion of exemplar material.

Assessment guidance

This unit will be assessed through a 150-minute written exam worth 120 marks. The paper is split into three sections, and each section (biology, chemistry and physics) is worth 40 marks. The exam will be set and marked by Pearson.

The paper will include a range of question types. These include:

- multiple choice
- calculations
- short answer
- open response.

These question types are intended to assess learners' discrete knowledge and understanding of the content in this unit.

Sample assessment materials will be available to help centres prepare learners. You should also give learners the table of command words found in the specification and talk through the words.

Getting started

This provides you with a starting place for one way of delivering the unit. Activities are supplied in preparation for the external assessment.

Unit 5: Principles and Applications of Science II

Introduction

This unit builds on the work covered in the principles and applications of Science I and develops the theme of co-ordination and control of the main organ systems including cardiovascular system, the pulmonary system and the urinary system as well as looking at the transport of molecules into and out of these systems.

Topic A – Properties and uses of substances

A1 Relating properties to uses and production of substances

- Learners will be able to understand extraction and purification of inorganic substances by looking at experiments that relate to this. They can carry out practical work testing for the acid-base nature of oxides and relate this to the extraction and purification of alumina from bauxite in industry. They can carry out electrolysis experiments, which will relate to the extraction of aluminium and the electrolysis of brine.
- You can make links with reactivity of metals and redox reactions studied in Unit 1 and help to ascertain the most appropriate production method, specifically for the extraction of titanium. The use of case studies for production and uses of different substances, such as alumina in refractories and calcium hydroxide in effluent treatment, will allow learners to discuss and present what they have learnt.

A2 Structures, reactions and properties of commercially important organic compounds

- Learners will next look at commercially important organic compounds. You will need to spend some time delivering the basics of the subject and you should begin with introducing naming conventions, classification, different ways of representing structures, three-dimensional shapes, isomerism, different types of bonding and physical properties. You should deliver this in short sections interspersed with problems that allow learners to apply their understanding. Learners should use molecular model kits to construct and visualise molecules that are under discussion. You can supply boiling point data for hydrocarbons to learners to discuss and explain trends.
- You will need to teach organic chemical reactions, but the subject is very practical and you should give learners as much opportunity as possible to experience this. Practical investigations to compare the reactivity of alkanes and alkenes will reinforce the differences in properties between these hydrocarbon types. Learners should also synthesise useful products such as alcohols and polymers. Organic mechanisms can be studied through the use of videos and animations to support delivery.

A3 Energy changes in industry

- Learners will finally look at energy changes in industry. You can support delivery of the basics (terminology, standard conditions and definitions of standard enthalpy changes) by demonstrations and practical work to show enthalpy changes. Practicals should link to previous reactions studied in this unit such as combustion and displacement. Learners should perform calculations based upon their experimental data and from supplied literature data, and consider the size and



Unit 5: Principles and Applications of Science II

magnitude of their answers.

Topic B – Organs and systems

B1 The cardiovascular system

- Complete a heart dissection including labelling the path of the blood through the heart and the identification of the main arteries and veins leaving and entering the heart.
- Assessor-led discussion on the identifiable structures in the heart that contribute to its function leading to labelling a diagram with these structures.
- Complete an investigation into ABO blood typing to identify the different blood types.
- Visit a hospital department to see ECG traces being taken and discuss with health professionals how these are used in diagnoses of arrhythmias.
- Use a stethoscope to listen to the lub-dub sound of the heart and apply this to atrial systole and ventricular diastole.
- Research the factors that increase the risk of cardiovascular disease and present this to the other learners.
- Use optical microscopes to investigate the effect of drugs on the heart rate of *Daphnia* (water fleas).
- Visit pharmacists to discuss the possible treatments available for cardiovascular disease and the benefits and risks of these treatments.

B2 Ventilation and gas exchange in the lungs

- Complete a lung dissection in order to identify the main structures of the lungs.
- Model lung and diaphragm structure using balloons in a bell jar with a flexible membrane.
- Assessor-led discussion on the mechanics of ventilation; kinaesthetic learners may benefit from acting out the movement of the diaphragm and rib cage during inhalation and exhalation.
- Use the collapsing can demonstration to show what happens when internal pressure reduces dramatically.
- Research task into how the structure of the lungs is related to their function to give oxygen for aerobic respiration and the removal of carbon dioxide.
- Measure lung capacity using a spirometer and lung volume bags and interpret graphs related to total lung capacity.
- Use a peak flow meter to measure expiratory flow and relate its use in diagnosing asthma.
- Interpret spirometer traces to explain the changes that occur during exercise.

B3 Urinary system structure and function

- Complete a dissection of the kidney to identify the major sections of the kidney.
- Produce a model of a nephron using string and paper to show the flow of the liquid part of the blood through the nephron and label a clear diagram showing the structures of the nephron.
- Use Clinistix to test urine for glucose and protein.
- Research the kangaroo rat, which can tolerate much higher concentrations of

**Unit 5: Principles and Applications of Science II**

sodium chloride than most other mammals, due to adaptations of its nephron.

- Learners should research how the body undergoes osmoregulation including the role of ADH, and then present their results to other learners.
- Produce a leaflet explaining the role of the kidney in maintaining a balance in terms of water, electrolytes and blood pressure.
- Visit a hospital nephrology department and examine a dialysis machine. It may be possible to talk to a patient on dialysis to understand how the process affects their lives.
- Investigate the criteria used by health professionals that determine which patient receives a kidney transplant.

B4 Cell transport mechanisms

- Make a poster of the fluid mosaic model of a cell surface membrane including phospholipids, glycoproteins, channel proteins, glycolipids, cholesterol and channel proteins.
- Investigate diffusion in agar cubes of different sizes using phenolphthalein indicator in different concentrations of hydrochloric acid to show diffusion in action, and how surface area to volume ratio affects the transport of molecules in living organisms.
- Investigate the process of osmosis using beetroot and a colorimeter in various salt concentration.
- Investigate osmosis using eggs with the shells removed (using vinegar) placed into high glucose solution or coloured water to see the effect of diffusion across cell membranes.
- Research the role of carrier proteins and protein channels in the process of facilitated diffusion to present to other learners.
- Research active transport in relation to creatures that live in the ocean and how they regulate salt levels.
- Research the processes of endocytosis and exocytosis in the transport of large molecules.

Topic C – Thermal physics, materials and fluids

This topic will give learners the opportunity to study concepts that have allowed scientists and engineers to make great advances in the technologies that give us a better quality of life. Much of the theory that you deliver is supported by practical experimental work that encourages critical thinking, problem solving, team working and allows learners to apply mathematical skills. Learners also develop their understanding and communication skills by giving presentations that, along with time dedicated to revision, will give a good basis for success in the examination.

C1 Thermal physics

- The ideas of energy transfer, doing work and efficiency are applied to mechanical measurements and the behaviour of gases and understanding of these concepts is supported by experimental work.
- The concept of conservation of energy is used as a basis for learners to understand the First Law of Thermodynamics and from this you should extend their knowledge to encompass kinetic theory and the ideal gas equation.
- An understanding of adiabatic and isothermal process together with the Second Law of Thermodynamics enables learners to explain how turbines, petrol and diesel engines work, and appreciate the reasons for their maximum efficiency being



Unit 5: Principles and Applications of Science II

limited. These concepts are also applied to heat pumps and refrigerators.

- Learners have to calculate the energy needed to raise the temperature of substances and change their state. This is supported by experimental work; the importance of these concepts applied to both industrial and domestic uses.

C2 Materials

- Some properties of materials are now considered. Density of substances is measured and the equation used for calculations. Hooke's Law is also tested for the elasticity of a spring. Various materials are stretched and their properties described.
- A demonstration, stretching a long wire gives learners the opportunity to determine tensile stress, strain and Young's Modulus from experimental results as well as using theoretical values. Metal fatigue and its possible consequences are also considered.
- Learners appreciate that energy is transferred in the stretching of wires and rubber and can determine this from graphs. You can also explain the differences in the stress-strain curves for different substances.

C3 Fluids in motion

- Learners consider streamline and turbulent flow of viscous fluids and carry out an experiment on viscosity. You can then link the rate of fluid flow to pressure and the Bernoulli principle is applied to various situations.
- Preparation of a revision timetable, time management of revision and tutor-led revision exercises will help prepare learners to attempt the sample examination material. This then gives a basis for tutor-led discussion and more focused revision prior to learners taking the examination.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit, alongside *Unit 1: Principles and Applications of Science I*, covers some of the fundamental core science concepts in biology, chemistry and physics.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/en/support/published-resources.html>) for more information as titles achieve endorsement.

Textbooks

Annets, F., *Applied Science L3 BTEC National*, Pearson Education, 2010 (ISBN: 978-1846906800).

Supports approach and subject matter for BTEC National Applied Science. The chapter on structure and function supports the unit content and has activities suitable for learners to access to practise skills and acquire knowledge and understanding prior to assessment.

Breithaupt, J., *New Understanding Physics for Advanced Level*, 4th edition, Nelson Thornes, 1999 (ISBN: 978-0748743148).

Presents concepts very clearly, and is well illustrated.

Chapman, B. and Jarvis, A., *Organic Chemistry, Energetics, Kinetics and Equilibrium*, Nelson Thornes, 2000 (ISBN: 978-0174482906).

Sets out the basics of organic chemistry and energy change.

Clark, J., *Calculations in AS/A Level Chemistry*, Longman, 2000 (ISBN: 978-0582411272).

Contains many relevant calculations and worked examples.

Duncan, T., *Advanced Physics*, 5th edition, John Murray, 2000 (ISBN: 978-0719576690).

Contains up-to-date examples and exam questions from recent past papers.

Ellse, M. and Honeywill, C., *Electricity and Thermal Physics*, revised edition, Nelson Thornes, 2004 (ISBN 978-074877663X).

Revised edition giving full coverage of the content.

Hill, G. and Holman, J., *Chemistry in Context*, Nelson Thornes, 2000 (ISBN: 978-0174482760).

Detailed and accessible general A-level textbook.

Kelly, D. and Holt, R., *Student Support Materials for AQA – A2 Physics Unit 5: Nuclear, Thermal Physics and Option Units*, Collins, 2010 (ISBN: 978-0007343867).

Can be used by learners as a study guide or revision guide.

Ramsden, E., *Calculations for A-Level Chemistry*, Nelson Thornes, 2001 (ISBN: 978-0748758399).

Contains many relevant calculations and worked examples.

Ramsden, E.N., *A-level Chemistry*, 4th edition, Nelson Thornes, 2000 (ISBN: 978-0748752997)

In-depth look at energy change, organic and inorganic chemistry.



Journals

Chemistry World

www.rsc.org/chemistryworld

Education in Chemistry

www.rsc.org/Education/EiC

Guardian Science

www.guardian.co.uk/science

Nature

www.nature.com

New Scientist

www.newscientist.com

Scientific American

www.scientificamerican.com

Technical journals requiring high level reading skills and ability to use and understand technical terms. Contain articles and latest news and research into related topics.

Videos

<https://www.youtube.com/watch?v=moPJkCbKjBs>

The fluid mosaic model.

Websites

www.ase.org.uk

Association for Science Education, which has many useful links for practical and engaging teaching.

<http://chemistry.about.com>

About Chemistry website – engaging chemistry practical demonstrations and videos.

www.cleapss.org.uk

Health and safety information when handling chemicals and performing experiments.

www.ecofys.com/files/files/ecofys-2014-international-comparison-fossil-power-efficiency.pdf

International comparison of fossil power efficiency and CO₂ intensity – Update 2014.

www.HSE.gov.uk/coshh

'Control of Substances Hazardous to Health' to ensure necessary risk assessments are carried out.

www.nationalstemcentre.org.uk

National STEM (Science Technology Engineering and Mathematics) Centre website – resources for supporting teaching and learning, links with employers and industry.

www.nuffieldfoundation.org/practical-chemistry

Nuffield Foundation website – a good range of practical chemistry experiments.

www.rsb.org.uk

The Royal Society of Biology is particularly helpful on dealing with organic material and live organisms such as *Daphnia*.



www.rsc.org

The Royal Society of Chemistry website has resources and videos to support the teaching of chemistry.

www.schoolscience.co.uk

Association of Science Education website has links to resources, activities, events and research.

www.youtube.com/watch?v=k4J86XmPZSU

Fluid flow patterns.

www.youtube.com/watch?v=LrRdKmjhOgw

Roller Coaster Law of conservation of energy.

www.youtube.com/watch?v=nkOtOMNS5bQ

Iso thermal and adiabatic processes.

www.youtube.com/watch?v=uZh8Dfymg38 Intro to Streamline (laminar) and turbulent flow.

www.youtube.com/watch?v=Xcrco59p40o

PV diagrams and First Law.



Unit 6: Investigative Project

Delivery guidance

Approaching the unit

This is a practical unit which gives your learners the opportunity to carry out a successful practical vocational investigative project that they are interested in and have chosen in consultation with you. Learners can use and adapt some of the key skills and techniques that they have previously used in a work experience placement or in education and used in other practical experimental units on the course.

Universities and industries welcome learners who have good knowledge and understanding, and excellent practical experimental, employability and project management skills. Learners will learn and reinforce the importance of a number of these key skills in literature search and review, planning, implementing, collecting and analysing, and presenting results from their chosen project.

To complete this unit your learners will need access to a laboratory or, for a field trip, a range of equipment, apparatus and materials for practical work. They will also need logbooks, diaries and materials for presenting projects as well as access to research materials – which include the internet, CD-ROMs, software packages, journals or magazines, and books.

The delivery methods proposed for this unit are, for example:

- discussions – class and small group discussions on the various stages of the project and the use of project case studies
- tutor presentation and guidance – briefing and monitoring learners at each stage of the project
- individual learner activity – where learners complete each stage of the project
- video clips – from which learners can learn and reinforce their knowledge about different experimental practical techniques and methods.

Delivering the learning aims

For **learning aim A**, introduce the unit by giving an overview and describing how it fits within the qualification and relates to other units. Discuss with learners the various types of vocational investigative science projects that previous learners have carried out, and have learners share experiences of any assignments and projects they themselves have completed previously. You could then discuss with the learners ideas about what sort of project they would like to carry out as an individual. Learners need to be aware of the requirements of project proposal aspects such as the need for a title, aims and SMART objectives, hypothesis and potential limitations for the project.

You need to introduce learners to ways in which literature searches and reviews should be carried out, analysed and evaluated. Teaching and learning opportunities should be presented to learners to allow them to develop skills in using systems and technology in their literature search and review. They will



need to understand that a proposal will need to be produced and approval gained. They also need to be given opportunities to develop critical thinking skills in the analysis of their literature search, including potential limitations in their project proposal and justifying their chosen hypothesis. Their project proposal could also include non-routine problem-solving skills and creative solutions.

For **learning aim B**, learners need to understand about schedules of work, with timelines, milestones and the importance of target dates. This will help prepare them to write their own schedule of work and to monitor their progress using logbooks and diaries. This will allow learners to complete a schedule using a template with realistic timelines taking into account the number of hours available. You could brief the learners on how to go about producing a plan using a typical template for this level of learner and how they would need to implement the project using the required resources. You could also highlight the need for learners to plan how to set up equipment, instruments or sensors, or prepare resources for fieldwork, and decide how they are going to collect, record, analyse and present data. You could present and discuss with them the need to ensure they have thought about contingency planning and what remedial action to take when necessary. Learners need to use problem-solving skills in contingency planning and justify changes to their project plan.

You could then brief learners on awareness of health and safety issues, explain who will carry out risk assessments, and ensure they take into account ethical and legislative issues. You could also ask a guest speaker to outline the importance of health and safety – this could be a health and safety representative from your centre or an outside speaker.

For **learning aim C**, which will be assessed alongside learning aim D, the implementation stage could be introduced, ensuring that learners are prepared for this stage and discussing any issues that they have before they go ahead. Learners need to understand the approved procedures and practices, and adhere to health and safety requirements and outcomes of risk assessment and ethical considerations. They will need to take responsibility for showing you that they are keeping their logbooks and diaries up to date. You could brief learners about presentation of data and they would need to take responsibility for ensuring their presentation of data is fit for purpose.

For **learning aim D**, you could brief the learners about methods of evaluating their findings using scientific protocol and terminology, including advice about referencing and bibliography for the finalised project report. Finally, you could brief and discuss with them methods of evaluating their findings.

For learning aims C and D, learners develop negotiating and influencing skills throughout, and critical thinking and problem-solving skills in justifying and reflecting on their conclusions and the limitations of their project.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Undertake a literature search and review to produce an investigative project proposal	A1 Literature review A2 Investigative project proposal	Present a project plan proposal supported by a logbook.



<p>B Produce a plan for an investigative project based on the proposal</p>	<p>B1 Schedule</p> <p>B2 Plan</p> <p>B3 Health and safety and ethical considerations</p>	<p>Present a project plan proposal supported by a logbook.</p>
<p>C Safely undertake the project collecting, analysing and presenting the results</p>	<p>C1 Experimental procedures and techniques</p> <p>C2 Collect, collate and analyse data</p> <p>C3 Data presentation</p>	<p>Present an evaluative report of the final project.</p>
<p>D Draw conclusions and evaluate the investigative project using correct scientific principles</p>	<p>D1 Scientific report for investigative project</p> <p>D2 Scientific evaluation of findings</p>	

Assessment guidance

This unit is internally assessed through a number of independent tasks. Each task should cover at least one entire learning aim and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion.

There are three suggested summative assignments for this unit as shown in the unit specification, each covering one or more learning aims. All learners must independently generate individual evidence that can be authenticated. The main sources of evidence are part of the final project report.

Learners should incorporate in-depth research that is corroborated by a fully referenced bibliography. Learners need to produce their final report in a style that allows assessors to assess the evidence presented for each individual criteria and to ensure that three assignment themes are present.

BTEC assessors must validate the practical work carried out by learners. Appropriate methods for this could be video/photographic evidence, and observation and/or witness statements. Technical staff could complete witness statements for relevant assessment criteria. Observation records alone are not sufficient sources of learner evidence; they should be used to support the original learner-generated evidence in the project report. This evidence could be in the form of a reflective account of what was done, results, log books/diaries, etc.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 6: Investigative Project
<p>Introduction</p> <p>Begin by introducing the unit to learners through presentation and discussing the unit specification, learning outcomes and assessment criteria and how it is assessed.</p>
Learning aim A – Undertake a literature search and review to produce an investigative project proposal
<ul style="list-style-type: none"> • You could brief learners about the choice of relevant areas of study for a project. Ask learners to collaborate in small groups to come up with examples of different projects that they have experienced. Each learner could then contribute to a class discussion on the type of projects they have experienced in education or through work experience. You could give learners the titles of previous projects carried out at the centre and any case studies of previous projects. • You could ask guest speakers to come in and discuss science projects and the importance of employability and project management skills, and the prospects of engaging with industry. • Ask learners to decide as individuals or in a group the area of study they are interested in, its vocational aspect and industrial sector. Learners should discuss their area of study with you for approval. • You should give a presentation to learners on how to go about carrying out a literature search and review, covering identification, location, reliability, extraction and referencing of sources of information. • You should brief learners about project proposals to ensure they propose its title, aims and objectives, hypothesis, background, rationale, resources and any potential limitations. • Once learners have acquired the relevant skills and knowledge, they should use the assignment brief to work independently to produce the required evidence.
Learning aim B – Produce a plan for an investigative project based on the proposal
<ul style="list-style-type: none"> • You should brief learners on the design of a schedule of work , start date, completion date, realistic timelines, milestones, and setting and achieving target deadlines. You should give them logbooks and diaries. • You should brief learners about producing a realistic working plan, taking into account how they will implement the project with the resources required and how they are going to collect, record, analyse and present data. • You should then brief learners on contingency planning and lead a discussion about remedial actions to make changes to a plan. • You should give a presentation and discuss with learners the need for health and safety, risk assessments and ethical considerations, taking into account legislative, COSHH and PPE requirements. • You could ask a health and safety representative to give a presentation, or an outside health and safety guest speaker.

**Unit 6: Investigative Project**

- Once learners are confident in planning an investigation, they should independently attempt the assignment.

Learning aim C – Undertake the project collecting, analysing and presenting the results

- You should begin by briefing and discussing with learners the need for good practical skills, to ensure they are using safe working practices when following procedures and practices, and when using equipment and instruments. The need to collect, record and analyse data, taking into account the need for accuracy, reliability, validity, precision and integrity, using appropriate methods of data processing and analysis.
- Also remind them about monitoring their projects using logbooks and diaries.

Learning aim D – Draw conclusions and evaluate the investigative project using correct scientific principles

- You should introduce the topic of how to write scientific reports and cover scientific protocol and terminology.
- You will need to brief learners about the structure and format, use of past tense, and the use of correct scientific terminology, referencing and bibliography. It is important that the references and bibliography are correctly written, and it may be helpful to review the Harvard referencing system with learners.
- Learners could look at examples of published scientific reports and analyse them in terms of style, format and type of communication.
- Encourage learners to develop skills including time management, keeping to and following appropriate standards and protocols, demonstrating safe working practice, giving and receiving constructive feedback, etc. Learners should be resourceful and show initiative where possible.
- Once learners are confident in the format of a scientific report and their evaluative skills, they should attempt the assignment.
- You could brief learners and discuss with them how to present data to ensure it is fit for purpose.
- Learners carry out the implementation stage, noting any limitations and improvements.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

Units in the new Level 3 BTEC Applied Science qualification that link to this unit are listed below.

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 3: Science Investigation Skills.*

The previous QCF Level 3 BTEC National in Applied Science also has units that link to this unit and resources produced or purchased for those units may be suitable for use in this unit.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Annets, F, Foale, S, Hartley, J, Hocking, S, Hudson, L, Kelly, T, Llewellyn, R, Musa, I, and Sorenson, J *BTEC Level 3 National Applied Science Student Book* (Pearson, 2010) ISBN 9781846906800

Contains *Unit 3: Scientific Investigation* material for 2010 specification.

Coyne, GS *The Laboratory Companion: A Practical Guide to Materials, Equipment and Techniques* (Wiley-Blackwell, 2005) ISBN 9780471780861

Contains information about material, equipment and techniques.

Journals

Nature

New Scientist

Scientific American

Websites

www.ase.org.uk

The Association for Science Education

www.HSE.gov.uk/coshh

Control of Substances Hazardous to Health

www.HSE.gov.uk

Health and Safety Executive

www.iop.org

Institute of Physics

www.nationalstemcentre.org.uk

National STEM Centre

www.rsb.org.uk

Royal Society of Biology



<http://www.rsc.org>

Royal Society of Chemistry

www.stemnet.org.uk/ambassadors

STEM Ambassadors



Unit 7: Contemporary Issues in Science

Delivery guidance

Approaching the unit

Learners may bring knowledge of contemporary issues through their own experiences – such as at home, previous studies, current affairs, through the media and charities, and so on.

You could give initial introductory input for your learners about a number of current contemporary issues and start a discussion on their thoughts and views on these issues. Learners should be encouraged to research and learn about contemporary issues through various forms of media and through discussion with peers, friends and family. Universities and industries welcome learners that have a good knowledge, understanding and the employability skills developed when studying contemporary issues.


To complete this unit, your learners will need access to the internet, newspapers, journals, magazines, and books.

The delivery methods proposed for this unit are, for example:

- discussions – class and small group discussions on case studies and new contemporary issues
- visiting/guest speakers from a variety of sources such as from charities and pressure groups, energy suppliers, manufacturers, local media, local government etc.
- tutor presentation/guidance – briefing and monitoring learners about individual research and valid appropriate websites and references
- group and individual learner activity – where learners can research relevant materials and case studies
- revision and mock paper examination sessions
- video and YouTube clips – where learners can learn and reinforce their knowledge and understanding of contemporary issues.

Delivering the topics

For **topic A**, introduce the unit by informing the learners about its different sections, how it fits within the qualification and how it relates to other units. Inform the learners about the resources available within your centre with regard to contemporary issues. Ask learners to work in small groups to discuss the definition of what is a contemporary issue and then discuss the definition with the learners, this could be supported by sharing previous experiences of contemporary issues to engage and motivate learners. You could follow this by discussing a particular contemporary issue and any ethical, social, economic and environmental aspects/impacts. You could then ask learners to carry out research on a contemporary issue with guidance from you about the validity and reliability of sources of information.



You could ask a guest speaker through STEMNET ambassadors or other relevant organisations to talk about a particular contemporary issue; learners would need to prepare, to take notes and ask questions with regard to any ethical, social, economic and environmental impacts. This could lead to a class discussion about any drawbacks, benefits, risks, misuses, solutions and conclusions about the contemporary issue. Engage the learners by asking them to research the other contemporary issues in the content in a systematic manner and review and evaluate their findings with regard to patterns, similarities, benefits, drawbacks, risks, misuses, solutions and conclusions.

You could then ask learners to answer typical examination questions with regard to social, ethical, environmental and economic impacts on different contemporary issues.

You could give a presentation on the influence of different organisations and individuals on science and technological contemporary issues with support from some current case studies that are in the reporting mediums. It would be useful to lead a discussion with learners about the influence of governments and their departments on some of the contemporary issues that you have covered such as the influence of the Environmental Agency government department on environmental issues. You could support this by asking a guest speaker from a government organisation to discuss their influence on a contemporary issue. Learners could then carry out some individual research on global organisations and give feedback on their findings about their influence such as any bias, policy issues, laws, drawbacks, benefits, risks, misuses and any solutions.

Learners could repeat this sequence to draw conclusions about how other organisations and individuals influence contemporary issues. You could then ask learners to review and evaluate their findings with regard to patterns, similarities, benefits, drawbacks, risks, misuses, any solutions and conclusions.

You could then ask learners to answer typical examination questions with regard to the influence of different organisations and individuals on contemporary issues.

For **topic B**, it would be useful to ask learners about their experience of the importance of interpretation and analysis of scientific information with regard to science practical experimental work. Discuss with the learners how they could apply this skill to contemporary issues and the different sources of information and data involved. Ask learners to carry out some research on a contemporary issue with regard to collecting any qualitative or quantitative data from more than one source, and to include any charts, tables, calculations, graphs, histograms, and so on. You could follow this with a class discussion on the findings and any variation of interpretation and methods of analysis of the data, and any conclusions drawn. You could then give a presentation about the evaluation of scientific information to include the reliability, validity and accuracy of sources of information and data. Learners could carry out some research with regard to reliability and validity and make comparisons from different sources. Introduce factors about sample size, references to further publications, bias, errors, inaccuracies, use and misuse of data, visual presentations and authenticity of data. Ask learners if they have any ideas about any potential areas for further development with regard to the contemporary issue.

Your learners as individuals or in groups could then review and evaluate their overall findings with regard to patterns, similarities, benefits, drawbacks, risks and misuses.

You could then ask learners to answer typical examination questions on interpretation, analysis and evaluation of scientific information with regard to contemporary issues.



For **topic C**, it would be useful to give an introductory presentation on the different types of reporting medium and how they report contemporary issues for different audiences. Your learners will need to gain an understanding of the fact that different types of reporting mediums have a rationale for the way they report contemporary issues. Ask learners to carry out a literature search and review of the reporting of a contemporary issue, and to make comparisons of how these have been reported. You could then ask learners to review and evaluate their findings with regard to patterns, similarities, differences and conclusions. Follow this up by giving a presentation using one type of reporting medium and ask learners about their thoughts on the reporting medium and its target audience. You could then ask learners to answer typical examination questions with regard to the different types of reporting mediums and their target audiences with regard to contemporary issues.

Your learners need to be familiar with the level of science used in different types of reporting medium. They need to be able to differentiate the level and technicality of the language used, the use of terminology, accuracy, the types of referencing used, any bias, use of visuals, the quality of the scientific reporting and conclusions drawn.

You could then ask learners to answer typical examination questions with regard to contemporary issues, and the reporting medium and target audiences. It is also essential for learners to be able to differentiate between reporting mediums and to be able to take an article and write it for a different type of audience.

Assessment guidance

This unit is externally assessed with a pre-release source booklet supplied prior to the sitting of the task. This source booklet is divided into two sections: Part A and Part B. Part A will contain three articles for the completion of the preparatory work for the written task in Part B.

Learners should undertake Part A during the first two weeks of the three-week assessment window under supervised conditions. Tutors are free to arrange the supervised two-week assessment period for Part A as they wish.

Learners will need to conduct preparatory work, which could include annotating the articles and making additional notes on the A4 sheet in this booklet.

Tutors cannot give any support to learners; they must complete the work independently. They must not take this source booklet out of the classroom. Learners may have access to IT or other sources of information.

Tutors must return source booklets to learners when they start Part B.

The written task booklet for Part B will be issued at the same time as Part A materials but must be kept securely and not released to learners until the start of the third week assessment window.

Getting started

This provides you with a starting place for one way of delivering the unit. Activities are provided in preparation for the external assessment.

Unit 7: Contemporary Issues in Science

Introduction

Begin by introducing the unit to learners through presentation and discussing the unit introduction, topics and summary of assessment. You could then explain how the unit fits within the qualification.

You could brief learners about how this unit will develop their skills and help them when studying other units within the qualification, and support them in preparation for the workplace or university.

At this stage, it may be worthwhile discussing with the learners what contemporary issues there are, and asking them to share their own experiences. You could follow this by explaining the big picture and getting them to draw a mind map of how all the aspects of contemporary issues fit together. The learners could also discuss contemporary issues with, for example, their friends and family to help them in their discussions while studying the unit.

Topic A – Contemporary scientific issues

- Brief learners about contemporary issues and aspects of ethical, social, economic and environmental impacts.
- Take one contemporary issue such as energy sources and discuss this with the learners.
- Brief the learners on the resources available to them to carry out investigations into contemporary issues.
- Ask learners to carry out research into energy sources from a number of media sources and write up their findings.
- Discuss with the learners their findings and draw conclusions, for example about any drawbacks, benefits, risks, misuses, problems to solve and any solutions.
- Invite a guest speaker to come in and discuss a contemporary issue and any new developments taking place in finding solutions/conclusions.
- Give a presentation to learners about the other contemporary issues shown in the unit content.
- Enable learners to carry out research into an example in each of the other contemporary issues in the content and ensure they take notes about the impact of any ethical, social, economic and environmental aspects.
- Ensure learners discuss in small groups their findings and present their findings in a whole class discussion.
- Follow this up by summarising the impact of any ethical, social, economic and environmental aspects with regard to any patterns, similarities, benefits, drawbacks, risks, problems, misuses and solutions.
- Ask learners to present their findings using a scientific poster, a leaflet or by use of PowerPoint slides.
- Learners should then answer typical examination questions with regard to social, ethical, environmental and economic impacts on different contemporary issues.



- Give a presentation to learners about the influence of different organisations and individuals on science and technological issues.
- Take one organisation such as the government and a relevant government department, and discuss its influence on a science and technological issue.
- Enable learners to carry out research into how the government and a relevant department have an influence on a science and technological issue.
- Discuss with the learners their findings and draw conclusions about their influence; to include for example any bias, policy issues, laws, drawbacks, benefits, risks, misuses, problems to solve and any solutions recommended.
- Invite a guest speaker from a government department to discuss their influence on a contemporary issue(s), enabling learners to ask questions and discuss with them any new developments taking place.
- Give a presentation to learners about other organisations and individuals who have an influence on science and technological issues shown in the unit content.
- Ask learners to carry out research into an example in each of the other organisations or individuals in the content and make notes about their influence on contemporary issues.
- Enable learners to discuss in small groups what their findings were and present their findings in a whole class discussion.
- You could follow this up by summarising the influence of organisations and individuals on science and technological issues such as any patterns, similarities, benefits, drawbacks, risks, problems, misuses and any proposed solutions.

Learners need to answer typical examination questions with regard to the influence of different organisations and individuals on contemporary issues.

Topic B – Interpretation, analysis and evaluation of scientific information

- Give an introductory presentation to the learners about the importance of information and data, its interpretation, analysis and evaluation. Discuss how the media may interpret the information and data to influence the outcomes they want.
- Discuss with learners how this topic overlaps and links with the interpretation, analysis and evaluation of data and information in other relevant units of the qualification.
- Ask learners to carry out an investigation on a contemporary issue with regard to collecting qualitative and quantitative data from more than one source; to include any visual data such as tables, charts, graphs, calculations or statements using data.
- Lead a discussion with your learners about their findings and draw conclusions from the use of information and data and any variations of interpretation and analysis of data.
- Give a presentation to learners about the importance of evaluating information and data, how it can be represented correctly or incorrectly in the media and include reliability, accuracy and validity of sources of information and data.
- Ask learners to carry out an investigation into a contemporary issue using different sources of information and data with regard to its sample size, authenticity, use and misuse, validity, reliability and accuracy.
- Enable learners to then discuss in small groups what their findings were and ask them to present their findings to a whole class discussion.

- Learners should follow this up by summarising their findings on sample size, references to further publications, bias, errors, inaccuracies, use and misuse of data, visual presentations and authenticity of data.

Ensure learners answer typical examination questions on interpretation, analysis and evaluation of scientific information with regard to contemporary issues.

Topic C – Scientific reporting

- Brief learners about how different types of reporting mediums target different types of audience with regard to contemporary issues.
- Take one contemporary issue from three different articles and discuss them with the learners. Discuss how the issue is reported to target different audiences.
- Ask learners to carry out research into a contemporary issue from three different media sources and review their findings with regard to patterns, similarities, differences and conclusions.
- Hold a class discussion to summarise their findings and draw conclusions about the differences with reference to the target audience.
- Ensure learners answer typical examination questions with regard to the different types of media and their target audiences with regard to contemporary issues.
- Discuss with learners how science and technology contemporary issues are reported and the relationship with the reporting medium, the target audience, the level and technicality of the language used, use of terminology, their accuracy, types of referencing, any bias, use of visuals, use of individuals and organisations.
- Using the above variables ask learners to carry out an investigation into contemporary issue from different sources.
- Discuss with learners what their findings were and ask them to present their findings in a whole class discussion, summarising their findings and drawing conclusions.
- Enable learners to present their findings about different reporting mediums using for example a scientific poster, a leaflet or by use of PowerPoint slides.

Ensure learners answer typical examination questions with regard to contemporary issues, and the reporting medium and target audiences and that they take an article and write it for a different type of audience.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 3: Science Investigation Skills*
- *Unit 5: Principles and Applications of Science II*
- *Unit 6: Investigative Project.*

This unit also links to a wide range of optional units available across the qualification.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Use of different reporting mediums is essential for this unit, such as tabloid and broadsheet newspapers and scientific articles.

Textbooks

Foal, S., Hocking, S., Llewellyn, R., Musa, I., Patrick, E., Rhodes, P. and Sorensen, J., *BTEC Level 3 Applied Science Student Book*, Pearson, 2010 (ISBN 9781846706800). This book contains units that cover content about contemporary issues.

Journals

Biologist

Royal Society of Biology.

Chemistry News and Chemistry World

Royal Society of Chemistry.

Physics World

Institute of Physics.

Nature

An international journal covering research spanning all areas of science.

New Scientist

Covering the latest news and articles about science and technology.

Physics World

Institute of Physics.

Scientific American

Latest science stories, articles and news.

Videos

www.youtube.com/watch?v=XhmstW6xrgE
Bioethics: Contemporary Issues in Science.

www.youtube.com/watch?v=DVZVSQ3Ieno
Contemporary issues in Physical Science.

www.youtube.com/watch?v=QdQBF_nr_EM
Global Issues in Science and Technology.

Websites

www.ase.org.uk
Association for Science Education – science resources for tutors, journals, textbooks, useful links.

www.HSE.gov.uk/coshh
Health and Safety executive information about the 'Control of Substances Hazardous to Health'.

www.HSE.gov.uk
Health and Safety Executive – information about health and safety.

www.iop.org
Institute of Physics – resources about theoretical and practical physics, journals, textbooks, useful links.

www.nationalstemcentre.org.uk
National STEM centre – resources for practical experiments and projects.

www.rsb.org.uk
Royal Society of Biology – resources about theoretical and practical biology, journals, textbooks, useful links.

www.rsc.org.uk
Royal Society of Chemistry – resources about theoretical and practical chemistry, journals, textbooks, useful links.

www.stemnet.org.uk/ambassadors
STEM ambassadors – central hub for allocation of speakers to schools/colleges.



Unit 8: Physiology of Human Body Systems

Delivery guidance

Approaching the unit

Physiology – the study of the physical and chemical systems in the human body – is a fascinating topic. Many learners looking for a career in nursing, medical, sports or veterinary sciences will be interested and excited by the topics in this unit (musculoskeletal, lymphatic and digestive), how the systems function and what occurs when disease or dysfunction affects the systems.

Learners will need to research the systems to understand how they function normally. Further research to gain an understanding of what can go wrong and the impact this may have on the health of the human body will be required. Some learners may have personal experience of disease and dysfunction of one or more of the systems and sensitivity will be required when approaching the unit. Learners will need to develop an understanding of the treatments that may be available to alleviate, if not cure some of the conditions that have been identified and researched.

A wide range of textbooks, access to journals and scientific magazines and the internet should be available to learners.

Along with opportunities for learners to engage in practical work, it is possible to use a wide range of delivery methods in this unit, for example:

- use of models, practical work and simulations to assist understanding of the complex mechanism involved in the three systems and to help engage learners
- encouraging learners to create case studies, based on real or fictional characters, in order to demonstrate the impact of disease or dysfunction can have
- TV documentaries and newspaper articles about dysfunction and advances in treatments to give stimulus material for further research
- discussions in small groups to explore the issue of dysfunction and its impact
- visits to a physiotherapy department or visits from a physiotherapist or osteopath
- opportunities to discuss conditions and treatments with practitioners diagnosing, treating or supporting people suffering from conditions
- opportunities to discuss conditions and treatments with affected individuals.

Learners can undertake group work, particularly in the teaching and learning stage, but all learners must produce their own individual evidence and present it for submission and assessment in their own way.

Delivering the learning aims

Learners need to undertake practical work, and assessors will assess and validate this for the unit. Centres must ensure they comply with all health and



safety guidance and regulations. Learners should be encouraged to risk assess practical work to help ensure they are aware of the safety issues and follow the relevant procedures and guidelines.

There is opportunity for dissection within this unit. Specific groups of learners or tutors, for ethical, religious or other reasons, may not feel that they are able to undertake dissection work as part of the unit. If practical dissection is not undertaken, suitable alternatives to enable learners to gain a full understanding of the anatomy and physiology of the body systems studied in the unit content should be available. This could involve use of documentaries on dissections/operations, computer-generated simulations and model making.

For **learning aim A**, use of a skeleton, models of joints, dissection of joints and simulations will give stimulus material to determine learner knowledge and understanding of the musculoskeletal system. Secondary source material and your input will be required to extend learner knowledge and understanding of the structure and function of the musculoskeletal system to meet the unit content requirements. A visit to, or from, a physiotherapist, osteopath, sports scientist or similar professional would give a vocational context. This would also engage learners and give detailed knowledge of disease and dysfunction and the corrective treatments available. Learners would have the opportunity to develop questioning skills in order to gain information to assist them in evaluating the impact of the conditions and treatments on human health.

For **learning aim B**, learner knowledge of the lymphatic system is likely to be limited. You could consider the use of posters and textbooks to allow learners to identify the position and then research the function of the lymphatic system components. Paired or small group presentations could then be used to share the information and encourage discussion. You could encourage learners to create a vocabulary sheet/table for the system. To develop cognitive and problem-solving skills, give learners questions to research, e.g. why would someone in a wheel chair be at greater risk of malfunction of the lymphatic system? How might a splenectomy impair the ability of a person to fight disease? Learners can present their findings to the rest of the group for discussion and questioning. Individual learners or small groups of learners can investigate and produce a case study on a specific disease/dysfunction of the lymphatic system.

For **learning aim C**, the digestive system and sources of nutrients in the diet should be more familiar to learners from Key Stage 4 work. You can establish learners' prior knowledge by small group working to make models and/or posters of the digestive system. Learners can then use these as the basis for discussion about the role of the components. Your input and secondary sources can be accessed to extend knowledge and understanding to meet the requirements of the level 3 programme and unit content. Learners should undertake practical work investigating the action of enzymes to emphasise chemical digestion in the various parts of the digestive system. You can use Visking tubing to model movement of the products of digestion from the gut into the blood. Photomicrographs will aid understanding of the structure and adaptations of the small intestine to facilitate absorption. Simulations from the internet are available to model diffusion, facilitated diffusion and active uptake of digested nutrients for assimilation.

Learners should establish the sources of nutrients in the diet so will require opportunities to refresh and practise techniques for testing foods. Flame tests and testing for non-reducing sugars may not be familiar to learners. Opportunities for them to acquire and practise these skills and to understand their relevance will need to be available to learners. Some learners may have personal experience of disorders and dysfunctions of the digestive system and may be keen to understand and know more about the cause and treatments.



Others will have little or no experience. Pairing learners with and without experience of specific diseases/dysfunctions will allow peer learning and help develop interpersonal skills. Learners will need to collaborate and discuss the issues, carry out additional research to address misunderstandings and identify corrective treatments and their effectiveness.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
<p>A Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments</p>	<p>A1 Structure of the musculoskeletal system</p> <p>A2 Function of musculoskeletal system</p> <p>A3 Disorders of the musculoskeletal system</p>	<p>Learners would use information gained from research, visits, dissections/videos, models and simulations to produce an illustrated report explaining and analysing the structure and function of the musculoskeletal system. An evaluation of a related disorder/dysfunction of the system and associated treatments must be included.</p>
<p>B Understand the impact of disorder on the physiology of the lymphatic system and the associated corrective treatment</p>	<p>B1 Structure of the lymphatic system</p> <p>B2 Function of the lymphatic system</p> <p>B3 Health matters and treatments related to the lymphatic system</p>	<p>Research work using the internet and TV documentaries to help learners in creating a presentation that describes and explains the structure and function of the lymphatic system in promoting a healthy body. An evaluative case study of the effect of a disorder/dysfunction of the system and possible treatments must be included.</p>
<p>C Explore the physiology of the digestive system and the use of corrective treatment for nutritional deficiency</p>	<p>C1 Structure of the digestive system</p> <p>C2 Function of the digestive system</p> <p>C3 Health matters and treatments related to the digestive system</p>	<p>A lab book/record of investigations modelling the functioning of the various parts of the digestive system. Photographs and information from the investigations will be used to create an information leaflet that explains the role and location of organs and evaluates dietary disorder in the system and possible treatments.</p> <p>Observation records of practical work undertaken to assess the nutrient content of food will be required. Evidence and conclusions from the investigations will be incorporated into the information leaflet.</p>

Assessment guidance

This is an internally assessed unit with one practically assessed criterion. There is opportunity for further learner practical work and while evidence of participation is not required, learners should have the opportunity to acquire new skills in addition to developing existing skills and knowledge. There is opportunity for dissection in the unit. It is not integral to the awarding of assessment criteria and tutors and learners can opt not to participate. Learners must understand and follow health and safety guidance and regulations at all times.

It is recommended that there are three assignments for the unit, one for each learning aim. A holistic approach to the pass, merit and distinction criteria is required.

Learners must give independent, valid and authentic evidence to meet the assessment criteria. Practical work submitted for assessment will need to be validated by the assessor. Observation records are not sufficient on their own; there must always be learner-generated evidence available for standards verification.

Learners can use information leaflets and/or presentations instead of illustrated reports and case studies, if preferred. PowerPoint handouts may not give sufficient evidence unless accompanied by presentation notes, transcripts, video evidence or witness statements identifying the level of detail that was delivered.

Secondary sources should be referenced and learners are expected to give a bibliography.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 8: Physiology of Human Body Systems

Introduction

Splitting learners into pairs or small groups to map their current understanding of each of the three learning aims would elicit information about current learner knowledge and understanding, and assist planning for delivery of the unit.

Learners could produce mind maps or have a topic list of simplified unit content to identify current knowledge in terms of 'good understanding', 'heard of it', 'no understanding'. Discussion should be encouraged between learners about the topics/unit content, in particular about dysfunctions, the impact on quality of life and treatments and their impact/availability.

It may be expedient to do this for each learning aim separately, as you are due to deliver them, rather than covering all three at the start of the unit.

Learning aim A – Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments

Access to a range of 'hands on' bones and skeletons would make an interesting and exciting practical introduction to this learning aim.

- If available, learners can have access to a human skeleton and try to name as many bones as possible from the unit content. You could source/borrow other animal skeletons and make these available for comparison. This will be particularly helpful to support research into types of joints and the range of movement they support.
- It may be possible to get bones and joints from a local butcher for learners to see and feel the weight and investigate the structure of the bones and joints.
- Dissections of chicken wings, legs, thighs will help kinaesthetic and visual learners to understand the structure and range of movement at joints. These will also allow learners to see the relationship between bones, muscles, tendons and ligaments.
- Models of the spine, cranium and different joints may be available and learners should be encouraged to handle these and observe how they articulate.
- If learners are not comfortable with handling biological specimens, they could be encouraged to make their own models of joints using cardboard and split pins, hardboard cut-outs and elastic bands.
- Learners should be encouraged to take photographs or videos of models/dissections.
- Simulations are available on the internet for learners to access to familiarise themselves with the bones and joints listed in the unit content.
- Demineralisation of bones by placing them in acid is an interesting activity and emphasises the importance of minerals in strengthening bones.
- You can use honeycomb chocolate bars to model the internal structure of bones.
- Learners should have the opportunity to observe for themselves the microscopic structure of bones and muscles; they can compare these to electron micrographs from the internet. You should encourage learners to draw the structure and relate

Unit 8: Physiology of Human Body Systems

their observations to textbook diagrams and accounts of structure and function.

- Different groups of learners can be encouraged to investigate a different type of joint and give a presentation to the rest of the class about its structure and function.
- You can encourage learners to carry out exercises (health and safety requirements and risk assessments will need to be considered) in order to understand the antagonistic nature of muscles at joints. They could do this in collaboration with a visiting physiotherapist or member of the Sports Department or local gym.
- You could ask learners to work in pairs or small groups, and give them (or allow them to choose a card at random) a disorder(s) listed in the unit content and then research the condition and the corrective treatments and their availability and effectiveness. Each group can then feed back to the class.
- Use of scientific texts, journals, information sheets from support groups for different conditions should be accessed (and referenced) to ensure knowledge and understanding is extended.
- Your input will be required to ensure that learners are accessing sufficient depth of coverage and accurate and appropriately detailed information. This is especially important if learners are encouraged to access virtual surgery websites. A learner bibliography must identify sources that they have accessed.
- Inviting 'specialists', physiotherapists, osteopaths, research workers from a local university in to centres will allow learners to develop questioning skills and give a vocational context for the learning aim. Some hospitals have patient meetings prior to hip/knee surgery where the procedure, post-operative care, rehabilitation and long-term prognosis is explained and opportunity to handle the prosthetics is available. It may be possible to arrange a visit to, or by personnel working at such a facility.

The assessment activity, producing an illustrated report, can be compiled by learners as a result of further individual research to consolidate their knowledge of the structure and function and of the musculoskeletal system. Learners could produce case studies to compare disorders that impair the normal functioning of the musculoskeletal system and to evaluate corrective treatments. They could base the case studies on individuals known to learners, TV characters or individuals created by the learners.

Learning aim B – Understand the impact of disorder on the physiology of the lymphatic system and the associated corrective treatment

Learners should already be familiar with the circulatory system but knowledge of the lymphatic system is likely to be rudimentary. You could use a song about the lymphatic system (see resources) as stimulus material, and this may suit aural learners.

- Learners should be aware of tissue fluid and its role in giving cells dissolved substances and in removing dissolved waste. Questions could be posed about how this fluid is removed, what would happen if it was not removed, why blood volume does not decrease as tissue fluid 'leaks' from capillaries.
- You can help learners to develop their critical thinking and problem solving skills. For example, you could show photographs of someone suffering from oedema and ask learners to discuss/speculate what has caused the swelling. You could show photographs of a patient with mumps and ask learners why this has happened.
- Learners may have heard the term 'spleen' from TV programmes about rescues and A & E departments. They could be encouraged to research where it is, what its function is and how removal (splenectomy) might affect a patient.



Unit 8: Physiology of Human Body Systems

- You could give learners an outline of the human body and ask them to show the lymphatic system and research the function of the components. Learners can give presentations of their findings to the rest of the group.
- Using a 'onesie' (jumpsuit) and attaching string/wool to it to represent the lymphatic system may appeal to kinaesthetic learners. Photographs can be taken and used in evidence for the assessment.
- Pairs or small groups of learners can choose (or be given) lymphatic system disorders to research. They can then produce an information leaflet and present this to the rest of the class. This will also help develop the interpersonal and communication skills of learners. Different disorders to those listed in the unit content should be researched during teaching and learning.
- Treatments for the disorders in order to try and establish normal functioning should be researched and included in the leaflet.
- Your input will be required to ensure breadth and depth is appropriate to the level of the programme and that information is accurate and understood by all learners.

For assessment, learners will use their own research notes and information leaflets to produce their own presentation describing the gross structure and function of the lymphatic system. Learners should produce case studies to explain and evaluate the physiological reasoning for the corrective treatments of disorders associated with the system listed in the unit content.

Learning aim C – Explore the physiology of the digestive system and the use of corrective treatment for nutritional deficiency

Learners should be familiar with the structure and function of the digestive system and some food tests from Key Stage 4 work. Recall and revision of this may be required. You (or a learner) wearing a long t-shirt with a representation of the digestive system painted/sewn on could spark interest and encourage discussion as an introductory activity.

- Production of a model gut using plastic pipe and outlines of digestive organs could be an exciting activity if learners are not familiar with it from previous work. Photographs could be taken for inclusion in the work to be produce for assessment.
- Use of an anatomical model of the digestive system or a dissection or video of a dissection would help learners appreciated the proximity of organs to each other and the overall scale of the digestive system.
- Producing a (life-size) poster of the digestive system and annotating the parts and their function in chemical/physical digestion would allow learners to demonstrate and build on their previous knowledge.
- Practical work will need to be undertaken to familiarise learners with skills and techniques involved in testing for nutrients in foods. Flame tests and testing for non-reducing sugars and vitamin C may not be familiar to learners and they will need to have the opportunity to acquire these skills and techniques. You should encourage learners to develop recording techniques and to be analytical in their approach to recording results, taking into account how a quantitative analysis can be achieved.
- There will need to be a formal opportunity for learners to be assessed individually on their skills in carrying out investigations to establish sources of the key ingredients/macronutrients of a balanced diet as indicated in the unit content. The assessor will need to validate the assessed practical work and learners will need to record their findings in the evidence submitted for assessment. The food substances used for assessment should be different to those used for teaching and learning. A

Unit 8: Physiology of Human Body Systems

range of substances should be available so that not all learners are using the same substances to help ensure valid and authentic evidence is produced.

- To support learners in explaining the role of digestive enzymes on nutrient uptake, opportunities for practical work on hydrolysis and assimilation should be undertaken. This is an opportunity for learners to work collaboratively in pairs or groups to develop investigative skills to be encouraged. You should cover the full range of enzymes in the unit content. Different groups of learners can investigate different enzymes and report their findings to the whole class.
- Videos, simulations and photomicrographs will help visual learners understand the structure and relevance of the adaptations found in the digestive system for absorption, active transport and diffusion of nutrients to occur.
- You could consider the use of Visking tubing to simulate the gut in practical investigations.
- Opportunities for learners to research how and why deficiency diseases occur must be available. Some learners may have personal knowledge and/or experience of diseases like coeliac disease, irritable bowel syndrome or colitis and may wish to concentrate their research on these conditions. Learners must be encouraged to research a wider range of deficiency diseases to cover the unit content. Groups of learners can focus on different nutrients and related deficiency diseases and then present their findings to the class.
- Research work using information leaflets, scientific journals and textbooks will need to be undertaken to allow learners to familiarise themselves with corrective treatments on human health. Learners should be encouraged to produce bibliographies.

Assessment requires learners to produce information explaining and analysing the role of the digestive system on nutrient uptake. This should incorporate evidence obtained during practical work.

Learners could produce the evaluative evidence of the impact of named nutritional deficiency and corrective treatments as a case study. Assessor input may be required to ensure that each learner chooses an appropriate disorder to allow the assessment guidance to be met for the distinction criterion. Different learners should be focusing on different disorders in order to help ensure work is authentic and valid. Learners will need to cite their references.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 5: Principles and Applications of Science II*
- *Unit 9: Human Regulation and Reproduction*
- *Unit 10: Biological Molecules and Metabolic Pathways.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Hartley, J., Annets, F., Meunier, C., Llewellyn, R., Hocking, S., Peers, A. and Parmar, C., *BTEC Nationals Applied Science: Student Book Level 3*, Pearson, 2016 (ISBN 9781292134093).

This book is a useful general reference and contains sections on the musculoskeletal system, lymphatic system and digestive system.

Journals

Scientific American

New Scientist

Technical journals requiring high level reading skills and ability to use and understand technical terms. Both contain articles and latest news and research into related topics.

Videos

Musculoskeletal system:

<https://www.youtube.com/watch?v=g6sLwgUHWtk>

10-minute video introduction to musculoskeletal system and how it works. Brief outline of some techniques for treating dysfunction and pain.

Lymphatic system:

<https://www.youtube.com/watch?v=P8jAtFxMKcA>

30-minute introduction to lymphatic system.

<https://www.youtube.com/watch?v=X4Wn0j3eJrA>

2 min 34 sec video showing organisation of the system.

<https://www.youtube.com/watch?v=BX8fBlme9vQ>

One of three videos about the lymphatic system.

Digestive system:

https://www.youtube.com/watch?v=zqNYgag_zsk

Introduction to structure of the alimentary canal and its modifications.

<https://www.youtube.com/watch?v=HL7-fYBtJ1Y>

10-minute video about digestion and absorption of protein.

<https://www.youtube.com/watch?v=k0kRSF80PJ0>

What is Crohn's disease? A 4-minute video about Crohn's disease and its effects on the digestive system.

Websites

http://arma.uk.net/musculoskeletal-disorders-msk/?gclid=CjwKEAjwgqWvBRC2kajZjqeOn0oSJADqBi-l125keXIWHT4odIHt6SCGE4BgTvYYAoZNNWntNiksfoCnT7w_wcB

Arthritis and Musculoskeletal Alliance. ARMA is the umbrella association body giving a collective voice for the arthritis and musculoskeletal community in the UK. Works with member organisations to improve standards of care for people suffering from musculoskeletal disorders.

<http://www.edheads.org/activities/knee/teacher.shtml> and <http://www.surgerysquad.com>

Opportunities for learners to research virtual knee/hip replacement and other surgeries. These sites contain some graphic photographs and video images of surgery and come with warnings about suitability for some learners. Centres are recommended to view content before suggesting the sites to learners.

<http://anatomyphysiologystudyguide.com/activities-by-system/lymphatic-system-immunity>

The site has a number of tracks and lyrics to help learners understand physiology. There is one about muscles, the skeletal system, the lymphatic system and digestive system.

<https://www.coeliac.org.uk/home>

Most conditions/disabilities have a support group, which is a good starting place for learners to obtain information and details of research.

<http://www.biology-resources.com/biology-experiments2.html>

Teaching and learning resources by D. G. Mackean. Experimental work in biology, available for download. Includes enzyme practicals.



Unit 9: Human Regulation and Reproduction

Delivery guidance

Approaching the unit

Keeping the human body functioning at optimum performance is a big challenge. Many biochemical reactions will only work in a very narrow range of parameters. As humans, we constantly challenge ourselves to go faster, work harder, longer, and so on. This unit will allow learners to understand how homeostasis maintains a stable environment within the body for the nervous, cardiovascular, respiratory, endocrine and reproductive systems. It will also give opportunities to investigate homeostatic dysfunction.

Learners will have some familiarity with the structure and function of the systems in the unit from Key Stage 4. They will need to increase the depth and breadth of their knowledge and understanding to be able to assess the role of the systems in terms of how they are controlled and coordinated.

A variety of delivery methods is available to engage and motivate learners, for example:


- discussions – small group and class discussions to will enable peer learning and encourage development of intrapersonal skills
- model making will help kinaesthetic and visual learners to better understand the concepts covered in the unit
- use of songs with lyrics targeting the technical vocabulary in the unit will promote familiarity and understanding of the terminology
- practical work to study reflex actions will promote understanding and develop collaboration between learners and skills in recording and analysing results
- visiting speakers or visits to a local fertility clinic or health professional to discuss control of the cardiovascular or reproductive systems would encourage communication skills and give a vocational context.

Group work is acceptable during teaching and learning. However, all learners must submit independently produced, valid and authentic work for assessment.

Delivering the learning aims

For **learning aim A**, practical work assessing reflex actions will allow a recap of Key Stage 4 work on the structure and give an interesting and engaging start to the unit. Making model neurons to construct a reflex arc using liquorice sweets (or string) and modelling clay will embed and revise their structure and prompt discussion about function. Animations and simulations available on the internet can also be accessed. Learners could attempt to make their own animation.

You should source anatomical models of the brain, spinal column, heart and lungs to allow learners to understand their anatomy. Some centres may wish to dissect a heart and lungs, but some learners and staff may not wish to participate. Prepared slides of brain tissue, nervous tissue, neurons, cardiac muscle, alveoli etc. could be observed by learners and compared with textbook and photomicrograph images.



Practical work to assess the effect of exercise on the cardiovascular system could be undertaken. Risk assessments must be carried out and health and safety guidance must be followed. A visit to a gym with monitoring equipment (spirometer) would allow learners to better understand inspiration, expiration and rate of ventilation. Your input, animations and access to secondary source material will be required to allow learners access to the unfamiliar and new aspects of the unit content; autonomic nervous system (sympathetic, parasympathetic systems), cardiac cycle. It may be possible to arrange for a trained professional to produce electrocardiograms of learner volunteers.

Learners will need to research cardiovascular diseases and neurological disorders. Learners should reference their secondary sources.

For **learning aim B**, Learners could work collaboratively to produce annotated posters (ideally life-sized) to show the position and function of the endocrine organs. They should be encouraged to research and include information about the difference between exocrine and endocrine and exocrine/endocrine glands.

Groups of learners could produce presentations about different homeostatic mechanisms – water, blood glucose and temperature. Your input and secondary sources will need to be available to extend learner knowledge. Each presentation must include feedback loops (positive/negative) as appropriate, identifying set point, receptors, coordinator(s) and effectors. For each homeostatic mechanism, learners will need to identify and research conditions caused by an imbalance in the homeostatic mechanism and how these can be managed. Learners could carry out practical work on testing glucose levels. (They will need to follow health and safety guidelines.)

For **learning aim C**, learners will need to recap the structure and function of the male and female reproductive systems. Opportunities to observe sperm and eggs under the microscopic as well as studying photomicrographs will allow learners to compare observed morphology with textbook diagrams. Research and your input will be required to ensure a full understanding of the role of hormones in gametogenesis, the menstrual cycle and conception. Learners should be encouraged to access simulations and animations on the internet.

Learners should consider, discuss and research factors that may affect fertility (meiosis during gametogenesis, obstruction of male/female tubules, hormonal control of egg/sperm development, hormonal regulation and control of endometrium and implantation, development of zygote, erectile dysfunction and antisperm antibodies).

Learners could undertake group work and then present their findings to the whole class about the efficacy of methods of promoting and methods of preventing contraception. Learners should be encouraged to access and include recent data and research findings relating to these topics.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the interrelationship and nervous control of the cardiovascular and respiratory systems	A1 Nervous system organisation A2 Cardiovascular and respiratory system regulation and control	A report looking at the organisation and function of the human nervous system, along with the importance of coordinating the cardiovascular and respiratory systems.
B Understand homeostatic mechanisms used by the human body	B1 Feedback and control B2 Glands and organs B3 Homeostatic mechanisms B4 Impact of an imbalance	A presentation on the mechanisms used to maintain homeostasis and the importance of normal homeostatic function.
C Understand the role of hormones in the regulation and control of the reproductive system	C1 Structure and function of reproductive anatomy C2 Reproductive processes	Learners are to put together a series of informative leaflets on the control of fertility.

Assessment guidance

This is an internally assessed unit with a maximum recommended number of three assignments, one for each learning aim.

Assessors could record TV documentaries and/or schools programmes on reproduction prior to delivery of the unit. It may be necessary to order or obtain prepared microscope slides.

It may be necessary to plan for visits to a gym or for visiting speakers to attend the centre.

Learners must give independent, valid and authentic evidence to meet the assessment criteria.

Learners should reference their secondary sources and supply a bibliography.

Getting started

This gives you a starting place for delivering the unit, based around the recommended assessment approach in the specification.

Unit 9: Human Regulation and Reproduction

Introduction

You could link this unit with a major sporting event (marathon, football, rugby, tennis, athletics) to put the idea of regulation of body systems and requirement for homeostatic mechanisms to be put into context.

Critical thinking skills can be developed by asking learners to consider and discuss, for example:

- Why do we not have to think about heartbeat and breathing when we are asleep?
- How and why can we survive extreme internal (as a result of extreme activity) and external (as a result of factors like environmental temperatures) conditions?
- How do drugs like ecstasy and alcohol affect osmoregulation in the body?
- Why are some people unable to produce eggs or sperm?

Learning aim A – Understand the interrelationship and nervous control of the cardiovascular and respiratory systems

- You could use practical activities investigating reflex actions – e.g. pupil reflex, knee jerk, catching a ruler – to introduce the unit.
- Making models of neurones and linking them to form a reflex arc would engage kinaesthetic learners and allow visualisation of the process.
- Microscopy to look at neurons, spinal cord and other nervous tissue alongside photomicrographs and textbook diagrams would help learners understand the structure of the components of the nervous system.
- Animation and simulations available on the internet will help learners visualise the reflex arc and transmission of nervous impulses.
- Anatomical models of the brain, spinal cord, heart and lungs (corrosion preparation of lungs) will give an insight into their structure, which you can link through discussion to their function.
- Dissection may be undertaken to show the structure and function of the heart and lungs in relation to anatomical models and textbook diagrams.
- A visit to a gym with physiological measuring equipment would allow learners to observe, measure and record changes to heart and breathing rate in relation to exercise.
- Use of an ECG recording(s) would allow learners to follow and understand the cardiac cycle. Learners could include these recordings in the assessment evidence for interpretation.
- Secondary source material and your input will be required to allow learners to understand how the physiological changes are regulated by feedback mechanisms.
- Learners could work in small groups to research and present their findings to the class on the autonomic system and the role of neurotransmitters.
- Learners can undertake individual research into neurological disorders.



Unit 9: Human Regulation and Reproduction

Learning aim B – Understand homeostatic mechanisms used by the human body

- You could introduce this learning aim using a song about the endocrine system (see 'Resources').
- Learners could produce a poster (ideally life-sized) to identify the position and function of the endocrine and exocrine glands in the body.
- Learners could work collaboratively in small groups to produce leaflets or presentations/card games on water/osmoregulation, blood glucose, temperature regulation and how feedback mechanisms operate under normal circumstances.
- You will also need to cover the impact on health of dysfunction for each system. You could allocate groups a different system to research the effects of dysfunction.
- Simulations and animations can be accessed and used to allow learners to visualise the homeostatic processes.
- Feedback mechanisms can be simulated by some learners being given appropriate body part labels (receptors and effectors) and other learners being given labels for water/glucose, 'heat', hormones and moving round the feedback loop.
- Secondary sources will need to be accessed to allow learners to identify 'normal' parameters.
- Tutor-led questioning and discussion will allow learners to focus on and analyse the impact each system may have on the other systems.
- Learners should be encouraged to access secondary source materials, textbooks, scientific journals and research articles and use these in their evidence for assessment.

For assessment, learners could present their findings as a portfolio of evidence. This could contain information leaflets on homeostatic mechanisms that the learner has produced using their own research. Learner generated evidence must be valid and authentic and assessor validation may be required to authenticate learner contribution to group activity submitted as evidence.

Learning aim C – Understand the role of hormones in the regulation and control of the reproductive system

- Media headlines about advances/breakthroughs in fertility treatment could be used as stimulus material for discussion about control and regulation of the reproductive system.
- You could divide learners into quiz teams to produce posters identifying the structure and function of the male and female reproductive systems and associated hormones. (Alternatively, learners could design a game to use to teach patients attending fertility appointments about the male/female reproductive system.)
- Microscope work to observe eggs, sperm and reproductive tissue would engage kinaesthetic learners and help all learners to understand scale and morphology in relation to secondary source material from textbooks and photomicrographs.
- A visit to a local fertility clinic or a visit from personnel working there would add a vocational context to the unit and allow learners to develop their questioning and interpersonal skills.
- Access to educational videos on reproductive technology and simulations/animations of meiosis, gametogenesis, implantation and zygote development would allow learners to visualise the processes and gain a better



Unit 9: Human Regulation and Reproduction

understanding.

For assessment, learners must produce their own leaflets describing the structure and function of the reproductive systems to include the role of hormones and their effect on reproductive health. Methods of preventing and promoting conception must be evaluated. This could be in a leaflet or as case studies produced by the learner.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 5: Principles and Applications of Science II*
- *Unit 8: Physiology of Human Body Systems.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Pearson L3 BTEC textbook

BTEC Nationals Applied Science: Student Book Level 3, Pearson, 2016 (ISBN 9781292134093).

This book is an up-to-date reference with a range of supportive features to aid learning and teaching.

Journals

New Scientist

Scientific American

Nursing Times

Technical journals requiring high-level reading skills and ability to use and understand technical terms. They contain articles and latest news and research into related topics.

Videos

<http://www.bbcactive.com/BBCActiveIdeasandResources/ScienceandMedicineVideosfromBBCActive.aspx>

BBC Active publishes a range of interactive resources and videos to support schools.

Websites

<https://www.nhlbi.nih.gov/health/health-topics/topics/hhw/electrical>

National Heart, Lung and Blood Institute. American organisation that promotes research, training and education for heart, lung and blood diseases. Animation of cardiac cycle.

http://www.abpischools.org.uk/page/modules/hormones/index.cfm?coSiteNavigation_allTopic=1

ABPI (Associations of the British Pharmaceutical Industry). Resources for Schools offers curriculum resources for tutors and learners. Site contains animations and interactive content for many topics including reproduction, and hormones.



<http://www.nhs.uk/conditions/Artificial-insemination/Pages/Introduction.aspx>

NHS website with links to a variety of topics relevant to this unit.

<http://www.songsforteaching.com/lyricallifesciencelearning/endocrinesystem.htm>

Website where you can download songs and lyrics about biological topics. You could use these as an introduction to the topic or to encourage learners to produce their own songs and lyrics.

<http://bigpictureeducation.com/action-potential-animation>

Wellcome Trust charitable organisation website with science education resources including a post-16 section to help young people engage with biomedical science.



Unit 10: Biological Molecules and Metabolic Pathways

Delivery guidance

Approaching the unit

Your learners will have come across respiration and photosynthesis and other biological systems in plants and animals. In this unit, you will be helping them to look at and appreciate the biological molecules that are the basis of the many biological systems in plants and animals. Therefore, most of this unit will be new to your learners especially in terms of the approach taken.


Your learners will need access to a suitable laboratory where they can carry out experiments concerning respiration and photosynthesis. They will also be required to research information about biological molecules and relate them to living organisms. A different emphasis concerning the fundamental molecules that are so important to all living organisms, is being studied in this unit. You will need to guide and discuss with your learners the role of the building blocks (biological molecules) that underpin all the systems in a living organism.

Delivering the learning aims

You may decide to do **learning aims A and B** together as they deal with structure and function and are assessed together. Four basic molecules: water, carbohydrates, proteins and lipids are the subject of learning aim A in terms of their structure. You will need to use 3D molecular models and any other visual representations such as computer-generated models so your learners can see the structure of these molecules. This will be very important in the proteins where your learners will find the 4D structures difficult to visualise. Understanding these structures is vital if your learners are to appreciate their functions in the next learning aim.

If your learners are thoroughly familiar with the 3D structure of the molecules in learning aim A, then their functions at a molecular level within living organisms will be made much easier for learning aim B. You will need to consider each of the groups mentioned in learning aim A in terms of how it functions in normal systems. This subject matter is very detailed and a mixture of research, class discussions, problem solving (such as matching a series of cards with functions written on them to the correct molecule) and the use of spider diagrams will show how their functions interact or in other cases are very specific.

The last part of this aim considers what happens if the molecular set-up is disrupted. A list of possible examples is given in the specifications but you could use other ones. Research could be a starting point and then use case studies or card games such as matching a particular disease with the associated biomolecular disruption. You must remember to include plants. The use of photomicrographs, videos and access to a website showing various diseases of living organisms resulting from biochemical malfunctions will make the subject more interesting to your learners. It is worth directing your learners to certain sites or giving them specific words to use in a search engine.



Your learners will be familiar with a more simplistic version of the respiratory pathways and equations compared with the ones they will now meet. You may decide to remind them of the work done previously in respiration and then start the practical work on the effect of activity on respiration.

If done in this order then the results of their experiments can be the starting point for a discussion on the biochemistry of respiration. Your input as a tutor will be needed plus visual aids such as computer-simulated models of the stages of aerobic respiration. Using as much visual material as possible such as flow charts, diagrams etc. will help your learners follow a complicated biochemical pathway.

Your learners can find out what factors other than exercise can affect respiration by doing their own research and taking part in class/group discussions. You could give them secondary data and case studies that focus on the factors affecting respiration.

Plants and photosynthesis are not usually of much interest to your learners, as they often prefer human-related topics. For **learning aim C**, you may decide to do some practical work in the laboratory based on what factors affect photosynthesis. You could do an introduction by getting your learners to think about food chains and how they all begin with plants. Use this to start your learners thinking about the role of photosynthesis and what may affect it. You will need to guide your learners regarding what practical work they do and plan it carefully because some tasks are quite time consuming and reliant on the time of year.

The theory work on the pathways in science will initially have to be tutor-led as well as using visual aids such as computer-simulated models of the light and dark stages. Use as much visual material as possible such as flow charts, diagrams etc. as these will help your learners follow a complicated biochemical pathway. You will need to have secondary data available as part of a class discussion.

Be aware of all health and safety regulations when doing practical work and make sure that you and your learners carry out risk assessments for all practical work.

Input from speakers or visits to sports training laboratories where the effects of exercise on athletes are measured would give the topic a vocational aspect.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
<p>A Understand the importance of biological molecules in living organisms and the effect of disruption on the structure and function</p>	<p>A1 Water structure and importance</p> <p>A2 Carbohydrate structure and importance</p> <p>A3 Protein structure and importance</p> <p>A4 Lipid structure and importance</p> <p>A5 Disruption in living organisms</p>	<p>A report or a visual display with explanations, that include:</p> <ul style="list-style-type: none"> the molecular structure of proteins and the basic biochemical properties they show links between molecular structure, their properties and role and importance in the human body, including the effect of disruption on the structure and function of biological molecules found in humans and plant growth regulators.
<p>B Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways</p>	<p>B1 Stages involved in respiratory pathway</p> <p>B2 Effect of activity on respiration</p> <p>B3 Factors that can affect respiration</p>	<p>A portfolio of evidence to include:</p> <ul style="list-style-type: none"> practical work and results which can be recorded in lab notebooks, signed off by the tutor/observer record of analysis, conclusions, evaluation and any research work can be by a written essay, diagrams, flow charts.
<p>C Explore the factors that can affect the pathways and the rate of photosynthesis in plants</p>	<p>C1 Pathways in photosynthesis</p> <p>C2 Factors that can affect pathways in photosynthesis</p>	<p>A portfolio of evidence, to include:</p> <ul style="list-style-type: none"> practical work and results which can be recorded in lab notebooks, signed off by the tutor/observer record of analysis, conclusions, evaluation and any research work can be by a written essay, diagrams, flow charts.

Assessment guidance

The assignments are a mixture of research and practical work. All practical work is done in a laboratory equipped for A level work. Your learners should be given instructions about each piece of practical work; they are not expected to devise their own methods. Your learners should be made aware that they will be observed and assessed as to how competently they carry out the practical work. You can, if you have the time, allow them to do non-assessed practical work before a final assessment is done. All practical work must be recorded in their laboratory notebooks, as this will be the basis of further assessment criteria.

For learning aim A, you will need to supply learners with a lot of information before they begin their research. You will need to remind them about molecular structures and how to represent them visually. Once you are sure about their understanding of structure, your learners can then begin their research on the functions of the molecules. Encourage your learners to present their work in a visual way using annotated diagrams and using the accepted notation for representing molecular structures. You will need to guide their research on the effects of disruption to biological molecules and use class discussion or some case studies to help your learners evaluate the effects of disruption.

A portfolio of evidence will be required for learning aim B, including your learners' practical notebooks in which are recorded the results of their experiments. These experiments will be observed and your learners must be made aware of what is being looked for. You will need to give secondary data to use in analysis and help learners to evaluate the harmful effects of some substances on respiration. The harmful substances may have been the subject of a research project at any time during this unit.

A portfolio of evidence will be required for learning aim C, including your learners' practical notebooks in which are recorded the results of their experiments. These experiments will be observed and your learners must be made aware of what is being looked for. The key word in the assessment criteria is 'competently' so results may not be as expected but you are observing how competently they carried out their work. You will need to give secondary data to use in analysis and help learners to evaluate the factors that affect the efficiency of photosynthesis. Encourage your learners to present their theory work in the most appropriate way, for instance, the stages of photosynthesis lend themselves to annotated flow charts.



Getting started

This provides you with a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 10: Biological Molecules and Metabolic Pathways

Introduction

Your aim in this unit is to introduce both background knowledge and practical skills that learners can transfer to other situations when the unit is complete. You should engage your learners actively with the practical work. As your learners will find some parts of this work difficult, some input via tutorials/lessons will be required. You will need to direct their research work and encourage the exchange of information by group and class discussions.

You may decide for instance, to do the practical work regarding respiratory activity and use the results along with secondary data as a discussion point. This can lead into the structure and role of biological molecules. This same idea applies to learning aim C.

Learning aim A – Understand the importance of biological molecules in living organisms and the effect of disruption on the structure and function

- Give tutor input, reminding your learners of their knowledge of molecules in terms of structure, and how to represent them diagrammatically.
- Learners should undertake individual activity practising the diagrammatical representation of biological molecules.
- Lead a discussion/research on comparing biological structures: how similar/dissimilar are they in structure and what are the implications, in terms of their activity?
- You should give learners a list of the functions of biological molecules and they must match the function against the biological molecules (water, carbohydrates, proteins, lipids).
- Group or individual research about what the effects of disruption are on the functions of biological molecules. You may need to give each group one or two factors to investigate, such as, what is the cause of lactose intolerance? Do not forget that plants are included in this work.

Learning aim B – Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways

You can do this suggested assignment in two ways, either by doing the practical work first and following up with theory or vice versa.

- You could give an introduction/encourage a discussion looking at the effects of exercise on respiration.
- Practical work on the effects of respiratory rates and exercise:
 - Find out the respiratory rates before and after exercise.
 - Find out the recovery rates after exercise.
 - What effect does exercise have on carbon dioxide output?
- Arrange an observation of your learners by a suitably qualified person as to their competency in doing the experiments.

Unit 10: Biological Molecules and Metabolic Pathways

- Learners could carry out individual research on the factors that affect respiration.
- Encourage a class discussion about the factors that affect respiration rates –use your learners' results, secondary data you give them and their own research on factors such as smoking, drugs, pollutants, disease etc.
- You could give input on the stages in aerobic respiration.
- Discuss with class how is the best way to represent these stages when they explain them to meet the criteria.
- Lead a discussion about the most appropriate way to present the information.

Learning aim C – Explore the factors that can affect the pathways and the rate of photosynthesis in plants

You can do this suggested assignment in two ways, either by doing the practical work first and following up with theory or vice versa.

- Encourage a discussion about how plants can make their own food molecules as opposed to ingesting and converting molecules to ones they can deal with, as in animals. This will need to include a reminder about the basic processes of photosynthesis, i.e. revision of GCSE work.
- Arrange for learners to carry out practical work on the factors that affect photosynthesis:
 - light intensity
 - CO₂ concentrations
 - water
 - temperature
 - plant pigments
 - wavelengths of light.
- You should arrange observation of your learners by a suitably qualified person as to their competency in doing the experiments.
- You could ask learners to carry out individual research on the factors that affect photosynthesis.
- Class discussion about the factors that affect photosynthetic rates – use your learners' results, secondary data you give them and their own research.
- Give input on the stages in photosynthesis.
- Discuss with class how is the best way to represent these stages when they explain them to meet the criteria.
- You could lead a discussion about the most appropriate way to present the information.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 3: Science Investigation Skills*
- *Unit 8: Physiology of Human Body Systems*
- *Unit 9: Human Regulation and Reproduction*
- *Unit 11: Genetics and Genetic Engineering*
- *Unit 12: Diseases and Infections.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Blankenship, Robert E., *Molecular Mechanisms of Photosynthesis*, 2nd edition, Wiley-Blackwell, 2014 (ISBN: 978-1405189750).
A useful reference book.

Ferrier, Denise R., *Biochemistry (Lippincott's Illustrated Reviews Series)*, 6th edition, Lippincott Williams and Wilkins, 2013 (ISBN: 978-1451187533).
An illustrated book to help the learner – written expressly for advance level learners.

Tortora, Gerard J. and Derrickson, Bryan H., *Principles of Anatomy and Physiology*, John Wiley & Sons, 2011 (ISBN: 978-0470565100).
A very well-known book which covers in detail all the information required for human biology – a standard reference book for learners.

Williams, Andrew, *Photosynthesis – Advanced Biology Study Notes: For Teachers and Students* (includes a mock exam), 1.2 edition, CreateSpace Independent Publishing, 2013 (ISBN: 978-1493588855).
This is helpful for learners to use and test their knowledge.

Journals

Using your search engine and typing in 'Biology journals' will give you access to a wide range of journals most of which are suitable for science tutors to refer to. Other journals such as these are useful for reference:


New Scientist

Scientific American

Websites

http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/plants

Good introduction to remind your learners of photosynthesis.



<http://www.bing.com/images/search?q=photosynthesis&qpv=photosynthesis&qpv=photosynthesis&FORM=IGRE>

Hundreds of diagrams illustrating photosynthesis at various levels – good discussion points and eye-catching images for your learners.

<http://biology.clc.uc.edu/Courses/Bio104/photosyn.htm>

Easy introduction for your learners to use.

http://www.bbc.co.uk/bitesize/higher/biology/cell_biology/photosynthesis/revision/1

Further information at a higher level for your learners to use.

http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/respiration

Aerobic and anaerobic respiration.

<https://www.youtube.com/watch?v=Rh6JaCj5cz8>

Video on human respiration.

<http://passmyexams.co.uk/GCSE/biology/aerobic-and-anaerobic-respiration.html>

Useful as a bit of light relief and to test your learners' knowledge.

<http://www.bing.com/images/search?q=biological+molecules&qpv=biological+molecules&qpv=biological+molecules&FORM=IGRE>

Lots of coloured images of molecules which make a good discussion starting point.

<http://chemistry.tutorvista.com/biochemistry/biological-molecules.html>

Good visual starting point for discussion on biological.

<http://dwb4.unl.edu/chem/chem869p/chem869plinks/www.gwu.edu/~mpb>

Mainly for tutors as gives a very detailed visual representation of metabolic pathways – good reference material.



Unit 11: Genetics and Genetic Engineering

Delivery guidance

Approaching the unit

This is a really interesting and fascinating area of biology; massive advances have occurred in the last 30 years. Building on basic genetics work studied at level 2, this unit will allow learners to study the basis of life, DNA, cell division and how characteristics are inherited. There will be opportunities to carry out practical work using genetic engineering techniques and to investigate advances and possible future advances in genetic technology. Breeding experiments will allow use of mathematics and statistics to calculate probability and predict ratios of inherited characteristics in generations of fruit flies.

Some learners will be interested in family ancestry and may be involved in researching their family trees. Others may have relatives or know people who have genetic diseases, and may be interested in how these are inherited. Many learners are interested in forensic science and DNA fingerprinting. These interests may attract learners to this unit.

You should encourage learners to read and research around the subject of genetics and genetic engineering. Some may have read books by Richard Dawkins, or at least have heard of him. Learners can be encouraged to watch documentaries about genetic engineering and its use in forensic science, food technology, commercial applications for food production and medical applications. While it is important for them to understand and be able to separate fact from fiction, it is also important that they realise this is an exciting area of science where the boundaries are being stretched. You should encourage learners to access journals and popular scientific magazines.


A wide range of delivery methods will be appropriate to allow access to the unit, for example:

- discussions, both as a class and in small groups, relating to advances in genetic technology and its role in the future
- production of photographic/video evidence of investigations carried out
- model making, to show the structure of DNA and protein synthesis
- practical work, to explore the stages of cell division, breeding experiments and genetic engineering techniques
- collaboration of learners to share results from practical work.

Group work is acceptable, but there must be evidence that learners have individually carried out certain practical procedures. This means that observation records will need to be validated by the assessor or other appropriate person.

Delivering the learning aims

Learners need to undertake practical work, and this needs to be assessed and validated by assessors for this unit. Centres must ensure they comply with all health and safety guidance and regulations. You should encourage learners to risk-assess practical work to help ensure they are aware of the safety issues and follow the relevant procedures and guidelines.



For **learning aim A**, use of simulations and animations of DNA and protein synthesis could give stimulus material to aid recall of knowledge from level 2, and allow learners to extend their understanding of the structure and functions of nucleic acids and protein synthesis. Model-making using paper shapes or sweets (e.g. liquorice allsorts) can be useful to help some learners understand the concept. Secondary source material showing the genetic code will be required. Discussion about how and why changes to bases occur, and the impact on the proteins created, should evolve from this.

For **learning aim B**, in preparation for assessment, learners will need to have the opportunity to prepare and stain microscope slides for examination. Handling and use of microscopes may need to be revised. You should demonstrate good biological drawing technique. You should give learners opportunities for practice prior to assessment using, for instance, purchased prepared microscope slides of material other than that to be assessed. Photomicrographs, simulations from the internet, and textbooks should be available, in conjunction with purchased slides of mitosis and meiosis, to allow learners to identify the stages of cell division. Kinaesthetic learners may benefit from the opportunity to model the actions of chromosomes during mitosis and meiosis, for example, by using pipe cleaners. Learners can take photos and use them as part of their report explaining and evaluating the behaviour of chromosomes in variation. Learners with appropriate IT knowledge and skills could produce their own animation of cell division.

For **learning aim C**, centre staff will need to be aware of the need to prepare in advance for learners to access live materials to carry out breeding experiments if *Drosophila* are going to be used. Learners should be familiar with monohybrid inheritance from level 2 work, but will need introducing to dihybrid inheritance. Many learners will need support and guidance with the mathematics involved in chi-squared testing in advance of assessment for this learning aim. Carrying out chi-squared tests on data generated by simulations from the internet or from alternative practical work would be preferable to learners just carrying out mathematical processing of secondary source data. For assessment, it will probably be necessary for learners to share results from the investigations they have carried out.

For **learning aim D**, learners may well be familiar with DNA fingerprinting from TV programmes, and some may have extracted DNA as part of their work for level 2. Learners are required to build on these experiences to demonstrate their ability to extract, separate and amplify DNA as part of the pass criteria for this learning aim. Kits are available for a modest cost from educational suppliers. A visit to an institution where commercial or diagnostic testing occurs will allow learners to compare techniques with those that they used. Visiting speakers and reports in popular scientific magazines and journals will keep learners informed about current developments and the potential developments of genetic engineering technologies; they need to carry out evaluation of these to achieve the distinction criterion. Research graduates from local universities or research facilities may be available to discuss their work during a visit to your centre.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the structure and function of nucleic acids in order to describe the process of protein synthesis	A1 Structure and function of nucleic acids A2 Genetic code A3 Stages in protein synthesis, where it occurs and how errors may occur	A portfolio of evidence to include: <ul style="list-style-type: none"> • photographic evidence of DNA models learners make • leaflet/report explaining the structure of nucleic acids and how they code for protein synthesis • annotated diagrams of the stages of protein synthesis, how and where the stages occur and analysis of impact of possible errors.
B Explore how the process of cell division in eukaryotic cells contributes to genetic variation	B1 Structure and function of the human chromosome B2 Cell division and its role in variation B3 Practical demonstration of slide preparation of dividing cells	A portfolio of evidence to include: <ul style="list-style-type: none"> • leaflet on structure and function of human chromosomes • observation record of microscope slide preparation of mitosis and meiosis • annotated diagrams identifying the stages in mitosis and meiosis • report explaining and evaluating how the behaviour of the chromosomes during meiosis leads to variation.
C Explore the principles of inheritance and their application in predicting genetic traits	C1 Principles of classical genetics C2 Further genetics	A portfolio of evidence to include: <ul style="list-style-type: none"> • observation record to validate the practical work carried out on <i>Drosophila</i> • statistical analysis of the patterns of inheritance ratios from practical work • genetic diagrams and report using appropriate terminology to predict and describe the results of genetic crosses.
D Explore basic DNA techniques and the use of genetic engineering technologies	D1 DNA extraction D2 Gel electrophoresis D3 DNA amplification D4 Transformation of cells D5 Uses of genetic engineering	A portfolio of evidence to include: <ul style="list-style-type: none"> • brief report on practical techniques carried out and their applications in industry and medicine • observation records to validate the practical work • report on how restriction enzymes and electrophoresis work with an explanation of stem cell therapies and their uses.

Assessment guidance

This is an internally assessed unit comprising of a number of practically-assessed criteria. It is recommended that there are four assignments for the unit, one for each learning aim. A holistic approach to the pass, merit and distinction criteria is required.

Advance planning is essential in the centre to ensure availability of practical equipment prior to work commencing on this unit. Suitable laboratory facilities will need to be available. Specimens and DNA kits will need to be ordered in a timely manner. Learners will require access to microscopes. Health and safety guidance and regulations must be understood by learners and followed at all times.

Learners must provide independent, valid and authentic evidence to meet the assessment criteria. Practical work will need to be validated by the assessor. Observation records on their own are not sufficient; there must always be learner-generated evidence available for standards verification.

The summary of unit content and assessment guidance suggests the use of photographic/video equipment. It is not intended that expensive or state-of-the-art equipment should be available. Many learners will be able to use their own phones and IT equipment to achieve adequate photos/videos.

If learners have access arrangements, the standards verifier may request evidence be made available. Secondary sources must be referenced, and learners are expected to provide a bibliography.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 11: Genetics and Genetic Engineering
<p>Introduction</p> <p>Introduce the unit by discussing genes, what they are, where they are found, and the structure of the DNA that forms them.</p>
<p>Learning aim A – Understand the structure and function of nucleic acids in order to describe the process of protein synthesis</p> <ul style="list-style-type: none"> Learners should work in small groups to produce a flipchart sheet that shows their current knowledge and understanding of chromosomes, genes, DNA, types of RNA, genetic code and protein synthesis. Oversee a class presentation of the group information, with each member of the group feeding back on at least one point discussed. Learners could create models of nucleic acids in pairs or small groups. Encourage feedback from all groups. You should comment as needed to ensure accuracy and extend knowledge. Individual learners should collaborate to produce a DNA model. Use of animations/simulations should be made for an assessor-led discussion on the structure and role of the types of RNA and stages in protein synthesis. Learners should understand the use of genetic code in protein synthesis. You could lead a discussion about occurrence and impact of errors that can occur during the stages of protein synthesis. Learners could carry out research using secondary sources and animations to consolidate their knowledge and understanding of the learning aim content. They can then produce individual portfolios consisting of diagrams and/or photos in a leaflet that explains the structure and function of nucleic acids, protein synthesis and the impact of errors associated with the process.
<p>Learning aim B – Explore how the process of cell division in eukaryotic cells contributes to genetic variation</p> <ul style="list-style-type: none"> Learners should carry out practical work to practise preparation of microscope slides (not the same slides as those required for assessment) and use of microscopes. Input from yourself about good drawing technique and the opportunity to practise skills will be required. Guidance is available in the specification. Learners should have the opportunity to use prepared slides with microscopes, Bioviewers (if available), secondary source texts and animations from the internet, to follow and understand the stages in mitosis and meiosis. Use of pipe cleaners will allow learners to model the stages of mitosis and meiosis; this will help consolidate their knowledge and understanding. A discussion about the stages and the impact on variation would be helpful at this point. Learners should follow instructions to prepare slides of mitosis and meiosis. Observation records are required to validate the level of competency demonstrated by learners. Learners should produce reports containing diagrams to explain the structure and function of chromosomes and an evaluation of their behaviour during cell division and the relevance to variation.

Unit 11: Genetics and Genetic Engineering

Learning aim C – Explore the principles of inheritance and their application in predicting genetic traits

- You should introduce learners to the techniques involved in breeding *Drosophila* to be able to obtain results for processing. Learners will need to maintain records of their investigations (in logbooks).
- While gestation is occurring, secondary sources and your input can be used to revise learner knowledge of monohybrid inheritance, leading to discussion and extension of knowledge to cover dihybrid inheritance of characteristics. Simulations are available on the internet.
- Learners will need to research and present information to peers on the work of Gregor Mendel and its importance in modern genetics.
- The mathematical abilities of learners will need to be extended to cover chi-squared testing and probability.
- Learners will need to undertake research work into genetic diseases. They will then need to make calculations and predictions of how crosses between non-affected, affected and carriers of these diseases affect the next generation. They should consider a wide range of diseases. Learners could work in pairs to choose a disease (you could have cards with diseases on them for learners to select from) and then feed back to the rest of the class.
- Learners will need to collaborate to share results from the breeding investigations undertaken.

Assessment requires learners to produce a portfolio of evidence that includes a report on the practical work they carried out with an analysis of their results. Notes produced from research into genetic crosses need to be presented, possibly as a report or leaflet, and must include predictions for monohybrid and dihybrid inheritance and variation.

Learning aim D – Explore basic DNA techniques and the use of genetic engineering technologies

- You could introduce the topic by showing clips of DNA being extracted and amplified (PCR), and electrophoresis of a DNA sample. You should encourage discussion about the science of what is happening and why. Learners will need to practise these techniques and to investigate their uses and possible future uses.
- A visit to a research laboratory/university where these techniques are used would add interest and a vocational context to the work. Alternatively, a visiting speaker would give learners the opportunity to ask questions and explore developments in this exciting field.
- Learners will research the other technologies (indicated in the unit content) and their current and potential uses. This will involve use of textbooks, the internet and access to scientific journals and, possibly, documentaries. Learners should research different technologies and then present their findings to the class.

Learners will be assessed on their ability to carry out the basic techniques they have practised. Assessors will need to validate the level of performance achieved by each learner in conjunction with learner reports of their own investigations. Using their research notes, the future of genetic engineering technologies and their applications in medicine and commerce must be analysed and evaluated in a report or information leaflet produced by individual learners for assessment.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 3: Science Investigation Skills*
- *Unit 10: Biological Molecules and Metabolic Pathways*
- *Unit 17: Microbiology and Microbiological Techniques.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Annets, F, Foale, S, Hartley, J, Hocking, S, Hudson, L, Kelly, T, Llewellyn, R, Musa, I, and Sorenson, J *BTEC Level 3 National Applied Science Student Book* (Pearson, 2010) ISBN 9781846906800

The chapter on genes and genetic engineering supports the unit content and has activities suitable for learners to access to practice skills and acquire knowledge and understanding prior to assessment.

You could use any current A-level textbook with a section on genetics and genetic engineering for reference.

Journals

Scientific American

New Scientist

These technical journals require high-level reading skills and the ability to use and understand technical terms. Both contain articles and the latest news and research into related topics.

Videos

<https://www.youtube.com/watch?v=gG7uCskUOrA>

From DNA to protein. Good summary of transcription and translation, and role of types of RNA.

<https://www.youtube.com/watch?v=d7ET4bbkTm0>

The Secret of Life – five episodes that will need relevant sections identifying for different parts of the specification content.

<https://www.youtube.com/watch?v=pOsAbTi9tHw>

Mitosis rap: Mr W's Cell Division Song. Animations, diagrams and video footage of stages of cell division.

<https://www.youtube.com/watch?v=1p47ndHOUHs>

Video lecture about dihybrid crosses.

<https://www.youtube.com/watch?v=QEG8dz7cbnY>

<https://www.youtube.com/watch?v=6QYgN-toA1A>

Gel electrophoresis – two instructional videos to prepare and read gel electrophoresis results.

<https://www.youtube.com/watch?v=LxbP82mi02Y>

Onion root tip observations. Opportunity to see stages in root tip mitosis with commentary.

Websites

http://media.hhmi.org/biointeractive/vlabs/bacterial_id/index.html

The Virtual Bacterial ID Lab, Howard Hughes Medical Institute.

Simulations and information about genetic engineering techniques and PCR.

<http://www.eurostemcell.org>

This website provides 'independent, expert-reviewed information and road-tested educational resources on stem cells and their impact on society'.

It is a good source of stimulus and information for learners and staff.

<http://www.ncbe.reading.ac.uk/ncbe/materials/dna/menu.html>

The National Centre for Biotechnology Education website contains a range of materials and practical protocols to help with education about DNA and modern genetics. It is useful for centre staff.



Unit 12: Diseases and Infection

Delivery guidance

Approaching the unit

For many learners, this will be the first opportunity they have had to explore the world of microbes, disease and infection. Most learners will be aware of 'bugs' and 'germs', and will know that people often become ill as a result of exposure to them. Understanding of the organisms that cause the diseases and infections that afflict us, and preventative treatments and cures, is often lacking.

This unit will allow learners to gain an understanding of five types of disease, their causes, possible prevention and how we try to treat them.

Outbreaks of infectious diseases like Bird Flu, SARS and, more recently, Ebola have caused global concerns about the possibility of pandemics and may motivate learners to want to know more about these infectious diseases and their causes.

Other learners may be keen to want to know more about non-infectious but equally debilitating degenerative, genetic, environmental and dietary diseases afflicting society today. Learners will have the opportunity to investigate some of these diseases, many of which are creating pressures on the National Health Service, as evidenced almost weekly in media headlines. The ability of the human body to respond and defend itself will also be studied.

There are opportunities for learners to undertake practical work, but there is no formal assessment of practical work in the unit.

Learners should be encouraged to 'read around' the subject, and they must access a range of secondary source materials. These should not be limited to textbooks but should include the internet and scientific and popular science journals to ensure up-to-date information is used. Learners must reference sources they have accessed.

You can use a wide range of delivery methods to engage all types of learners and learning styles, for example:

- discussions, both as a class and in small groups, relating to research and developments in preventative and corrective treatments
- model-making to embed understanding of specific response mechanisms to disease and infection
- presentations of facts and information that individuals or small groups have researched to feed back to the rest of the class
- practical work on the transmission of pathogens
- use of simulations and software programmes to visualise the spread of infectious disease.

Delivering the learning aims

Learning aim A requires learners to investigate and familiarise themselves with different types of diseases and infections that affect humans. Learners may have little prior knowledge and understanding of the five main types of pathogens, and diseases associated with them may be sketchy. Class discussion and mind mapping may be an effective way to establish knowledge and possible misunderstandings to help ensure effective delivery of the learning aim. Stimulus material from videos and TV programmes could be used to illustrate characteristics of pathogens and engage learners.

Dietary and genetic diseases should be more familiar to learners from Key Stage 4 work. Assessment of prior learning using mind maps, vocabulary sheets for learners to indicate their own level of knowledge as 'well known', 'some knowledge' or 'never heard of it' will give a baseline for each learner for progression. Many learners will have little first-hand experience of environmental diseases, but may be familiar with recent outbreaks of drinking water contamination, and may know people who have had skin cancer 'scares'. Excerpts from TV programmes/documentaries such as *Embarrassing Bodies* can be a discussion point. Learners may have elderly relatives who have degenerative conditions, and may be able to communicate with other learners about these conditions and the issues they present. Group work and presentations to the class will allow learners to develop research and presentation/communication skills and will enable the unit content to be covered. Learners can also use diseases with which they have some familiarity or interest for assessment purposes.

Learning aim B focuses attention on how infectious diseases are transmitted and how this can be prevented. There are opportunities for non-assessed practical work, as learners can swab surfaces and culture bacteria. (Health and safety guidance will need to be observed.) 'Sharing of body fluids' simulations can be undertaken. Discussion about preventative methods can lead learners to choose (or be given/select a card that lists) a method from the unit content to research, and then present this to the rest of the class. All learners should research an organisation involved in management of infectious diseases. Some learners may be interested in using software simulations/games to track progress of an infectious disease from patient zero, or to try to track contacts from infected individuals back to patient zero.

Learning aim C leads learners to focus on treatments and how disease can be managed. Accessibility, availability, how treatments are administered, and patient choice will need to be researched in order to be evaluated as part of the assessment. In a centre with a diverse learner population, this may lead to interesting debates and sharing of ethnic, social and religious views and beliefs. Small-group work to produce information leaflets or a presentation to the rest of the class will allow coverage of the unit content, develop peer learning and give opportunities for development of intrapersonal skills.

For **learning aim D**, learners will have some knowledge of human defence mechanisms from Key Stage 4. There are opportunities for kinaesthetic and visual learners to produce models of different lymphocytes or antigens to explore the mechanisms by which the body is protected. Learners could undertake practical work on antigen/antibody specificity. Aural learners could produce a poem, song or rap of the associated vocabulary and actions of the defence mechanism.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
<p>A Investigate different types of diseases and infections that can affect humans</p>	<p>A1 Pathogens and infectious diseases</p> <p>A2 Dietary and environmental diseases</p> <p>A3 Genetic and degenerative diseases</p> <p>A4 Progression of disease over time</p>	<p>Having researched a variety of infectious and non-infectious diseases, learners could produce case studies relating to their chosen diseases. The case studies would detail the cause and the effect the disease can have on body systems over time. The effect on the quality of life of the individual suffering from the disease must also be evaluated.</p>
<p>B Examine the transmission of infectious diseases and how this can be prevented</p>	<p>B1 Methods by which infectious diseases can be spread</p> <p>B2 Methods by which infectious diseases can be prevented from spreading</p> <p>B3 Management of infectious diseases</p>	<p>In addition to research work, practical work and simulations should be used to ensure that learners are familiar with the methods by which infectious diseases can be transmitted. Prevention of transmission at a personal level and by organisations must be researched. A report or information leaflet can be produced as evidence.</p>
<p>C Understand how infectious diseases can be treated and managed</p>	<p>C1 Methods of treatment</p> <p>C2 Access to and acceptance of treatment</p>	<p>Research will need to be undertaken on the different methods of treating diseases. The mode of action of the treatments will need to be analysed. The accessibility or appropriateness of treatments for some people, will be evaluated and reported.</p>
<p>D Understand how the human body responds to diseases and infections</p>	<p>D1 Defence mechanisms</p> <p>D2 Non-specific</p> <p>D3 Specific</p>	<p>Information leaflets detailing and comparing the components of the two defence mechanisms and their mode of action, could be produced.</p>

Assessment guidance

This is an internally assessed unit consisting of four learning aims. It is recommended that there are four assignments, one for each learning aim. A holistic approach to the pass, merit and distinction criteria is required.

Centres may consider a holistic, project-based approach to delivering teaching and learning to cover the unit in the following way:

- infectious diseases, their cause, transmission, prevention, progress over time and treatment
- non-infectious diseases; dietary; environmental; genetic; degenerative; their causes, how they are acquired, prevention, progress over time and treatment
- understanding of the response of the human body to disease and infection.

Revision of the key concepts associated with each learning aim, prior to assessment commencing, would be permissible and advisable.

It is, of course, possible to deliver and assess the unit in the more conventional style, which addresses teaching and learning for each learning aim individually, immediately prior to assessment.

If suggested practical work is to be undertaken, you will need to implement advanced planning to ensure availability of equipment. Risk assessments should be carried out, and health and safety guidelines will need to be followed.

Leading up to delivery of the unit, you may want to try to capture media headlines, TV programmes and documentaries on issues to cover in the unit.

During teaching and learning, learners can do much of the work in small groups. Work for assessment, however, must be independently produced by each learner, drawing on materials they and their peers have produced during teaching and learning. Additional independent research will be required to make sure that the criteria are fully met in the valid and authentic evidence that each learner is required to submit to meet the assessment criteria, guidance and unit content.

If learners have access arrangements, the standards verifier may request evidence to be made available. Secondary sources must be referenced and learners are expected to supply a bibliography.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 12: Diseases and Infection

Introduction

Prior to starting the unit, you could encourage learners to read a fictional book/watch a film about spread of disease. A classic book (by Robin Cook) and film (2011) which may be familiar to some learners is *Contagion*. Stimulus material of this nature can be used for discussion about disease organisms, how they are spread and the impact they can have on society. It should also lead to a debate about boundaries relating to fact and fiction.

Alternatively, you could use some short video clips of diseases as a stimulus to initiate discussion to establish learners' prior knowledge and understanding (or possibly misunderstanding). Excerpts from *Monsters Inside Me* (a TV series/documentary) or *Embarrassing Bodies* could also be used.

Media headlines about pressure on the National Health Service due to an ageing population, increase in childhood diabetes or increasing incidence of skin cancer can be used to introduce some of the non-infectious diseases that are part of the unit.

Learning aim A – Investigate different types of diseases and infections that can affect humans

- You could use mind maps of vocabulary sheets/key areas of unit content for learners to indicate their prior knowledge and understanding, and to identify focus areas for your input and learner research.
- Learners could look at photographs/photomicrographs, Bioviewer slides of the different types of pathogens, and identify key characteristics and features.
- Learners could create a card-sorting game to allow them to match types of pathogen, features, life cycle (where appropriate) and disease. They can carry out a similar activity for non-infectious diseases.
- Pairs or small groups of learners could then choose or be given a disease(s) to research in which to become an 'expert' before presenting their findings to the rest of the class. The presentation could take the form of PowerPoint, radio interview, a 'Mastermind' quiz, leaflets, fact file, etc.

The evidence presented for assessment must be verifiably valid and authentic. Each learner must produce their own evidence relating to the five types of pathogen, a disease associated with each type. They must explain causes of a non-infectious disease from each of the four categories. Learners can choose diseases other than those in the unit content to allow them to explore areas of interest or experience. They can use work prepared as part of a pair or group towards assessment, but there must be validating evidence from the assessor as to what each individual learner actually did to meet the criterion without additional support and guidance.

Learning aim B – Examine the transmission of infectious diseases and how this can be prevented

- You could ask learners to pass round an object that has been covered in a germ simulating gel/powder (commercially available) that will fluoresce under UV light; this could give a tangible model of how many pathogens can be transmitted. A practical exercise can also be used to demonstrate good hand-washing technique,

**Unit 12: Diseases and Infection**

leading on to one aspect of preventing transmission.

- Transfer of pathogens via body fluids can also be simulated practically.
- Learners could use agar plates to culture swabs taken from surfaces in the laboratory. (Health and safety guidance and risk assessments must be in place.)
- You could discuss methods of preventing the spread of disease and divide learners into small groups to research and present information to the rest of the class.
- Individual learners will need to choose an organisation to research in order to achieve the distinction criterion.

The information gathered individually and from peer presentations can be synthesised into a report, information leaflet or similar by the learner to generate independent valid and authentic content.

Learning aim C – Understand how infectious diseases can be treated and managed

- There is a lot of scientific terminology and vocabulary in this learning aim. You could encourage learners to produce a 'dictionary' of terms and definitions.
- Learners should have discussions in small groups and then present to the class about why some people may not want to access or use treatments.
- In small groups, learners can explore how and why treatments are accessible and may or may not work.
- Visiting speakers from a national or global organisation may be able to help learners understand some of the barriers that exist in making treatments available. This should also help develop their intrapersonal and communication skills.

Learners could produce a report or a case study evaluating the types of treatment, their accessibility and availability to meet the assessment criteria.

Learning aim D – Understand how the human body responds to diseases and infections

- You could use a song or poem about the immune system to give an engaging introduction to this learning aim.
- Learners could produce collaborative posters or flow charts in small groups to ascertain their prior knowledge of defence mechanisms.
- You could use vocabulary sheets or unit content for learners to identify their prior knowledge and aid you in delivering the content.
- To assist learners to visualise antigen and antibody models of the components of the specific defence mechanism, you could use mini marshmallows, gummy sweets, jelly beans, etc. and cocktail sticks. Some learners may be able to produce animations.
- Your own input, secondary source material, textbooks, internet and journals will need to be accessed by learners to extend their knowledge and understanding to meet the level required for this level 2 programme.
- Learners could produce a computer-generated story board/animation to demonstrate components of the specific defence system.
- An Ouchterlony double diffusion assay could be demonstrated/carried out by learners to show antigen and antibody specificity to support the distinction criterion.

For assessment, learners can produce information leaflets evaluating the components



Unit 12: Diseases and Infection

of the defence mechanisms found in the body. Knowledge and understanding of the material must be independently and authentically generated by each learner.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 11: Genetics and Genetic Engineering*
- *Unit 17: Microbiology and Microbiological Techniques*
- *Unit 20: Biomedical Science.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Annets, F, Foale, S, Hartley, J, Hocking, S, Hudson, L, Kelly, T, Llewellyn, R, Musa, I, and Sorenson, J *BTEC Level 3 National Applied Science Student Book* (Pearson, 2010) ISBN 9781846906800

Any current A level textbook with a section on genetics and genetic engineering could also be used for reference.

Journals

Scientific American

New Scientist

These technical journals require high-level reading skills and an ability to use and understand technical terms. Both contain articles and latest news and research into related topics.

Videos

<https://www.youtube.com/watch?v=fNaAisFiPdU>

Lecture about how bacteria cause disease.

https://www.youtube.com/watch?v=M1pUoYBbEpI&list=PLN_S70QYaRLDA9gBqA04-JbECYz6eCsGs

What you need to know about infectious disease.

https://www.youtube.com/watch?v=Adg5d98kl8M&index=2&list=PLN_S70QYaRLDA9gBqA04-JbECYz6eCsGs

Flu attack! How a virus invades your body. Animation of flu virus reproduction.

Websites

<http://www.animalplanet.com/tv-shows/monsters-inside-me>

Monsters Inside Me is a series of TV programmes which showcase studies of individuals suffering from diseases. You could use these as an introduction to the unit. However, you should review the programmes before showing to learners, as some scenes can be very graphic.

<http://www.songsforteaching.com/biologyecology/microorganisms.htm>

Songs and lyrics about biological topics can be downloaded from this website.

http://www.educationworld.com/a_lesson/best-instructional-videos-pandemic-plague.shtml

Education World has an introduction with short videos about three pandemics in history. It could be used as an introduction to the unit.

<http://blog.discoveryeducation.com/blog/2012/05/06/great-resources-to-teach-epidemiology>

This site has ideas for simulations of the spread of contagious diseases.

<http://www.microbiologysociety.org/education/resources/microbiology-today.cfm>

The Microbiology Society online journal, *Microbiology Today*, has videos and information relating to microbiology.

<http://www.brainfacts.org/About-Us>

BrainFacts.org has factsheets and access to information on the latest research and development into brain diseases. It also contains a section on degenerative disorders.

<http://www.hhmi.org/biointeractive/about-biointeractive>

BioInteractive offers multimedia resources, virtual laboratories, simulations and teacher guides on a variety of scientific topics.



Unit 13: Applications of Inorganic Chemistry

Delivery guidance

Approaching the unit

This unit is made up of three inorganic chemistry topics (pH, oxidation and reduction (redox), and transition metal chemistry) that will be useful for learners who will study chemistry or biology at a higher level and also useful for those who progress to industrial laboratory work. All three topics include practical work, so learners will have the opportunity to become more skilled and personally organised in the laboratory. Throughout, you will be able to lead learners in problem solving and collaborative discussion.

Delivering the learning aims

For **learning aim A**, it is essential that learners understand the differences between strong and weak acids and alkalis, and the meaning of the acid dissociation constant, K_a . A number of websites deal with the Brønsted-Lowry definition of acids and bases, which is a useful model at this level. All learners must also understand the relationship between pH and the concentration of hydrogen ions, $[H^+]$, in solution and be able to calculate pH for solutions of strong acids, strong alkalis, weak acids and buffer solutions. Learners will undertake practical work to find K_a , investigate buffer action, and determine the appropriate indicator to use for a titration. More advanced learners will demonstrate more understanding of the underlying concepts. Many industrial laboratories, even relatively small ones, use pH meters routinely and some use acid-base titration, often with autotitrators. If it is not possible to organise for learners to visit a laboratory or for a guest speaker to visit your centre, it should be possible for you to visit laboratories and to describe what you observed. It may be possible, with permission, to take photographs of equipment. The company may be able to give examples of its documentation.

One way of introducing redox reactions, the topic for **learning aim B**, is by encouraging learners to build on their knowledge of the reactivity series and displacement of metal ions in solution by the ions of a more reactive metal. Learners grasp the idea of writing the oxidation, reduction and redox reactions for this process. Standard reduction potentials follow as a way of expressing a metal ion's tendency to be reduced to the metal in terms of a voltage, measured relative to the zero volts of the standard hydrogen electrode. Standard cell voltage may be easily calculated for combinations of metal/metal ion half-cells and the principles are easily extended to combinations involving half-cells of other types. Learners may then be introduced to the concept of oxidation number, which allows them to identify, from the species in the equation, whether a given chemical reaction is a redox reaction. Learners have the opportunity to carry out titrations based on redox, and to explore their industrial use. Once again, learner and tutor visits to companies are useful.

Learning aim C introduces learners to transition metals and transition metal complex ions. Unknown transition metal ions in solution used to be identified using test-tube reactions. Learners will have the opportunity to explore these reactions. Understanding reactions of transition metals gives learners insight into the behaviour of metals that are used industrially, for example, in boilers.

However, the main purpose of studying transition metals is to give a foundation for future study, given that transition metal ion complexes are often involved as catalysts for chemical and biological reactions and as drugs. University chemistry and biological science departments often display research posters in corridors and many of these involve applications of transition metals. If a university trip for learners is planned, perhaps to see advanced instrumental techniques in operation, you should be aware of the opportunity to highlight that up-to-date research involves applications of transition metals.

You should deliver learning aim C after learning aims A and B so that learners will have a background knowledge of acid-base and redox reactions.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Investigate acid-base equilibria in order to understand buffer action and to optimise acid-base titration procedures	<p>A1 Calculation of the pH of strong acids, strong alkalis, weak acids and buffer solutions</p> <p>A2 Practical investigation of the behaviour of strong and weak acids and alkalis and buffer solutions</p>	pH calculations. Results of finding K_a , descriptions and explanations of buffer action. Results and graphs from four pH titrations and a statement justifying choices of suitable indicators for titrations. A report comparing titrations using indicators, pH meters and autotitrators.
B Investigate oxidation-reduction reactions in order to understand their many applications in analysis	<p>B1 Displacement reactions and electrochemical cells</p> <p>B2 Use of oxidation number</p> <p>B3 Titrimetric methods involving oxidation-reduction reactions</p>	Oxidation, reduction and redox equations and standard cell voltages for a range of electrochemical cells. Comparison of three measured cell voltages with the standard voltages. Justified identification of the redox reactions in a list of six given reactions. Results and calculations for a range of redox titrations plus explanation of the redox bases for these titrations. Observations from the oxidation of an alcohol with acidified dichromate. A review of the extent to which iodine/thiosulfate and chemical oxygen demand is used in industry.
C Investigate practically a range of reactions involving solutions of transition metal ions in order to understand the basis for their qualitative analysis	<p>C1 The nature of transition metal complexes</p> <p>C2 Reactions of transition metal complexes</p>	Answers to questions about complexes. Results table for test tube reactions involving transition metals and explanations of the reactions including equations. A PowerPoint



		presentation summarising the types of reactions that transition metals undergo and providing a reaction scheme to identify five transition metal ions in solution.
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Assessment guidance

Assessment should take place once learners have the necessary knowledge and understanding and sufficient experience of the practical techniques associated with each learning aim. Most of the pass-level assignment tasks involve practical work. Merit and distinction tasks in general involve understanding the concepts on which the practical work is based. The teaching and learning activities should be aimed at making all the assessment criteria accessible. Learners should experience using effective study strategies.

Assessment activities are likely to take place over several sessions. You should be aware of the need to limit the amount of practical work available to learners in each assessment session in order to give learners time to undertake merit and distinction tasks. If all the practical tasks associated with a learning aim are available, learners may be tempted only to attempt pass-level activities, instead of attempting all the activities that they are capable of completing.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 13: Applications of Inorganic Chemistry

Introduction

Prepare a PowerPoint presentation giving some examples of the industrial and academic research applications of pH, redox reactions and transition metals. The presentation should have gaps to allow learners to discuss what they know already and to research one particular topic for each aim, for example, acid number of biodiesel, the importance of chemical oxygen demand (COD) in water pollution, the structure of haemoglobin, catalase and vitamin B12.

Learning aim A – Investigate acid-base equilibria in order to understand buffer action and to optimise acid-base titration procedures

Include as many industrial examples of the use of pH measurement and acid-base titration as possible. Encourage learners to develop a problem-solving approach by carefully structuring discussions. Learners should use examples to support their arguments when developing analytical and evaluative skills. Encourage learners to take responsibility for their practical activities in terms of planning, preparing, following instruction sheets, recording, tidying up and disposing of waste correctly. Learners could work in pairs when using pH meters to develop teamwork in terms of manipulation of equipment and recording results. The following list of activities is one way of approaching the unit content.

- Explore in detail what learners understand by 'pH' and 'the pH scale', and the sorts of substances with different pH. Learners could use a calibrated pH meter to measure the pH of household compounds over the full range.
- Learners could compare the pH of 0.1 mol dm⁻³ solutions of hydrochloric acid, ethanoic acid, sodium hydroxide and ammonia in order to introduce the concept of strong and weak acids and bases.
- Working in pairs, learners could, using measuring cylinders, carry out serial dilution of 0.1 mol dm⁻³ hydrochloric acid (strong acid) and sodium hydroxide (strong alkali) to give the following concentrations: 10⁻², 10⁻³, 10⁻⁴, 10⁻⁵, 10⁻⁶. Learners could measure the pH of these and you could explain that the pH is approximately minus the power to which 10 is raised. You could question learners about the pH that they would expect from a 10⁻³ mol dm⁻³ solution of the strong acid, nitric acid, and a 10⁻⁴ mol dm⁻³ solution of the strong alkali, potassium hydroxide. pH could be defined as $\text{pH} = -\log[\text{H}^+]$ where log is the power to which ten is raised. ($[\text{H}^+]$ is concentration of hydrogen ions.) You could suggest that, because 0.05 is between 10⁻¹ and 10⁻², the pH of a 0.05 mol dm⁻³ solution of hydrochloric acid would be between 1 and 2. Learners could use their calculators to work out $-\log 0.05$ and then measure the actual pH. Learners could practise using their calculators to work out the pH of a range of strong acid solution concentrations and also the hydrogen ion concentration of a range of pHs ($[\text{H}^+] = 10^{-\text{pH}}$).
- You could introduce the ionic product for water, $K_w = [\text{H}^+][\text{OH}^-]$, which allows learners to calculate $[\text{H}^+]$ for a strong alkali ($[\text{H}^+] = 1 \times 10^{-14}/[\text{OH}^-]$). It is a good idea to stress that learners should enter 10⁻¹⁴ into their calculators as 1 × 10⁻¹⁴ using the scientific notation function. Learners should be able to work through calculations of the pH of strong alkali solutions of various concentrations and to



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work out the $[\text{OH}^-]$, given the pH.

- Explain Brønsted-Lowry theory and ensure learners are comfortable with the notion of hydrochloric acid as an acid and Cl^- as the conjugate base. Define a general acid dissociation constant, K_a , for an acid HA ($K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$) and prompt learners to identify strong and weak acids from their K_a value. Ensure learners understand the notation $\text{p}K_a$ ($\text{p}K_a = -\log K_a$) as it is common in books and websites. Introduce the equation $[\text{H}^+] = \sqrt{K_a \times [\text{HA}]}$ for calculating $[\text{H}^+]$ of a weak acid. Learners may then calculate the pH of weak acid solutions, given K_a and the acid concentration, and also calculate K_a and $[\text{HA}]$.
- Introduce the Henderson-Hasselbalch equation, which is based on the equation that defines K_a . Explain how K_a may be found from the pH at half the volume needed to titrate the acid. Learners may then find K_a by this method. It is essential that they are able to practise the process before undertaking the assessment activity. Learners should discuss how closely the group results agree with each other. Learners would discuss how close the K_a found was to the literature value and the main sources of error. They could investigate the effect of a small change in the measured pH at half the titration volume by calculation, and could investigate whether a small error in calibrating the pH meter or a small error in finding the end-point could lead to errors in K_a .
- The Henderson-Hasselbalch equation leads on to buffers. Explain what an acidic buffer is and then let the learners investigate the action of buffers practically and by researching books and websites. This should include buffer action in blood.
- Learners could carry out a pH titration for a weak acid/strong base or a strong acid/weak base (adding, say 0.5 cm^3 at a time) and establish the pH range of the jump in pH. Explain that, for an indicator to be suitable, it must change colour within that pH range. Learners may research the pH ranges of indicators, find a suitable indicator, and confirm that it gives the correct end-point by carrying out an indicator titration. This would be sufficient to prepare the learners to find indicators for all the titration combinations indicated in the assessment guidance.
- Plotting $\Delta\text{pH}/\Delta\text{volume}$ versus volume for the pH titration should allow you to explain how autotitrators work. Learners could discuss which titrations are most accurate: pH titrations, indicator titrations or autotitrator titrations. Encourage learners to be specific and to give examples when leading class discussions.

Learning aim B – Investigate oxidation-reduction reactions in order to understand their many applications in analysis

Learners may further develop their problem-solving skills and the ability to take part in discussions in order to get the most from this unit. There is scope for working collaboratively on structured worksheets and on pooling information from planned research on industrial practice. Learners will have to be personally organised in order to make maximum independent use of group research and discussions. The list below represents one way of tackling the unit content.

- Begin the topic by dropping some shiny, silvery, granulated zinc into copper(II) sulfate solution in a beaker and asking the learners to comment on what is happening. Lead learners into describing this as a word equation and then as a symbol equation. Explain why this reaction is, in fact, an oxidation/reduction (redox) reaction and write the half equations. Learners should carry out a few displacement reactions and then write half equations for oxidation and reduction and a complete, balanced redox reaction for the metals being added to a solution of the ions of a less reactive metal, based on the reactivity series.
- Explain how a table of standard reduction potentials would be constructed from

Unit 13: Applications of Inorganic Chemistry

combinations of half-cells with the standard hydrogen electrode. Use the table to predict the reaction that will take place from various metal/metal ion half-cells, construct the oxidation, reduction and redox reactions, and calculate the cell voltage under standard conditions. Show the learners how to assemble such cells and measure the voltage. Learners will have to do this independently as part of the assessment.

- Extend the logic used for calculating standard cell voltage for metal/metal ion half-cells to other types of half-cells. Learners should practise carrying out construction of the oxidation, reduction and redox reactions, and calculation of the cell voltage under standard conditions.
- You could use the table of standard reduction potentials to introduce the oxidation of Fe^{2+} by acidified manganate(VII). Learners should write the oxidation, reduction and redox equations for that reaction and carry out a titration of iron(II) sulfate solution with standardised potassium manganate(VII) solution.
- Introduce rules for calculating oxidation numbers. Learners could complete a worksheet on calculating oxidation numbers. Explain how to work out that an equation is a redox equation, by working out the oxidation numbers of the atoms on the left- and right-hand sides of the equations.
- Give learners practice in identifying redox equations from a list. Explain the use of dichromate(VI) as an oxidising agent. Learners can research the hazards associated with its use and the use of kits for determining chemical oxygen demand (COD). Learners could oxidise ethanol with acidified dichromate solution and be led to identify that the absorbance of light at two different wavelengths could be used as a measure of concentration.
- Visit a company where kits based on dichromate(VI) are used for determining COD. If the company also uses iodometry, learners may also see for themselves how it is used. Learners should research use of redox methods in other companies.
- Introduce iodate as a primary standard to standardise thiosulfate solution. Learners can make and standardise a potassium iodate solution.
- Explain that thiosulfate reacts with iodine in solution in a 2:1 mole ratio. Explain that an excess of potassium iodide may be added to an analyte solution and generates iodine in an amount proportional to the amount of analyte (e.g. Cu^{2+} or hypochlorite (ClO^-)). Learners can use standardised thiosulfate solution to determine the concentration of Cu^{2+} in solution. Learners can practice explaining the redox equations involved and why the titration works.
- Learners can use standardised thiosulfate solution to determine the amount of another analyte, for example ClO^- , in bleach. Learners can practice explaining the redox equations involved and why the titration works.

Learning aim C – Investigate practically a range of reactions involving solutions of transition metal ions in order to understand the basis for their qualitative analysis

Encourage learners to make detailed, accurate observations of practical work and to record them carefully. Learners should discuss the sorts of detail that they could record and the possible reasons for differences in results. Encourage learners to speculate on what has happened in the reactions and how that could be explained using equations. Near the start, present the goal of developing a key for identifying metal atoms and encourage learners to make notes that will help them do this. This learning aim should further develop learners' problem-solving and personal organisation skills.

- Deliver a presentation to illustrate key terms to do with transition metals and



Unit 13: Applications of Inorganic Chemistry

complexes. The presentation should pose questions, to allow learners to research key points including square bracket notation for complexes. Learners could answer questions based on suitable reference material to identify some of the characteristics that transition metals share. They should make careful notes and record information sources in preparation for the assignment task.

- Explain ligand substitution and give learners the opportunity to carry out ligand substitution in hexa-aqua complexes with chloride and ammonia safely and to reverse the reaction by adding water. Learners should explore the reaction between $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ and SCN^- and the reaction that takes place to form $[\text{Cr}(\text{H}_2\text{O})_5\text{SO}_4]^+$ by warming a solution of chromium(III) sulfate which contains $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$. Explain carbon monoxide poisoning.
- Explain crystal field theory in simple terms. Learners could identify the colours of light absorbed by some metal ions in solution and discuss the possible reasons for the differences and intensities of colours, including the presence of different ligands and the possibility of different coordination in some cases.
- Introduce the acidity of metal ion complexes and give learners practice in writing equations where H^+ is progressively lost when hydroxide is added. Describe the cases where a charged, soluble hydroxide complex is formed when excess hydroxide is added. Learners should carry out reactions adding hydroxide to transition metal complexes where the oxidation state of the metal is 2+ and 3+.
- Learners should investigate the addition of ammonium hydroxide dropwise and in excess to transition metal ion solutions. You could encourage learners to explain the reactions, using suitable equations.
- Learners should investigate the addition of carbonate to 2+ and 3+ transition metal ion solutions, noting whether the gas carbon dioxide is produced in addition to any precipitates. Learners should explain the reactions using suitable equations.
- You could lead the learners to devising a simple reaction key to allow them to distinguish between ions in solution. If this is too difficult, you could present a reaction key for learners to follow.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

The experience of using pH meters and carrying out acid-base titrations in Unit 2 will allow learners to be more effective in their practical work for learning aim A. If learners visit an industrial laboratory in relation to Units 2 or 4, there may be scope for researching applications, related to learning aims A and B.

Many industrial laboratory technicians and apprentices in industry will use pH measurements, acid-base and iodometric titrations, and determine COD.

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 3: Science Investigation Skills*
- *Unit 6: Investigative Project*
- *Unit 19: Practical Chemical Analysis.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Videos

<https://www.youtube.com/watch?v=RX6rh-eefIM>

This series of videos by Bozeman Science gives verbal explanations of redox reactions and other topics, which may be useful for revision or consolidating understanding.

Websites

<http://www.chemguide.co.uk>

Although this website is aimed at AS level and A level learners, it contains explanations of the topics that are broader than required for particular syllabi and thus targets the BTEC content effectively.

<http://www.rsc.org/learn-chemistry>

The Royal Society of Chemistry's website has links to resources relevant to the topics in the unit.

<http://preparatorychemistry.com>

An Introduction to Chemistry by Mark Bishop contains links to eBook chapters on acids and bases and on oxidation and reduction.



Unit 14: Applications of Organic Chemistry

Delivery guidance

Approaching the unit

Learners may bring knowledge of organic chemistry through their previous studies and through Units 1, 4, 5 and 10 in this qualification.

You could give initial introductory input to your learners about how the aims of the unit fit into the overall study of chemistry and how it relates to the study of biology and biochemistry.

You should encourage learners to read about the applications of organic chemistry and any new developments that are reported in scientific magazines.

Universities and science industries such as the pharmaceutical and polymer industries welcome learners that have a good fundamental knowledge and understanding of organic chemistry concepts and their applications, together with the practical skills involved in the preparation of organic chemicals.

To complete this unit your learners will need access to the internet, journals or magazines, and books.


The delivery methods proposed for this unit are, for example:

- discussions – class and small group discussions on case studies and new techniques/discoveries and applications
- practical sessions where learners will carry out organic chemistry practical preparations
- visits to a university or a science organisation that uses, manufactures or analyses organic chemicals
- visiting/guest speakers from industry or a university or a professional body that could be arranged through STEMNET
- tutor presentations/guidance – briefing and monitoring learners about individual research and appropriate websites and references
- group and individual learner activities – where learners can research relevant materials and case studies
- video and YouTube clips – where learners can learn and reinforce their knowledge and understanding of underlying organic chemistry concepts through demonstrations of various organic chemistry techniques.

Delivering the learning aims

For **learning aim A**, introduce the unit by informing learners about the introduction, aims and assessment criteria, how it fits within the qualification and how it relates to other units within the qualification, especially Unit 4 (learning aims B and C) and Unit 5 (learning aim A).

Your learners will need to know the names of organic compounds using the IUPAC system and the structures of halogenoalkanes, alcohols, aldehydes,



ketones, carboxylic acids, acyl chlorides, amides and acid anhydrides. They will need to know how they are represented using their general, molecular, structural and skeletal formulae, their functional group and where relevant their primary, secondary and tertiary structures.

Brief learners about the properties and reactions of halogenoalkanes, and the difference in bond energies and their relationship to bond lengths for C-Cl, C-Br and C-I. Introduce nuclear substitution reactions as the most characteristic reactions of halogenoalkanes, such as the hydrolysis of bromoethane to produce ethanol and the reaction of potassium cyanide with iodoethane to produce propanenitrile. This can be followed by showing learners SN1 and SN2 mechanisms such as the reaction between 2-bromo-2-methylpropane and hydroxide ions and the reaction between bromopropane and hydroxide ions. Using group work, ask your learners to write out some mechanisms of given halogenoalkane reactions. Your learners will also need to understand the elimination reactions of halogenoalkanes such as the reaction of bromoethane and hydroxide ions.

As an introduction to alcohols, you could ask learners to test their pH, carry out a combustion test to check the sootiness of their flame and find out why alcohols are so soluble in water. Give learners some rubbing alcohol and water, ask them to measure out 25 cm³ of water and 25 cm³ of rubbing alcohol and mix them together in a measuring cylinder, then ask the learners why there is a reduction in volume and how this is related to hydrogen bonding and the size of the molecules. Learners will need to know the functional group of alcohols, their characteristic reactions together with their reaction conditions with sodium and oxidation reactions to form aldehydes, ketones and carboxylic acids.

Introduce amines and discuss their properties with learners, covering how amines like ammonia are bases with a lone pair of electrons, and how they react as nucleophiles. Ask learners to investigate some commercially important compounds of amines and amides, such as the polyamides nylon and Kevlar. At this stage, you should give learners an exercise to predict some multi-step synthesis reactions to obtain given products from some examples of carbonyl and non-carbonyl starting material reactants.

For **learning aim B**, ask learners if they have any knowledge of the properties of benzene as an aromatic substance. One way of approaching how learners could investigate the structure of benzene is by discussing with them the possible different structural formulae with different bond lengths such as the Dewar and Kekulé models and then asking them to find the evidence in support of the different models. You could then show the learners the hybridisation model using sigma and pi bonding. Follow this by introducing the names of some common aromatic compounds. Ask learners to predict the smokiness of the flame of benzene or other aromatic compounds, and compare this to hexane. It is important for learners to have an understanding of the main reactions and properties of benzene and other aromatic compounds. Introduce the addition reactions of benzene, to include chlorination and hydrogenation and substitution reactions of benzene, to include nitration, sulphonation, alkylation and the reaction to produce phenol. Ensure learners are able to give evidence for the electrophilic substitution reaction mechanism for the nitration of benzene. Ask learners to work in groups to name a number of mono-substituted benzene compounds and then introduce the concept of how the mono-substituted atom or group effects the position of any further substitutions on the benzene ring.

For **learning aim C**, introduce the topic of isomerism by asking learners where they have heard of the concept in their studies of organic chemistry in other units and discuss isomerism by introducing three-dimensional models of some examples. Give learners some examples of relevant molecular formulae and ask



learners to work in groups to build three-dimensional models of some simple isomers. It is important that learners have a knowledge and understanding of the different types of isomerism. Ask learners to produce a scientific poster or a mind map of the different types of isomers, to include their representations and three-dimensional structures. Learners will need to know that isomers have different physical and chemical properties; ask learners to investigate some given examples. Introduce the fact that many isomers occur naturally as optical isomers such as sugars and amino acids and how important it is to know the properties of the different isomers. Ask learners to investigate the effects of optical isomers of thalidomide and the difference between starch and cellulose in terms of being different isomers of glucose.

For **learning aim D**, introduce the topic of preparative organic chemistry by informing learners about health and safety rules and regulations that apply to organic reactions in a laboratory, the use of fume cupboards and PPE. Brief learners about how important it is to ensure that equipment and apparatus is set up properly and that they should seek permission before starting a reaction. Discuss with them the types of apparatus and equipment they will be using, such as carrying out test/boiling tube reactions and the use of Quickfit® apparatus, and how important it is to follow set procedures using a step-by-step manner and not take short cuts. Also how important it is to write up their experiments in their laboratory report books using the correct headings, in the past tense and using the correct terminology. Ask learners to refer back to the reactions that they have studied in theory in learning aims A and B.

With regard to halogenoalkanes, ask learners to carry out hydrolysis reactions of 1-chlorobutane, 1-bromobutane and 1-iodobutane and how this experiment links with rates of reactions. Learners should carry out mild oxidation of ethanol to produce ethanal and further oxidation to produce ethanoic acid; ask learners to test the products. With regard to the reactions of amines, ask learners to carry out some reactions with butylamine such as its reaction with hydrochloric acid and also its reaction with copper sulphate solution.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the structures, reactions and properties of functional group compounds	<p>A1 Reactions and properties of non-carbonyl compounds: halogen alkanes, alcohols, amines</p> <p>A2 Reactions and properties of carbonyl compounds: aldehydes, ketones, carboxylic acids, esters, acyl chlorides, amides</p>	<p>A research report showing the different types of reactions for both carbonyl and non-carbonyl functional group compounds.</p> <p>Learners could produce visual presentations such as flow charts, mind maps, data charts, diagrams for the carbonyl and non-carbonyl compound properties and reactions and their different types of mechanisms.</p>
B Understand the reactions and properties of aromatic compounds	<p>B1 Structure and reactions of benzene</p> <p>B2 Reactions of mono-substituted benzene compounds</p>	<p>A research report showing the typical addition and substitution reactions undergone by benzene. Diagrams and explanations showing how the structure of benzene was established. Diagrams showing the different effects of mono-substituents on the benzene ring and their reactions. A summary of important industrial uses of benzene and example mono-substituent compounds.</p>
C Understand the types, structures, reactions, uses and properties of isomers	C1 Types of isomerism: structural, chain, positional, functional group, stereoisomerism, geometric, optical	<p>A research report showing 2D and 3D structural diagrams of the different types of isomers. A summary of the different properties of cis and trans isomers. Simple models of optical isomers such as amino acids and sugars and their effects. Their industrial importance and therapeutic/chemical importance.</p>
D Investigate organic chemistry reactions in order to gain skills in preparative organic chemistry	<p>D1 Carry out appropriate reactions of non-carbonyl compounds</p> <p>D2 Carry out appropriate reactions of carbonyl compounds</p> <p>D3 Carry out appropriate reactions of aromatic</p>	<p>A portfolio of reactions that learners have carried out in the course of this unit, including observations of safe working and risk assessment.</p>



	compounds using methyl benzene or methylbenzene	
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Assessment guidance

This unit is internally assessed through a number of given independent assignments/tasks. Each task should cover at least one entire learning aim and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion.

There are four suggested summative assignments for this unit as shown in the assessment criteria, each covering one learning aim. All learners must independently generate individual evidence that can be authenticated; this also applies to learners who have completed their assignments in a group. The main sources of evidence are part of each assignment.

Learners should incorporate research that has a referenced bibliography. Learners need to produce their assignment reports in a style that allows assessors to assess the evidence presented for each individual criterion and to ensure that four assignment themes are present. Learners could produce evidence using research reports that contain flow charts, mind maps, diagrams, tables, photographs of models, or technical scientific posters or leaflets. Tutor observation reports should accompany learner evidence for learning aim A. The assessment plan and recommended approach is funnelled to give a thematic approach for learners to give progressive evidence that is coherent and to allow for higher command words/verbs to be used when moving from pass to merit to distinction grade.

Getting started

This provides you with a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 14: Applications of Organic Chemistry

Introduction

Begin by introducing the unit to learners and discussing the unit introduction, learning aims and assessment criteria. Brief the learners on how the unit fits with other units and within the qualification as a whole.

Revisit some underlying concepts of organic chemistry covered in Unit 5.

Learning aim A – Understand the structures, reactions and properties of functional group compounds

- Brief learners about naming organic compounds and how they are represented as different types of formulae and as 3-dimensional models, including relevant primary, secondary and tertiary compounds.
- It is important for learners to be able to write formulae using IUPAC names, produce simple molecular models, distinguish between functional groups, and using relevant formulae name organic compounds.
- Inform learners about the main reactions of halogenoalkenes.
- Give a presentation to learners about organic reaction mechanisms following experience they have had of mechanisms used during their studies of alkanes and alkenes and complete SN1 and SN2 mechanisms for halogenoalkanes.
- Ask learners to write out some mechanisms and predict products from similar halogenoalkanes reactions that they have covered.
- Cover the physical properties and typical reactions of alcohols.
- Get learners to mix 25 cm³ of rubbing oil and 25 cm³ of water and get them to give reasons why there is a reduction in volume.
- Ask learners what they know about bases and how to test for them. You could then ask them to compare ammonia to amines, why they are nucleophiles and the typical reactions they undergo.
- Ensure learners carry out research into the uses of halogenoalkanes and alcohols.
- Introduce the carbonyl group and cover the typical reactions and tests of aldehydes and ketones.
- Introduce learners to the mechanisms involving the carbonyl group for typical reactions and ask learners to write mechanisms for similar reactions to the ones you have covered. At this point you could remind learners that for assessment, they will need to produce a research report showing the different types of reactions for both carbonyl and non-carbonyl functional group compounds.
- Introduce learners to organic acids and the carboxylic acid functional group, what makes a substance an acid and what properties it would exhibit. You could then cover the typical properties and reactions of carboxylic acids.
- Ensure your learners investigate some of the commercially important compounds that relate to aldehydes, ketones and carboxylic acids.
- Cover the typical reactions and properties of acyl chloride, amides and acid anhydrides.



- Ensure learners investigate commercially important amines and amides.
- Introduce to learners and ask them to plan and draw multi-step reaction synthesis.
- Invite a guest speaker to come and talk about the importance of organic chemistry in both the fields of biology and chemistry.

Learning aim B – Understand the reactions and properties of aromatic compounds

- Introduce benzene and ask learners what they know about benzene.
- Ask learners to investigate the structure of benzene and the evidence to support its structure.
- Discuss with learners the evidence that supports its structure, of benzene, its formulae and hybridisation model.
- Introduce the combustion of benzene and ask learners about the smokiness of its flame compared to alkanes.
- Cover the addition and substitution reactions of benzene and the substitution mechanism. For assessment, learners will need to produce a research report showing the typical addition and substitution reactions undergone by benzene.
- Ask learners to complete the reaction mechanisms of some similar reactions.
- Introduce mono-substituted compounds of benzene, their reactions and the effects of the mono-substituent on further substitution reactions on the benzene ring.
- Get learners to predict further substitution on the ring giving them similar compounds to the ones covered. You could then discuss with the learners their predictions.
- Enable learners to investigate the applications of typical aromatic compounds.

Learning aim C – Understand the types, structures, reactions, uses and properties of isomers

- Give learners molecular formulae of alkanes and alkenes that have isomers and ask them to draw structural formulae and produce molecular models of possible isomers.
- Cover an overview of the types of isomerism in the content and ask learners to produce a scientific poster or leaflet about different types of isomers.
- Ask learners how they would be able to test the differences between isomers and then introduce the physical properties of isomers.
- Inform learners that isomers exist in nature and how important it is to use the correct isomer in medicine.
- Enable learners to investigate the use of different isomers in medicine and ask them to investigate the difference between starch and cellulose.
- Discuss with the learners their findings and the industrial importance of isomers. For assessment, learners should produce a research report showing 2D and 3D structural diagrams of the different types of isomers.

Learning aim D – Investigate organic chemistry reactions in order to gain skills in preparative organic chemistry

- Discuss with learners what they know about health and safety, risk assessment and use of PPE. Inform them that they will be observed on their use of practical skills during the practical sessions.
- Brief learners on how important it is to be able to set up apparatus/equipment



properly with regard to organic preparations, how important it is to follow given procedures in a step-by-step fashion and the importance of the use of the fume cupboard for many reactions.

- Discuss with the learners some of the reactions they will be carrying out and where they have covered them in theory in learning aims A and B.
- Ensure learners are aware that when they are writing up their practical experimental reports for assessment that they write out the chemical equations to include the changes in functional groups and the specified reaction conditions.
- Brief learners before each practical session about any hazards and precautions they need to take and get them to show you their apparatus/equipment before starting any practical experiment. Ask learners to carry out the given practical experiments in order of halogenoalkanes, alcohols, amines, aldehydes and ketones, carboxylic acids, esters, amides, methyl benzene or methoxybenzene and phenol during given practical dates and times. Get learners to write down any observations, in a log book/practical report book, of any changes occurring during and at the end of the experiment.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 18: Industrial Chemical Reactions*
- *Unit 19: Practical Chemical Analysis.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Foal, S., Hocking, S., Llewellyn, R., Musa, I., Patrick, E., Rhodes, P. and Sorensen, J., *BTEC Level 3 Applied Science Student Book*, Pearson, 2010 (ISBN: 978-1846706800).

This book contains Unit 28 Industrial Applications of Organic Chemistry 2010 specification.

Hudson, M. and Fullick, A., *Edexcel A level Science: AS Chemistry Students' Book*, Longman, 2009 (ISBN: 978-1405896351).

Comprehensive cover of halogenoalkanes, alcohols and isomerism with regards to alkanes and alkenes.

McDuell, B. and Fullick, A., *Edexcel A level Science: A2 Chemistry Students' Book*, Longman, 2009 (ISBN: 978-1408206058). Comprehensive cover of carbonyl compounds, carboxylic acids, aromatic compounds, isomerism and organic synthesis.

Journals

Nature

An international journal covering research spanning all areas of science.

New Scientist

Covering the latest news and articles about science and technology.

Scientific American

Latest science stories, articles and news.

Chemistry World

Royal Society of Chemistry – articles about developments in chemistry.

RSC News

Royal Society of Chemistry – latest news in chemistry.

Videos

<https://www.youtube.com/watch?v=NMUVW1CpIBA>

Nucleophilic Substitution SN1 and SN2.

www.youtube.com/watch?v=urMZ2UqQ8s8

Preparation and purification of an ester.

Websites

www.ase.org.uk

Association for Science Education– science resources for tutors, journals, textbooks, professional development, membership, conferences, useful links, curriculum and assessment for science experiments.

www.HSE.gov.uk/coshh

Control of Substances Hazardous to Health.

www.bbc.co.uk/schools/gcsebitesize/science/triple_edexcel/organic_chemistry

GCSE Bitesize Organic Chemistry background.

www.cleapss.org.uk

Supporting practical science and technology with regard to health and safety.

www.gatsby.org.uk

Gatsby Foundation, supporting practical science in schools and colleges.

www.HSE.gov.uk

Health and Safety Executive– information about health and safety.

www.HSE.gov.uk/coshh

Health and Safety executive information about the 'Control of Substances Hazardous to Health'.

www.nationalstemcentre.org.uk

National STEM centre – resources for practical experiments and projects.

www.nationalstemcentre.org.uk/elibrary/list/17572/organic-chemistry

National STEM Centre – Organic Chemistry.

www.rsb.org.uk

Royal Society of Biology – resources about theoretical and practical biology, journals, textbooks, professional development, membership, conferences, useful links, curriculum and assessment for science experiments.

www.rsc.org.uk

Royal Society of Chemistry – resources about theoretical and practical chemistry, journals, textbooks, professional development, membership, conferences, useful links, curriculum and assessment for science experiments.

www.rsc.org/learn-chemistry/wiki/Lab:List_of_advanced_level_Practical_Chemistry_experiments#Organic_chemistry

Royal Society of Chemistry – organic chemistry practical experiments.

www.stemnet.org.uk/ambassadors

STEM ambassadors– central hub for allocation of speakers to schools/colleges.



Unit 15: Electrical Circuits and their Applications

Delivery guidance

Approaching the unit

Science technicians working in industry, education, health or modern research laboratories must frequently demonstrate a clear understanding of electrical concepts and feel confident in the use of instruments and measuring devices. This unit will give learners the knowledge and skills necessary to undertake essential tasks related to electrical circuits and their components. Learners will not need to have detailed prior knowledge of the subject material. The main emphasis in this unit is on development of practical skills, a logical approach to problem-solving, and independence in report writing and research.

Your learners will be expected to plan investigations and carry out practical activities with precision and accuracy in order to improve their understanding of electrical 'flow' in a circuit, the use of measuring devices and the numerous components involved. You will introduce them to new electrical terms, calculations and concepts, and they will gain a clear insight into the applications and practicalities of electrical circuits and machinery in all walks of life, developing both their investigative and research skills.

Your learners will need access to essential electrical equipment and research materials, books and the internet. Excursions to linked organisations such as power stations, industrial complexes and electrical distributors would be of significant value. You can use a wide range of delivery methods for this unit, which could include:

- practical demonstration and investigation – covering the essential requirements of safe working practices, knowledge of circuit components, calculations and measurement techniques
- PowerPoint® presentations – used to introduce the various topics and for your learners to present their work individually or in a group activity
- videos – a wealth of up-to-date presentations are available for you to support formal laboratory teaching with information supplied from industrial establishments
- case studies – these are of value when highlighting the dangers of misuse of electricity and its associated machinery and devices
- discussion – as a means to determine understanding of the subject material by your learners and to inform your way forward in the topics covered.

Delivering the learning aims

The learning aims covered in this unit are best delivered through a programme of formal tuition, practical demonstration, investigation and research.

Your learners will need access to:

- DC electrical circuit boards and the components identified in unit content
- suitable range ammeters, voltmeters, multi-meters and high-impedance analogue or digital (DSO) oscilloscopes – single or dual trace
- a signal generator, microphone and speakers
- standard transformer packs
- 12 V DC power supplies and suitable single cells
- domestic wiring/fuse samples
- rheostats
- electrolysis apparatus
- RCCB and ELCB (for demonstration purposes)
- a variety of sensors for circuit use
- thermocouple components, piezoelectric example model
- data loggers and associated sensors (pH, moisture, light, temperature, pressure)
- a working model for AC transmission (demo) or National STEM Centre e-library video.

For **learning aim A**, your learners are to give definitions from notes and research for the main terms, units and relationships used in basic electrical circuits. A document, such as a poster or leaflet for electrical/electronic symbols must be produced. Group work presentation or PowerPoint can also serve the purpose. Your learners must comprehensively list all the electrical terms in the unit content section, giving a brief description of each. This may be done by producing a definition catalogue or poster. You can produce demonstration circuits to give evidence and support of electrical quantities and some relationships and your learners can then demonstrate their ability to use correct electrical relationships and calculate values of electrical quantities.

Give the learners formulae sheets which incorporate many or all examples of standard suitable calculations that can be performed by the learners and assessed. Ensure that learners have the opportunity to perform unaided calculations of essential electrical quantities using studied relationships, where possible. Graphical representations for electrical relationships should be produced as necessary (e.g. resistance, power, charge) and used to explain relationships within the circuit operation.

For **learning aim B**, practical circuit building and understanding of how and where to measure voltage, current and resistance should be developed through teaching and learning opportunities to allow learners to develop competency and confidence with equipment. Learners should develop a clear understanding of the nature of current 'flow' in circuits and be able to present their work in an acceptable investigative form. It is essential to ensure that good combinations of series and parallel circuits are also investigated in order for your learners to gain



valuable experience in more realistic circuit designs. Potential divider circuits should also be included. There is some value in a generalised comparison between digital and analogue devices for electrical measurement, but this does not need to be over-emphasised.

For **learning aim C**, learners need to be familiar with the essential differences between AC and DC voltage supply. Use the standard internal diagram of a cell to show the passage of electrons and link this to the DC voltage supplied by a thermocouple and solar cell. For AC voltage, you will need to ensure that learners are familiar with and understand all the principles of Faraday's Law and Lenz's Law, initially by demonstration and then by asking learners to produce practical and reporting evidence. Electromagnetic induction forms the basis of modern-day electrical systems and must be well covered in tuition. Discuss aspects of step-up and step-down transformers as applied to transmission of AC voltage and explain power loss as heat from electrical cables. Explain RMS values and their DC equivalence, peak voltages and the nature of AC as a sinusoidal waveform. From this, the domestic ring main can be outlined fully in schematic or photographic form, showing the wiring within a standard home setting and the various appliances and terminals. Your learners can be introduced to the variety of methods put in place to reduce risk from mains electricity, such as fuses and circuit breakers, and a further discussion can develop on the equipment seen in practice and the numerical values attached. You can then progress to the industrial equivalents by showing images or video of industrial machinery and the safety devices employed. The differences between domestic and industrial applications can be presented by learners in a formal document. Introduce the Electricity at Work Regulations, 1989, and a study of the physiological effects of electricity in the body as a means of helping further understanding of prevention of electric shock. You should emphasise different effects on the heart of AC and DC. You can also explain that circuit resistance (and body resistance), current and time are the important elements that determine the extent of electric shock.

For **learning aim D**, you should explain transducers in terms of accepted electrical and physical characteristics. The confusion of 'passive' or 'active' depending on text used can be reduced by attention to their usage rather than energy conversion. In general terms, real transducers (e.g. thermocouple, piezoelectric) produce their own EMF. LDRs, thermistors and strain gauges do not, and should be more properly referred to as electrical sensors. You should give formal guidance on the use of data logging devices and ensure that your learners use data logging devices as often as practically possible, taking information from physical changes. They should become familiar with data collection, processing and display. You should not need to explain particular functions of the devices in detail – learners simply need to appreciate their usefulness as measurement devices. You should incorporate suitable practical investigations into both passive and active transducers, allowing learners to determine the relationships involved and to produce valid graphical representation of their results. Emphasise the need for detailed conclusions in their reporting and insist on a range of instruments for measuring and recording. Previous work on the oscilloscope will help in the use of this device for practical display of the conversion of sound into a waveform using a speaker, for example. Learners need to develop competency in constructing simple circuits to demonstrate standard circuit measurement practice using the devices in the unit content. It is essential that learners have direct experience of all these measuring devices in a variety of realistic scientific settings.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits	A1 Electrical symbols, units and definitions A2 Electrical formulae and relationships A3 Electrical properties and uses of materials	Scientific report including use of terms, symbols, units and example calculations. Practical investigation of ohmic/non-ohmic conduction devices. Practical circuit assembly, combination circuits and recorded results.
B Construct series and parallel circuits for use in standard electrical applications and measure electrical values	B1 Circuit characteristics B2 Measurement devices	Records of measurement results of circuit values, resistance values, calculated and predicted comparison. Potential divider circuit work – diagrams and report.
C Examine AC and DC production and health and safety aspects in domestic and industrial applications	C1 DC production C2 AC production and transmission C3 Domestic applications and mains supply C4 Industrial applications C5 Safety, human physiology and electricity and legislation	Report using laboratory and research notes on domestic mains characteristics. Practical investigation into production of induced current/voltage. General study of uses of AC and DC electricity in the home. Case study comparing industrial uses. Report on physiological study of electric shock effects (AC and DC). Industrial site visit to produce site safety report and outline of safety devices.
D Examine the uses of transducers, sensors and other measurement devices	D1 Uses of passive transducers D2 Uses of active transducers D3 Uses of sensors and other measuring devices	Circuit construction and report on transducers, sensors and other measurement devices. Report on applications and operation of transducers, sensors and measurement devices.



Assessment guidance

This unit is internally assessed through a number of independent tasks. Each task should cover at least one entire learning aim, and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion. There are four suggested assignments for this unit, which cover the learning aims individually.

All learners must independently generate individual evidence that can be authenticated. The main forms of evidence are likely to be written reports, diagrams and investigative articles. There will also be practical observational work including laboratory logbooks, circuit diagrams, schematics and possibly photographic evidence. Learners should incorporate in-depth research that is supported by a fully referenced bibliography.

The use of presentations is important and the forms of evidence should include: slides, preparation notes, script, cue cards, peer assessment records and an observation record or witness statement where appropriate. The completion of observation records is to be carried out by the assessor and the learner's colleagues in placements or part-time work; other departmental staff and laboratory technicians could complete witness statements. Observation records alone are not sufficient sources of learner evidence; the original learner-generated evidence must also support them. Assessors should remember that they are assessing the content of the presentation against the learning aim, and not the skill with which the presentation was delivered.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 15: Electrical Circuits and Their Applications

Introduction

Outline the learning aims of the unit, the content involved and the expectations for learners in terms of independence and group activities. Begin with a group discussion of the general electrical terms and phrases, determining the extent of learners' knowledge and understanding, and asking them to consider the vast array of applications which electricity has in our lives.

Learning aim A – Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits

- You should begin with an overview of the principles of electricity, particularly electrical terms and relationships. You should give learners a document that lists all the terms to be used in the unit, together with their definitions, for learners to become familiar with and have access to during their course of study.
- The use of voltmeters and ammeters will be extensive for this unit, and learners will need to have access to these and all other electrical circuit devices on a regular basis. Ask learners to link the devices to their appropriate application in electrical circuits by producing a suitable information poster. This poster should not be submitted as evidence.
- Use appropriate circuit designs on PowerPoint or worksheets to highlight the general characteristics for series and parallel circuits and give learners suitable introductory calculations linking current, voltage and resistance. You will need to explain the fundamentals of current flow in both types of circuit using clear diagrams. Learners should complete the basic calculations by individual answers. It is, therefore, important to address the correct use of a suitable calculator prior to starting this activity. Make sure that you have demonstration circuits constructed and on display in order to use them effectively when delivering information of circuit construction, equipment and calculations. This will help to reinforce understanding of the relationships studied.
- Introduce the various laws and formulae through formal tuition and example problems, checking that all learners are able to produce detailed notes and follow the appropriate stages in calculations. Many of the terms and relationship formulae will undoubtedly be unfamiliar to learners at first. Learners could create large industrial posters that include all relevant terms, formulae and example calculations in addition to their personal notes.
- Introduce learners to materials and their uses in electrical circuits with suitable physical examples. This will involve a Q&A session on insulators and conductors, and also ohmic and non-ohmic conductors. Use graphs to illustrate these. You should ensure that sufficient focus is placed on the characteristics and importance of capacitors in circuits, and demonstrate AC applications. Again, the use of graphs to show charge and discharge is important. Your learners should make valid and accurate notes with example graphs.
- Discuss semiconductors with your learners in a general format, identifying the two main elements, silicon and germanium, and give basic information on their mode of operation, for example, mixed with other elements to adjust their conductivity in a



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circuit and thereby control other parts of the circuit. A diode can be used as a graphical example.

- Recap on the general principle of the capacitor in a circuit that has both AC and DC running through it. Explain, in general terms, how the capacitor offers high resistance to DC (e.g. low frequency noise) and low resistance to higher frequency AC signals, thereby acting as a 'filter'. Your learners only need to take suitable notes on this aspect. Demonstrate, by graphical representation and explanation, the exponential charge/discharge for capacitors.
- Assessment will occur when learners have had the opportunity to develop their skills. During assessment, they will use the assignment brief to work independently to produce the evidence indicated in the assignment brief.

Learning aim B – Construct series and parallel circuits for use in standard electrical applications and measure electrical values

- With sufficient apparatus and range of resistor values for the group, arrange your learners into pairs. Ask them to construct a working DC circuit using one resistor and then progress to using two and then three resistors in a series circuit. Learners should not be given the opportunity to practise building the same circuits that they will be required to build in the assignment brief. Your learners will need to draw and measure values of voltage and current at suitable points in order to confirm resistance values. Ask them to construct parallel circuits using the same components. Learners should develop skills in producing scientific reports with suitable diagrams and calculations.
- Instruct your learners to assemble a range of independent combination series and parallel circuit types with descriptions using a range of components. Your learners are to complete individual measurement of quantities using digital and analogue devices for later comparison.
- Based on experimental results, ask your learners to give a general summary of their findings comparing calculated values with experimental measurement from circuit work. They should share this with the class and make a collective evaluation. A Q&A session will be useful: Are the values of resistance close to manufacturer values? Why? Is there a significant difference between using analogue to digital devices for measurement?
- Introduce the simple potential divider circuit as a diagram, explaining the general principle. Ask your learners to construct at least two circuits using resistor values that are both equal in one circuit and different in the second circuit. They should confirm the measured values of voltage by calculation and include it in the full circuit report together with suggested applications of the potential divider.
- Explain the nature of measured voltage drop across components in terms of transfer into heat energy, and give an opportunity for learners to consider internal resistance in their calculations.
- Assessment will occur when learners have had the opportunity to develop their skills. During assessment, they will use the assignment brief to work independently to produce the evidence indicated in the assignment brief.

Learning aim C – Examine AC and DC production and health and safety aspects in domestic and industrial applications

- Give an initial introduction to a circus of practical demonstrations which are to be shown. These will be:
 - 1 magnetic fields around wire carrying current (using plotting compasses)
 - 2 AC production (magnet and coil)

Unit 15: Electrical Circuits and Their Applications

3 principle of the simple motor (movement of wire in a magnetic field).

Your learners must take valid notes with clear, well-drawn and well-labelled diagrams. You should outline the important rules that apply to your demonstrations, introducing Fleming's right- and left-hand rule, Faraday's Law and Lenz's Law. Learners must include these points in their notes.

- Introduce the differences between AC and DC using a demonstration circuit and oscilloscope. You may then wish to discuss the operation of the device in terms of varying the wave amplitude and time base. It is important to ensure that all aspects of the AC wave are reviewed and you can then ask your learners to produce a scientific poster, from demonstration and additional research, which illustrates an accurate set of fully labelled diagrams describing the characteristics of AC and DC waveforms and identifying the differences between them. This poster should not be submitted as evidence.
- Discuss the meaning of root mean square (RMS) values as the AC equivalent of DC current by producing the same heating effect on a resistor. Use the value as 'peak voltage divided by the square root of 2' and state that the AC wave is varying continuously. Explain to learners that it is strictly not the average value of AC since this would obviously be zero. Use the oscilloscope to illustrate the 'peak-to-peak' voltage and how it can be easily found by counting the squares.
- Introduce the principles of the step-up and step-down transformer using a working demonstration. The transformer equation must be given to learners, together with suitable example questions, so that they can quickly identify the simple ratio technique.
- Discuss why electricity is transmitted on the National Grid as AC and show the video presentation (National STEM Centre e-library) by a tutor using a working model of power lines and transformers. Summarise the content of the video and ask learners to identify the advantages of AC transmission over DC transmission in terms of power loss.
- The domestic ring main can be introduced as a general diagram illustrating wiring systems, voltages and current values for specific appliances, and fuse ratings. From this, learners can produce a large schematic which can also include notes on the need to use transformers to reduce AC voltages to useable DC voltages and the variety of electrical safety devices used.
- Present your learners with an opportunity for two case studies: 'Application of DC electricity for industrial electrolysis' and 'Application of AC electricity in producing a speedometer'. The same case studies should not be used for practice and assessment. Learners need to be supported to understand how to produce case studies. You may wish to include a variation of these topics based on suggestions in the unit content or include your own. Learners will also be expected to give additional comments on the safety devices used in industrial settings, such as line isolation monitoring and isolating transformers.
- You should give formal tuition on the effects of AC and DC on the human body, typical internal electrical values and conduction characteristics, and the length of exposure time to current. You will also review electrical safety devices – fuses, circuit breakers and earthing systems – and introduce the Electricity at Work Regulations, 1989. Instruct your learners to produce group presentations with the title 'A Report into Health and Safety when using Electricity'. You will need to outline the topics for inclusion in the reports: biological considerations, operation of a defibrillator, safe levels of DC, etc.



Unit 15: Electrical Circuits and Their Applications

Learning aim D – Examine the uses of transducers, sensors and other measurement devices

- You can begin this section with a display of both types of transducers: passive and active. Many of these will be in enclosed form so the fundamental 'working' parts may not be easily visible. You can outline the functioning points with a simple schematic of each device set alongside the component. Your learners will then present a document in the form of a 'Guide to transducers and sensors' which illustrates each example with diagrams and its applications.
- Introduce practical investigations for all the sensors listed in the unit content. Your learners could carry out the following practical experiments providing full scientific reports with diagrams, photographs, results and conclusions:
 - 1 pressure sensor – biological blood pressure device
 - 2 pH sensor – calibrating a pH meter
 - 3 moisture sensor
 - 4 temperature sensor
 - 5 LDR – operation of a light dependent resistor in a circuit.

One or more practical applications of these devices will be included in the reports.

- Ask your learners to carry out an investigation into the operation of an active transducer – construction and operation of a thermocouple, for example, to measure a given solution and to use a simple calibration method by using a standard thermometer (need for amplification). Your learners should then give details of the mode of operation and comment on improvements to their design if any can be identified.
- You should introduce a series of activities designed to demonstrate the ability of learners to use a variety of measurement devices effectively and with confidence. This will involve demonstrating some devices and recapping on others already used in the unit. This includes:
 - oscilloscopes to calculate suitable AC voltages (peak-to-peak, root mean square, for example) by accounting for vertical scale divisions. Additional use of the oscilloscope to calculate the frequency of the AC signal input using the horizontal scale divisions
 - practical use of ammeter, voltmeter and multi-meter and investigation records during circuit analysis linked to learning aim A
 - practical evidence of the use of data logging for recording and storage of data from a range of sensors (e.g. pressure, pH, temperature). Learners should give displays of information for analysis.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 3: Scientific Investigation Skills.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Bird, J, *Electrical Circuit Theory and Technology*, Newnes, 2007 (ISBN: 9780750681391).

Videos

www.youtube.com

You can find a useful range of electrical safety videos on YouTube.

Websites

www.allaboutcircuits.com/education

This site references online textbooks, video lectures and worksheets on electricity and electronics.

www.iee.org.uk

The Institution of Engineering and Technology.

www.physicsworld.com/cws/home

Physics World online.

www.hse.gov.uk

Health and Safety Executive – information about health and safety.



Unit 16: Astronomy and Space Science

Delivery guidance

Approaching the unit

This subject will give your learners many fascinating facts and theories and an insight into human innovation and adaptability. They will need to plan observations and carry out research into the numerous associated industries, which includes materials and manufacturing, mechanical and electrical engineering, computers, communication, design, chemical research and engineering, education and practical research, aeronautics and aerospace.

Learners will need to develop their knowledge and understanding of the key areas in astronomy and space flight, and of the links between these exciting topics and related industries. They should look at the advances made in space flight and the varied subject disciplines associated with space science development, improving their investigative and research skills as they study.

You will introduce your learners to many new concepts and ideas, and they will need access to essential research materials, books, magazines, periodic journals, the internet and excursions to linked organisations. You can use a wide range of delivery methods for this unit, which could include:

- PowerPoint presentations – used to introduce the various topics and for your learners to present their work individually or in a group activity
- videos – a wealth of up-to-date presentations are available for you to enthuse your learners in current knowledge and theories and also as a means for research into historic space flight programmes
- case studies – many opportunities exist for a number of case studies to be highlighted in both space flight (past, present and future) and astronomy, present day developments and new discoveries
- discussion – you can use this as a means to determine understanding of the subject material by your learners and to inform your way forward in the topics covered
- practical demonstration and investigation – covering the essential requirements of safe working practices and knowledge of optical instruments, celestial coordinates, correct visual methods and recording techniques.

It is important for you to emphasise to your learners that the subject of astronomy and space science involves a high degree of independent research and personal study. Learners should have a general awareness of the subject material before beginning the course.

Delivering the learning aims

The learning aims in this unit should be delivered through a programme of tuition, facilitated learning, research and practical investigative work. You need to address health and safety issues for observations of solar activity and independent night-time activities.



Your learners will need access to:

- computer facilities, internet, relevant CD-ROMs, simulation models for essential research materials and aids to personal study of animation and actual video images
- portable telescopes (min. 50 mm refractive/100 mm reflective), binoculars (10 × 50 mm) and projection attachments to support naked eye observations and mapping
- optical physics equipment: lenses (converging and diverging), mirrors (concave spherical and parabolic if possible) and suitable light sources, for laboratory investigation of light, magnification and focus.

For learning aim A, you can introduce the topic by finding out what your learners already know about the solar system. Develop a discussion and then give a comprehensive overview of the most up-to-date knowledge of our solar system and the components within it. In groups your learners could then engage in research and produce detailed information about the internal structure of the Sun, Earth and Moon, which will serve to highlight the variation in terms of 'activity' which prevail in these objects and demonstrate the differences between stars, planets and moons. The Sun's effect on all objects in the solar system, and those objects which have extremely long orbital periods (e.g. comets), should be emphasised to illustrate the extent of the Sun's gravitational field and the limits of the solar system. The definition in this unit of 'other solar system' objects and features should be explained as referring mainly to everything apart from the Sun, Earth and Moon. The amount of information for these is now vast and you may wish to deliver just the essential aspects and simply allow learners to develop a PowerPoint of one feature from the list supplied, then collate them. It is important that your learners deal with data correctly, such as distances and diameters, and they should begin to compile a lot of information about the solar system and the methods we use to obtain this information. Learners could then produce a case study of a lander or orbiting spacecraft linked to a specific planetary or fact-finding mission.

For learning aim B, you should emphasise the importance for learners to fully appreciate the health and safety aspects of astronomical observations and all other practical activities that they will carry out. You should focus this on possible eye damage when viewing the Sun and full Moon, giving details to family members about your learners' locations and safe night-time observing. A visit to a planetarium in a local university may help to introduce observations. You can demonstrate telescope construction with simple models and then concentrate on reflectors, refractors and associated ray diagrams. The physics for this section can be quite involved, but you should emphasise the aspect of practical investigation.

You should make use of a list of Earth-based radio and satellite telescopes and text or internet images when discussing observations using wavelengths other than the visible range. Actual astronomical observations and mapping are fundamental to the completion of this unit and to the development of important transferable skills. Show your learners the correct procedure for solar observations using the projection method, and supervise them initially. You should also contact parents or guardians to ensure that out-of-hours observations by learners are conducted safely. Give your learners adequate guidance to ensure that they can identify regions of the sky quickly and to minimise the time spent on observations. Naked-eye observations are sufficient for most of the activities in this learning aim. Your learners must be able to record observational information and data accurately, so you will need to give introductory lessons on angles, celestial coordinates, phases of the moon, etc.



Learners will appreciate their observations much more if they can follow and 'capture' a sequence of sunspots across the face of the Sun over the course of a number of days, for example.

For learning aim C, you will introduce your learners to the practicalities of space flight, spacecraft design, useful spin-offs from space research and the future of space travel. In doing so, this section leaves aside the essential astronomical principles of the unit and concentrates on the fundamentals of space flight. Your learners can begin to develop an understanding of the design aspects required for spacecraft and rockets achieve orbit if you pose the question: 'How can we get into space?' Encourage a group discussion so that you can determine the general knowledge and understanding of your learners. Further develop the group activities to produce a list of important points in the known design of rockets and spacecraft. Use current video footage of working on the International Space Station (ISS) as a means to link the practical work of space research to the difficult conditions faced in a near-zero-gravity environment. Your learners would benefit from a focus into the planned development of a human mission to Mars in order to carry out research into the problems to be overcome weighed against the effort to achieve the goal. This can also lead you to develop a discussion concerning the morality of space flight when the Earth and its inhabitants are facing very difficult circumstances. The contextual nature of this topic should enhance the learning experience by illustrating that the progress made in space flight has had real impact in terms of biological, chemical and physical advances. You can then introduce the wider industrial context. You must ensure sufficient internet access to meet the demands of the research necessary to complete this learning aim, particularly in relation to materials development and commercial space ventures.

For learning aim D, your learners should demonstrate the principles of distance measurement and to report on the techniques used for deep space objects, following initial formal teaching of the principles involved. You will need to explain the various stages in the life of a star and show how these fundamentals help in our understanding of the development and demise of almost all known objects in the Universe. At this point, you may wish to link the life cycle of stars to that of our Sun, you can then introduce the Hertzsprung-Russell (H-R) diagram. Detail how the information in the diagram is related to observed stars, including the Sun.

You could arrange learners into groups and show them clips from different programmes that attempt to explain our theories of the origin of the Universe; they can then discuss all the relevant information to develop a summary. You could also discuss similarities and differences in the summaries further. You can give a number of accounts of the suggested fate of the Universe, asking for a spokesperson from each group to put their point across. Your learners can then make an informed decision as to what they collectively believe will be the eventual outcome and why. This learning aim is likely to be delivered best by a combination of formal lecture, practical task, computer-aided modelling, group discussion, independent research and visits to related educational lectures.

The subject material for this unit is both interesting and challenging, in terms of the concepts, terminology and application of science. Further tuition may be necessary to ensure that the celestial coordinates and star identification are accurately portrayed and that sufficient time is awarded to convey the significance of the Cosmic Microwave Background for supporting the theory of the Big Bang.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the fundamental aspects of the solar system	A1 Features and characteristics of the Sun A2 Features, characteristics and relationship factors of the Earth and Moon A3 Features and characteristics of the inner and outer planets A4 Features and characteristics of other solar system objects	A scientific report and diagrams. Use of terms and numerical values. Presentation document. Outline of features/numerical values associated with Earth and Moon. Diagrams and text information for all planets. Descriptions of smaller components. Case studies of spacecraft encounters.
B Undertake measurement and observation of astronomical objects	B1 Earth-based telescope design and features B2 Space-based telescope design, features and observatories B3 Night sky-mapping and observations B4 Day time observation	Descriptions of important telescopes, optical and radio. Geographical positions. Report on specific telescopes using range of wavelengths. Investigating focal points of concave mirror and convex lens. Practical observation logs. Map of night sky and terminology definitions. Practical observation by projection of sunspot activity.
C Investigate the essential factors involved in space flight	C1 Spacecraft design C2 Practicalities and physics of spaceflight C3 Future of spaceflight and exploration C4 Earth-based applications of space technology	Report on spacecraft materials using specified named vehicles. Conditions for space flight. Maths associated with speed, gravitational forces, re-entry conditions. Case study: PowerPoint spacecraft designs, Moon missions, Mars probes, space stations, international plans.
D Understand the fundamental concepts outlined in astrophysics and cosmology	D1 Principles of star creation D2 Principles of the 'death' of stars D3 Observable characteristics and properties of stars D4 Origin and theories of evolution of the universe and astronomical dimensions	Space spin-offs: Examples of research activities performed by astronauts. Information poster outlining the life cycle of stars. Report of star characteristics linked to star formation and death.



		<p>Detailed H-R diagram aspects.</p> <p>Trigonometric parallax principles outline.</p> <p>Presentation: Origin-end of universe – current theories and evidence explained.</p>
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Assessment guidance

This unit is internally assessed through a number of independent tasks. Each task should cover at least one entire learning aim, and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion. There are four suggested assignments for this unit, which cover the learning aims individually.

All learners must independently generate individual evidence that can be authenticated. The main forms of evidence are likely to be written reports, diagrams and investigative articles. There will also be practical observational work including logbooks, sketches and possibly photographic evidence. Learners should incorporate in-depth research that is corroborated by a fully referenced bibliography.

The use of presentations is important and the forms of evidence should include: slides, preparation notes, script, cue cards, peer assessment records and an observation record. The completion of observation records is to be carried out by the assessor and the learner’s colleagues in placements or part-time work; other departmental staff and laboratory technicians could complete witness statements. Observation records alone are not sufficient sources of learner evidence; the original learner-generated evidence must also support them. Assessors should remember that they are assessing the content of the presentation against the learning aim, and not the skill with which the presentation was delivered.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

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Introduction

Begin by introducing the unit to learners through a group discussion exploring the level and breadth of their subject knowledge to date. Outline, in clear terms, the learning aims of the unit, the content involved and the expectations for learners in terms of independence and group activities.

Learning aim A – Understand the fundamental aspects of the solar system

- Give an introduction to the Earth-Moon system using an appropriate video clip. Insist on notes taken by learners. It may be useful to outline, very briefly, how our current knowledge has developed from mistakes and observations in history. Ask learners to produce a report and diagrams on the Earth-Moon system showing a cross-section of each body and describing surface features, orbits, eclipses and other characteristics.
- Demonstrate the close links between the Sun, Earth and Moon by using appropriate models and video images, outlining the forces involved and their effects on each other. Learners could then produce a PowerPoint presentation that shows the effects of these objects on each other and the cycles of orbits, eclipses and other effects experienced from Earth.
- Explain the processes of nuclear fusion by formal tuition. Include the chemical composition of the Sun and the internal structure. You should outline nuclear fusion in terms of the 'fusing' of protons and the conditions required. Describe the Sun's atmosphere and spectral lines, referring to the principles of emission and absorption and chemical elements. Ask learners to produce a full diagram of the Sun in cross-section, highlighting the internal processes taking place. The Sun's internal processes should be shown clearly and coherently with an accurate explanation of the importance of emission and absorption spectra.
- Our knowledge and understanding of the objects in the solar system changes regularly. The wealth of information makes it difficult to cover the topic in a short presentation, so you should aim to give a very brief overview of key aspects to date. Open the topic to learners, asking them to give full details of the solar system using a variety of presentations including posters, PowerPoint and modelling. All other planets, relevant minor planets, important moons, comets, meteors and outer bodies are to be included. This could be completed in groups and the individual subjects – for example, Jupiter and its moons, Saturn's moons and ring system – may be separated out to compile a whole-class piece of work.
- Give key points on Kepler's laws of planetary motion. Include the ellipse, which you can ask learners to demonstrate themselves using two tacks, a sheet of paper, string and a pencil, the changing velocity of planets using equal area triangles, and the principle that T^2/R^3 ratio is the same for all planetary motions and also for all man-made or natural satellites. This latter law can be shown by asking learners to calculate T^2 and R^3 from known data. Conversions will be expected from years into seconds and from kilometres into metres.
- Introduce some basic information about previous and more recent space probe missions to highlight where our current knowledge has come from. Learners can



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then choose from a suggested list to produce a case study, for example, Voyager 1 and 2, Mars Lander, Giotto, Rosetta/Philae to comet 67P. Learners will develop and refine their research techniques in this activity and learners can voice their findings in group discussion.

- Arrange a visit to a science museum which has a collection of meteorites. Following the visit, ask learners to report on meteor showers, asteroids and both Kuiper Belt and Oort Cloud. This work should be linked to their visit to the museum.

Learning aim B – Undertake measurement and observation of astronomical objects

- You should introduce the topic by using a series of photographs or a PowerPoint display, which shows the wide variety of land-based and space-based telescopes which are currently used. Through formal tuition, introduce the basic principles of reflector and refractor optical types with diagrams that learners should draw accurately. You will then need to outline the main principles of telescopes that do not detect visible light by explaining the differences in wavelength and the images which can be produced. Learners will then identify the different types of telescopes in current use using a report style document and appropriate diagrams. The report will be based on both ground-based and space-based telescope designs. Examples of each type are to be fully described and the mode of operation outlined: reflectors, refractors, radio telescopes, microwave, infrared, ultraviolet, X-rays and gamma rays.
- To enhance learners' understanding, demonstrate the basic method and then ask learners to give a practical determination of focal points for converging and diverging lenses and concave mirror using a twin-hole ray box. If possible, in terms of equipment and time, you could task learners to build a simple Newtonian reflector.
- Practical observational astronomy should be introduced with a visit to a planetarium or similar establishment. You can then make references to the night sky using maps and slide images. You will need to give the mapping of the night sky careful thought and special attention, since many learners will be new to the subject. Suitable maps are to be made available and the coordinates explained carefully, ensuring, by a simple test, that all learners are able to plot the position of an object. The use of iPads to show the current position of constellations may work to good effect at this point. Learners should then be given an opportunity, by night-time observation, to identify a significant number of constellations, various planets and prominent stars, plotting them on their maps and providing coordinates which can then be compared in the next tutorial session. Jupiter, Saturn, Mars, Venus, Mercury, the Moon, Vega, Deneb, Altair, Rigel, Betelgeux, the Pole star, etc. are useful starter objects for this purpose. Constellations will need to be identified by learners using their common and correct names. You will need to comment on the safety aspects of night-time observations and remind learners about the completion of accurate logbook recordings of data over a suitable timescale.
- Ask learners if they have any knowledge of constellations or objects that may only be visible in the southern hemisphere. Give learners a list of a few constellations and stars in response. Attempt to project the celestial equator from a globe of the Earth and illustrate why southern observers see a different night sky. Ask your learners to produce a map similar to that of the northern hemisphere.
- Give a firm, clear warning to learners when introducing practical observations of the Sun, explaining the danger of looking directly at the Sun, with or without optical aids, or looking for too long at projected images. Once the basic method of projection has been demonstrated in the laboratory or in video, and learners have

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practised the method themselves, they should make suitable recordings of sunspot activity over a period of seven days across the face of the Sun. They should use circular templates and accurately record the size of sunspots as drawings. They can then calculate the Sun's possible rotational period. If conditions allow, a transit of Mercury would present a further or alternative opportunity.

- Instruct learners to produce further explanation in a report from their sunspot observational logs. They should be able to estimate the size of sunspots from the known diameter of the Sun based on their observational drawings. There should be some attempt to produce good definition in their sunspot drawings.
- Introduce this next phase of observations with a safety warning about night-time viewing and suitable lighting techniques. Learners must ensure that someone knows where they are when carrying out their observations. You must ask that your learners produce an explanation, in a report, of the passage of a planet(s) or other suitable observable astronomical body in the night sky over a suitable period of time. Their log must include detailed maps showing motion against background stars, coordinates of motion and other relevant labels, such as constellations, stars (with known types/classes indicated), other planets in the field, known galaxies if observable, etc. If learners have access to telescopes or powerful binoculars, they could give observational records of the motion of the four Galilean moons around Jupiter or phases of Venus. Learners could carry out observations of other events, such as eclipses, transits and comets if the phenomena are available. Observations of meteor showers are of limited value, but are interesting. Learners can use photographic evidence for most observations listed.

Learning aim C – Investigate the essential factors involved in space flight

- Show a suitable video clip of a launch of the Apollo Saturn V rocket or Space Shuttle. With audio, these launches are very impressive and give a good starting point for discussion. You may wish to show the launch of Space Shuttle 'Challenger', to enhance the discussion by introducing the real risks of space flight. Ask your learners to research and report, with the aid of a poster, on the general principles of space flight, the forces involved in propulsion of a rocket and general data for fuel, length of 'burn' and mass at lift off. Examples can be taken from known values for Saturn V or the Space Shuttle. You should include the need for 'gimbals' in stability and stages in propulsion, and perhaps ask learners to demonstrate this by attempting to balance a ruler upright on their hands.
- You should use suitable video footage of actual space missions and astronauts in space. This may include early space flight or the ISS. Point out the main aspects that need to be considered at the various stages of the video, then ask learners to present a group report detailing the factors which need to be considered for space flight to be achieved. This will include: data of fuel and stages of sustained lift when overcoming gravitational forces, velocity required for low orbit (escape velocity calculation from Earth and the Moon, for example) and gravitational assist for distance flights; costs involved; implications for human travel – space suit design, micro-gravity environment, radiation zones and psychological aspects of sustained missions.
- Give information on the use of gravity assist for longer distance space flight and introduce the activity as a case study. Your learners can produce a scientific report for a magazine based on an overview of the flights of Voyagers 1 and 2 to the outer planets using a rare planetary alignment and gravitational 'sling-shot'.
- Ask learners to discuss what the present uses of satellites are. Let them know that satellites have a variety of orbital 'heights'. Link the discussion to communication



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and geo-stationary orbits at a distance of 36 000 km, low-earth orbits for Earth research and the ISS. Pose the question: 'What happens to all this machinery when it is no longer needed?' You can illustrate this with the eventual return to Earth and burn-up of Sky-Lab over Western Australia in 1979. Problems associated with the build-up of space debris and the future of space flight can form the basis of a research report entitled 'Plans for clearing unwanted and dangerous pieces of spacecraft'.

- Introduce this topic by asking learners to research and produce a series of posters or information leaflets which outline:
 - the benefits of continued space exploration – tabulated document identifying and explaining the knowledge and applications learned from planetary and space exploration
 - the benefits of space research – tabulated document outlining at least three developments used in everyday life from all the categories listed in the contents section.
- Open a discussion based on 'The future of space flight'. Your learners should produce a variety of views on this topic. You can present a table of items known to have been developed from space technology or developments in the need for new technology in space. Ask your learners to present a well-worded journalistic report-style document which outlines:
 - the main accomplishments of space exploration to date and the impact to society in terms of benefits and costs (human, environmental and financial);
 - a detailed overview of the proposed space missions from all nations involved, manned and un-manned;
 - an appraisal of the difficulties needed to be overcome;
 - the reasons for the missions; and
 - a coherent personal viewpoint on the benefits of the programmes to science, research and human development.

Learning aim D – Understand the fundamental concepts outlined in astrophysics and cosmology

- Outline the key aspects of the Hertzsprung-Russell (H-R) diagram by formal tuition. The importance of the diagram to graphically illustrate the life cycle and characteristics of known stars should be the focus. Ask learners to produce a clear and detailed poster showing this diagram and set a number of questions on the spectral class and luminosity. Give further tuition on the current knowledge relating to the life cycle of stars with masses equal to or smaller than our Sun and those with masses greater than our Sun. Learners must then include this cycle as a diagram on the poster, which they can then compare between groups. It is important to encourage questioning based on the exact sizes and masses of stars and their proposed life cycles. You will need to explain fully the positions of prominent and well-known stars on the H-R diagram and the interpretation of the diagram itself.
- Introduce the methods used to determine distances to stars and galaxies for practical work. Your learners will be investigating the trigonometric parallax method of distance measurement by mathematical means, which can be carried out on a suitable table in a laboratory using trigonometry. There are many worksheets available for this method. Learners should become familiar with the method used and how it relates to the different positions in the Earth's orbit to distant astronomical objects. The work will be evidenced by diagrams and calculations.

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Outline in general terms how Cepheid variable stars or 'standard candles' are used for greater distance measurement. Include also the use of some supernovae explosions such as in the Pinwheel galaxy, which happened in 2011. This event has been well photographed. Mention that a collective approach to distance measurement is called the 'Distance ladder', and that the uncertainties are reduced but increase with distance of the object.

- Ask learners about their understanding of the origin of the Universe to determine the extent of knowledge. Give a timeline and sequence of events from current theory and dispel any misunderstandings which may have been identified in the Q&A session. With the help of video clips, give information for both Steady State and Big Bang theories, emphasising that the latter theory appears to be the preferred model with some slight variations. Make sure to include 'Olber's Paradox', which links the brightness of the Universe to its age. You should then introduce a diagram that outlines the known composition of the Universe. Learners can produce independent reports on descriptions of main theories, discussion on differences and similarities, and an overview of the evidence in support of the main theory with a focus on red-shift and cosmic microwave background.
- Following on from the previous topic, discuss the possible fate of the Universe identifying aspects of the critical density. Present an opportunity for learners to research and summarise this topic as a case study – 'The Fate of the Universe'. Learners should detail the possible outcomes based on density and present a discussion of alternative ideas. You could use a projected time-line from 13.7 billion years ago (the Big Bang) to 9.1 billion years ago (formation of the solar system) to present day to 10 billion years in the future (our Sun becomes a white dwarf) to 10^{150} years in the future (Photon age – Universe reaches low energy state). Assessment could be supported through observation records.
- This entire topic can be finalised with a useful class discussion on the possibilities and the probabilities of 'life' elsewhere in the Universe. You will need to give a definition of life in terms of a life cycle based on carbon. You should also mention how many exo-planets have been discovered and that water, already known to exist frozen on Mars, is a vital ingredient. The principle of discovery of exo-planets can be illustrated using an object moving across a torch beam to show a decrease in light emission. You can encourage learners to present their own views on whether life could exist elsewhere, in the form of a clearly worded essay or newspaper article.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 4: Laboratory Practical Techniques and their Application.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Couper, H *Universe: Stunning Satellite Imagery from Outer Space*, Cassell, 2007 (ISBN: 9781844034376).

This book contains full-colour photographs and descriptions of the solar system and deep space objects from Hubble Space Telescope and other satellites.

Hope, T, *Spacecam: Photographing the Final Frontier*, David & Charles, 2005 (ISBN: 9780715321645).

This book contains photographs and information in co-operation with NASA on space flight, the Universe and Earth's geography.

Kerrod, R and Scott, C *Hubble: The Mirror on the Universe*, David & Charles, 2008 (ISBN: 9780715329238).

This book contains an impressive and inspirational set of photographs of deep space objects from the Hubble Space Telescope.

May, B, Moore, P and Lintott, C *Bang! The Complete History of the Universe*, Carlton Books Ltd, 2007 (ISBN: 9781844422319).

This gives an up-to-date account of our knowledge on the possible creation and the possible end of the Universe with useful photographs, images and timelines.

Moore, P *Philip's Astronomy Encyclopedia*, Philip's, 2002 (ISBN: 9780540078639).

This book contains an A-Z dictionary of terms with coloured images, detailed explanations and star maps.

Journals

British Astronomical Association

This is a bimonthly journal containing relevant observational guides, forthcoming astronomical events, etc.

The Sky at Night (also www.skyatnightmagazine.com)

This is a monthly publication providing useful observational practices and forthcoming events in the night sky.

Videos

www.youtube.com

On YouTube you can find the successful Apollo 8 Saturn V launch, the final launch of Endeavour illustrating the difference in launch of the shuttle to Saturn V, plus the dangers of space flight in the Shuttle Challenger disaster. You can also find ultra-high-definition video from the International Space Station here.

<https://www.youtube.com/watch?v=CiLNxZbpP20>

Video IP1 12 Comet Shoemaker-Levy collides with Jupiter

This video relates to the collision of a comet with an outer planet, outlining our dependence on large planets to protect us from large collisions and also giving evidence of historical collisions.

The Wonders of... collection (*The Wonders of the Solar System, The Wonders of the Universe, The Wonders of Life*) is presented by Professor Brian Cox and available on BBC DVD (2014). These programmes give clear and up-to-date information about important aspects in this unit.

<https://www.youtube.com/watch?v=SGP6Y0Pnhe4>

This is one example of videos about working on the International Space Station (ISS).

Websites

<http://www.wired.co.uk/news/archive/2015-07/28/nasa-4k-views-of-earth-iss>

NASA footage shot on board the ISS showing astronauts experimenting, and views of Earth from space.

www.esa.int

The official website of the European Space Agency.

www.jpl.nasa.gov

Jet Propulsion Laboratory, California Institute of Technology.



Unit 17: Microbiology and Microbiological Techniques

Delivery guidance

Approaching the unit

The emphasis for this unit is on assessed practical work that learners will use to meet the criteria. Your learners will have some experience of this practical work, but you should aim to extend their skills to ensure they have competences that are transferrable to the workplace.

You will need access to a suitable laboratory and equipment for using microscopes and dealing with microbes. As the tutor, you will be involved in ensuring your learners work within health and safety regulations. Your learners must be fully aware they will be observed and assessed during the practical work. Your learners will be expected to present the outcomes of their practical work in an accepted format.

Ideally, work placements will help your learners develop laboratory skills in microbiology, but if this is not possible, then visits or talks from staff involved in the work will help give a vocational context to this unit. This is an exciting unit because of the emphasis on practical work and the development of microbiological skills.


As they do this unit, your learners will be increasingly aware of the role played by microbes in recent outbreaks of very serious epidemics abroad and how easily they can be transmitted globally.

This unit will help your learners to appreciate the opportunities available in not only the NHS but in the many laboratories that supply microbiological services. Your learners will need to be aware that a number of jobs are at degree level but this unit gives a foundation so they can make an informed choice of career. There are many training posts available for technicians who work under the supervision of qualified microbiologists, so job progress is a feature of microbiology. There is also the challenge of working in an environment where microbe mutation and therefore resistance to antibiotics is a constant possibility.

Delivering the learning aims

Learning aim A is assessed along with learning aim B, so you may decide to do the practical work on microbes by using microscopes and then research their structure etc. Whichever approach you use, your learners can work in groups to research the structure, characteristics, classification and replication of micro-organisms. Make sure your learners look at a variety of micro-organisms as suggested in the specifications. You might suggest each group concentrates on a particular group of micro-organisms, but you will then have to arrange for exchange of information between groups. The learners' final reports must be their own individual work, in order to cover all the assessment criteria.

Learning aim B, although assessed with learning aim A, is focused on practical work. The setting up and using of light microscopes and different lenses requires observation to ensure the learners undertake the procedures correctly. This will also include the preparation of slides and mounting of samples using different



techniques. The structure of micro-organisms is explored using a light microscope and an oil immersion lens. Your learners may need reminding about using microscopes. Your aim is to observe them setting up and using microscopes safely and competently in order to demonstrate transferrable skills.

Your learners will need to research other types of microscopes so they are aware of the capacity of these microscopes, plus the advantages and disadvantages in their use. If visits to laboratories with, for instance, an electron microscope are possible, this would aid your learners in their understanding of such machines.

You may decide to do learning aim C prior to learning aims A and B so your learners are familiar with aseptic techniques prior to working with microbes.

For **learning aim C**, which will be assessed alongside learning aim D, your learners will be demonstrating their competences in aseptic techniques in order to culture micro-organisms. This is practical work and you should try to make the laboratory as near to a workplace scenario as you can. For instance, you should insist on laboratory coats being worn and not being removed from the laboratory, and instruct learners that only essential writing materials should be taken into the laboratory, with all bags/coats etc. being left outside. Strict hygiene rules are applied prior to entry. Within the laboratory the same COSHH rules must be applied with learners wearing gloves, eye protection, etc. The usual disinfectant sprays for work benches being used prior to and after work with gloves being disposed of in safety bins and frequent changes of gloves as needed. Obviously, work placement in a microbiological laboratory would be ideal, but wherever the work is carried out, your learners must be observed doing practical work in order to meet the criteria.

Your learners will need to research how commercial laboratories deal with micro-organisms in terms of biocontainment. It will be interesting for them to compare different situations including those in their own laboratories and perhaps also at a local university.

Learning aim D is based on assessment of your learners' work carried out in a laboratory. Group work will be the most efficient and effective way of approaching growth requirement and inhibitors. It would be very time consuming to expect your learners to carry out all the possible experiments. You will probably have to delegate to your groups certain practical work, and then hold feedback sessions. In this way, all your learners will have enough knowledge to meet the criteria.

Again, this aim is based on observation of your learners as they carry out practical work so you must ensure that, even if they work in groups, each learner does demonstrate the skills being assessed in the criteria. Class discussions will be important if your learners are to analyse their data. You will need to give some case studies involving secondary data so your learners can be involved in coming to conclusions about growth factors and their effects.

For this unit, it is expected that practical guidance on what to do will be given to your learners, so there is no need to require methods to be written up. The criteria are focused on your learners competently carrying out the practical work which you have set, being able to report their findings, and undertaking analysis, evaluation and justification.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the importance of microbial classification to medicine and industry	A1 Micro-organisms and infectious agents A2 Classification A3 Micro-organisms in medicine and industry	<p>A research report using any appropriate format that covers four of the listed micro-organisms.</p> <p>Practical work setting up and using light microscopes and oil immersion lenses to look at the structure of micro-organisms. Scientific drawings of specimens, laboratory notebooks and practical write-ups supported by tutor observations. A presentation of their work, which also outlines the uses and limitations of the instruments used when compared to other types of microscopy, including specimen preparation and imaging.</p>
B Undertake microscopy for specimen examination in laboratories	B1 Microscopes B2 Specimen and slide preparation B3 Setting up and using a compound light microscope	
C Undertake aseptic techniques to culture micro organisms	C1 Safety and prevention of contamination in microbial culturing C2 Growth media C3 Inoculation and incubation	<p>Laboratory notebooks recording the practical work done plus observations of practical work by suitably qualified staff. Any parts not covered in practical work can be addressed by research reports.</p>
D Explore factors controlling microbial growth in industrial, medical and domestic applications	D1 Growth requirements D2 Growth inhibitors D3 Measuring microbial growth	

Assessment guidance

Assessment is based on practical work carried out in a laboratory with facilities and equipment for advanced level work. There must be access to microscopes and suitable equipment for working with micro-organisms. The laboratory must comply with all health and safety requirements and risk assessments must be done for every experiment both by the tutor and learner.

Your learners are not expected to give the method details for their experiments; these will be supplied by yourself so their laboratory notebooks should show all their results, analysis, etc. Any alterations your learners made to the method given them should be noted.

For learning aims A and B, the research report must cover all of the micro-organisms listed. Your learners can present the report in a number of forms, such as using annotated diagrams that will cut out long descriptive passages. This same technique could be used for classifying the micro-organisms and detailing their methods of reproduction. Your learners will need guidance on the presentation and detailed discussion on what should be included in their work.

The second part of this assignment focuses on practical work with microscopes and the observation of micro-organisms. These parts of the assignment are assessed by observation of your learners setting up and working with a microscope along with the illustrations produced. You will need to encourage your learners to carry out some research on different types of microscopes and their advantages and disadvantages. You will need to guide your learners on how to present this work.

Learning aim C is assessed as far as possible by observation of practical work. You must expect your learners to observe all health and safety regulations and everybody to carry out risk assessments. Your learners may have some experience of working with microbes but be prepared to do some demonstrations to remind them of the techniques to be used and how to follow the instructions given. Your learners will be following instructions given to them so, as the assessor, you will be concentrating on the competence shown by your learners in preparing growth media, inoculating it and carrying out growth counts. Be prepared to guide your learners via discussion and research about biocontainment measures used in different laboratories.

Learning aim D is assessed as far as possible by observation of practical work. You must expect your learners to observe all Health and Safety regulations and everybody to carry out risk assessments. You will be giving your learners instructions on the experiments to be done regarding factors that affect the growth of micro-organisms. The assessment is by observation, in order to see your learners are working competently at investigating what factors affect the growth in micro-organisms. Your learners can share the data they accumulate from their experiments but you will need to guide their discussions and help them with any analysis. You must ensure each of your learners has sufficient data from their experiments to meet the criteria. You will need to give some secondary data, perhaps set out as a case study, on other research about the factors that affect growth in micro-organisms.

Your learners must use their laboratory notebooks as part of the written evidence of their work. However, writing out the methods again is not required for assessment.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 17: Microbiology and Microbiological Techniques
<p>Introduction</p> <p>Start with a class discussion of what learners understand microbes to be. Are they useful or harmful? Where are they found and what do they look like? Use a spider diagram or flow chart to summarise these first thoughts. You may prefer to start with learning aim B, which is more practically based, before tackling learning aim A.</p>
Learning aim A – Understand the importance of microbial classification to medicine and industry
<ul style="list-style-type: none"> • Group research and discussion to come up with the main classifications of microbes, the characteristics of each of the groups and their methods of replication. • Groups should feed back to the whole class by presenting their work on a whiteboard, for example, so everybody can note it. • Encourage class discussion to get a consensus about classifications and their characteristics, and how replication helps in this classification. • Discuss with your learners the best methods of presenting this information – flow charts/diagrams/verbal presentation (assess content not presentation skills, and you will need to have some form of written notes to back up a presentation).
Learning aim B – Undertake microscopy for specimen examination in laboratories
<ul style="list-style-type: none"> • Give a demonstration of the parts of a microscope and the correct way to set one up and use it with prepared slides. You could give them a suitable handout to use as they practise the skills before an actual observation. • Encourage learners to practise the correct setting up and use of a microscope including using an oil immersion lens. • Learners should practise observation of slides of micro-organisms and recording what is seen using appropriate diagrams. • Carry out assessment observation of your learners setting up, using and recording their observations with a microscope. • Learners should practise specimen and slide preparation. • Carry out assessment observation of specimen and slide preparation. • Ask your learners or groups to research light, phase contrast and electron microscopes and draw up a table of their characteristics, advantages and disadvantages. • Use these tables as a discussion point with the whole class, making sure they understand the different techniques and consequent implications associated with each type of microscope. Details of the structure and workings of microscopes are not required unless they are needed in order to meet the criteria.
Learning aim C – Undertake aseptic techniques to culture microorganisms
<ul style="list-style-type: none"> • Give a demonstration on the preparation and inoculation of different growth media.

Unit 17: Microbiology and Microbiological Techniques

Emphasise safety procedures and as part of the class discussion after the demonstration, build up a visual representation of safety procedures that learners must follow.

- Learners should carry out research on classifications in biosafety, and safety procedures including levels of safety and biosafety cabinets.
- They should then research different growth media used in microbiology.
- Organise group/individual work, following procedures given to your learners, to: prepare growth media; inoculate media following regulations; and incubate the media following regulations.
- Carry out an assessment of preparation and inoculation of growth media using aseptic techniques.
- Carry out an assessment of measuring microbial growth. This may be done after your learners' own media have shown growth, or you may prefer to have more standardised media prepared with growths for your learners to measure.
- Encourage group/class discussions about the practical work done and the outcomes. Summarise these outcomes.
- Encourage group/class discussions about their understanding of biocontainment prior to carrying out research.
- Visits to microbiology laboratories/work placement/visiting speakers can be used at any time during the assignment.
- Learners should decide, with guidance, how to present their results and conclusions from their experiments. They will also need to present their research on biocontainment which includes their own laboratory compared to those in other establishments. Your learners must also evaluate their own aseptic techniques.

Learning aim D – Explore factors controlling microbial growth in industrial, medical and domestic applications

You should give a demonstration/discussion on the following:

Growth requirements

- Nutrients could include carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, water, minerals, trace elements.
- The need for light, temperature preferences.
- Ability to thrive in carbon dioxide-loaded atmospheres.
- Growth surfaces.
- pH level preferences such as acid/alkaline or neutral.
- You will need to guide learners about the practical experiments to be done. There will not be time for every learner to do every experiment. You will need to discuss with your learners how the work will be divided up and the use of class discussions to summarise the outcomes. Observation of the learners' practical work is part of the assessment criteria.

Growth inhibitors

- Irradiation – set this as a theory research for your learners and for class discussion.
 - Antimicrobials – antibiotics, antivirals set as a research project, or learners can use household products that claim to be antimicrobial products.
 - Antifungals – set this as a research project or learners can use household



Unit 17: Microbiology and Microbiological Techniques

- products that claim to be antifungal products.
- Disinfectants such as household products.
 - Sterilisation procedures: ask the groups to do research on this topic and relate it to procedures used in food preparation, operating theatres, etc.
 - Osmotic potentials in strong salt/sugar solutions as preservatives: use class discussion in addition to practical work to relate this to the use in preserving food stuffs etc. in industry.
 - Controlled atmosphere for food preparation.
- You will need to guide learners about the practical experiments to be done. There will not be time for every learner to do every experiment. You will need to discuss with your learners how the work will be divided up; use class discussions to summarise the outcomes. Observation of the learners' practical work is part of the assessment criteria.
 - Give demonstrations on:
 - colorimetry for fungal, bacterial and viral growth showing turbidity
 - haemocytometer such as in yeast cell counts
 - mycelial discs measured as increase in diameter or dry mass
 - counting bacterial colonies and use of serial dilution.
 - Learners should carry out group/individual work, following procedures given to them, to practise some of the techniques shown in your demonstration.
 - Group work on case studies can be set around the topics mentioned above. This will help your learners to apply the knowledge gained from their practical work.
 - Give case studies that include secondary data about growth inhibitors for your learners, to discuss in relation to their own findings.
 - Give guidance to your learners about the presentation of their work. Where instructions about practical work were given to your learners, they should not need to submit them as part of the assessment.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 5: Principles and Applications of Science II*
- *Unit 8: Physiology of Human Body Systems*
- *Unit 11: Genetics and Genetic Engineering*
- *Unit 12: Diseases and Infections*
- *Unit 20: Biomedical Science.*

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Alexander, SK and Strete, D *Microbiology: A Photographic Atlas for the Laboratory*, Benjamin Cummings, 2000 (ISBN: 9780805327328).

Deacon, JW *Fungal Biology*, 4th edition, Wiley-VCH, 2005 (ISBN: 9781405130660).

Lammert, JM *Techniques for Microbiology: A Student Handbook*, Benjamin Cummings, 2006 (ISBN: 9780132240116).

Madigan, MT, Martinko, JM, Bender, KS, Buckley, DH and Stahl, DA *Brock Biology of Microorganisms*, 12th edition, Pearson, 2014 (ISBN: 9781292018317).

Taylor, J *Bath Advanced Science – Micro-organisms and Biotechnology*, 2nd edition, Nelson Thornes, 2001 (ISBN: 9780174482550).

Waites, MJ, Morgan, NL, Rockey, JS and Higon, G *Industrial Microbiology – An Introduction*, Wiley-Blackwell, 2001 (ISBN: 9780632053070).

Journals

Biological Sciences Review

Microbiology Today



Websites

www.bbsrc.ac.uk

The Biotechnology and Biological Sciences Research Council is a UK Research Council and NDPB and is the largest UK public funder of non-medical bioscience. It predominantly funds scientific research institutes and university research.

www.britmycolsoc.org.uk

The British Mycological Society, providing useful educational resources on fungi.

www.microbeworld.org

Microbe World explores the world of microbes with vivid images and descriptions. Learn about microbiology, what microbiologists do, how they do it, and current topics.

<http://www.microbiologysociety.org>

The Microbiology Society is a membership organisation for scientists who work in all areas of microbiology. For tutors and technicians to refer to.

<http://www.microbiologyonline.org.uk/teachers>

The Microbiology Society online teaching resources.

www.saps.plantsci.cam.ac.uk

Science and Plants for Schools (SAPS). For both tutors and students up to 'A' level standard – ideas and references.

www.virology.net

Online catalogue of virus pictures and links to other virology websites.

www.ncbi.nlm.nih.gov/pubmed/10656352

Abstract of an article on antimicrobial activity of home disinfectants.

www.bbc.co.uk/education

Bitesize offers good classroom resources, with links to BBC Science, BBC Lab UK and BBC Nature.

You can also use search engines, entering the following terms:

- antibacterial efficacy of disinfectants
- agar-disc diffusion method
- disinfectant efficacy testing procedures
- surface effectiveness test.



Unit 18: Industrial Chemical Reactions

Delivery guidance

Approaching the unit

It is essential to set this unit in the context of chemical industry from the start. Learners need to understand the scale of industrial chemical processes and how they are controlled to ensure the optimum product yield, minimum costs and maximum safety. If you cannot arrange a visit for the learners, visit chemical plants yourself to build a portfolio of examples to use with learners. If your hosts allow it, take photographs to illustrate your points. Obtain as many relevant photographs and videos as possible. Encourage your learners to find out and record industrial applications of physical chemistry concepts from the beginning. Where possible use industrial speakers (for example, production managers) and show videos.

This unit has three learning aims that deal with aspects of physical chemistry (thermodynamics, rate and chemical equilibrium). The fourth deals with how industry uses the concepts when operating chemical processes. The skill of applying knowledge to real situations will be useful to learners, whatever progression route they choose from this course. Although there is a focus on the industrial application of physical chemistry, the way the unit is written also allows you to ensure that learners have the theoretical knowledge that they will need to be able to study higher education chemistry courses.

Delivering the learning aims

Learning aim A should develop learners' confidence in carrying out calculations using their own data and data from standard data books or the internet. Learners will measure and calculate enthalpy changes as part of learning aim A. It is important to introduce the need to use the heat from exothermic processes to keep them under control. Learners will need to understand applications of heat exchange for learning aim D. As in other units, you should encourage learners to identify specific and realistic error sources in experiments and to estimate the effect on the final, calculated result of changes to measurements. Learners should be prepared for working backwards from a literature value of an enthalpy change to plan an experiment to measure it. Learners will learn about entropy, Gibbs energy and how to predict whether a reaction is feasible under standard conditions.

The study of reaction kinetics is developed at every level from level 2 through to degree level. Understanding kinetics allows mechanisms to be established which allow industrial chemical reactions to be controlled better – for example, faster, slower or more of a particular product. **Learning aim B** builds on the understanding of the factors affecting rate of reaction gained at level 2. All learners should be able to explain those factors in the context of the reactions studied, in terms of collision theory, activation energy and the distribution of molecular energies. You will introduce learners to rate law expressions for calculating rate of reaction. Learners will understand not only why reaction rate increases with temperature but will also be able to calculate activation energy for a reaction from the rate constants at different temperatures.

Many industrial chemical reactions are equilibrium reactions. When introducing **learning aim C**, explain that, to maximise the yield, the operators may have to alter the conditions. An understanding of how factors such as changes in concentration, pressure, temperature and presence of a catalyst affect equilibrium is essential. You will need to design activities so that learners understand that:

- once the reagents are mixed, it takes time for the rates of the forward and backward reactions to become equal
- the concentrations do not change after equilibrium is established
- the concentrations of reactants and products do not need to be the same at equilibrium – it all depends on the equilibrium constant
- the equilibrium constant is a way of formalising how much the balance of products and reactants is in favour of the products of a reaction (learners understand the significance of the expressions for equilibrium constants better when they have values to substitute into the expressions they have written)
- altering concentration, pressure and temperature disrupts equilibrium
- the equilibrium constant depends on temperature – increases with temperature for endothermic (forward) reactions
- changes to concentration and pressure (at constant temperature) initially speed the relevant forward/backward reaction but equilibrium will be re-established and the equilibrium constant will have the same value
- if you continuously remove a product, the reaction producing that product will be faster than the reverse reaction. Equilibrium will not be re-established. More and more product will be produced.

Use industrial or other real examples to illustrate your explanations. The Haber Process, the Contact Process and the production of ethanol by hydrating ethene are examples of industrial equilibrium reactions. Learners may already be familiar with the bicarbonate buffering system in the blood if they have studied acid/base equilibria in Unit 13:



This equilibrium reaction is also of relevance to global warming.

It may be useful to explain acid/base equilibria so that learners may investigate the effect of adding small amounts of H^+ (for example, in the form of hydrochloric acid) or OH^- (for example, at sodium hydroxide) to a weak acid.

The Haber Process, Contact Process and sulphuric acid production, production of ethanol from ethene and synthesis of methanol are suitable industrial reactions on which to base much of the **learning aim D** assignment work, since all involve equilibrium processes (learning aim C), consideration of factors affecting rate (learning aim B) and also thermodynamic factors (learning aim A). The Solvay process, production of nitric acid and phosphoric acid, catalytic cracking of petroleum products may also be of relevance. Fluidised bed technology is an example of making use of increased available surface area for reaction and heat exchange due to the small particle size and the continuous particle movement. You must give learners the opportunity to apply the knowledge gained from learning aims A, B and C.



Learners should only attempt assignments once they have all the skills and knowledge that they will need to achieve the criteria, of which they are capable. Give your learners different models for taking notes so that they can find a method that suits them. They will need to use material from the teaching and learning sessions that prepare them for assessment.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Investigate chemical thermodynamics in order to understand spontaneous reactions	A1 Enthalpy changes A2 Entropy and Gibbs energy	Observation reports of measurement of enthalpies of reactions plus completed worksheets from the practical activities, discussion of the assumptions made, evaluation of the sources of error and calculations of expected values. Worksheets containing calculations, involving enthalpy changes, entropy changes, Gibbs energy and equilibrium constant.
B Investigate factors affecting rate of reaction in order to understand collision theory	B1 Factors affecting rate of reaction	A workbook containing calculations of rates of reaction, the results and conclusions of experimental investigations into the factors affecting rate of reaction and explanations of the results of these experiments. Worksheets showing the analysis of the results of initial rate experiments and calculations of activation energy from data on rate constants at different temperatures.
C Investigate chemical equilibrium in order to understand the extent to which reactions go to completion	C1 Chemical equilibrium	Worksheets describing the features of equilibrium reaction, showing calculations of K_c and describing/explaining the effects of changes in concentration, pressure, temperature and the presence of a catalyst on equilibrium, and analysis of the effects of temperature on equilibrium constant.
D Understand how industry controls chemical reactions, using physical	D1 Physical chemistry concepts of industrial importance	An explanation of the reason for three specified features of the operation of an industrial process. An explanation of



chemistry concepts		three further factors that may be altered on the basis of physical chemistry concepts. Analysis of other industrial processes in terms of the physical chemistry concepts involved.
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Assessment guidance

In this unit, the learners will carry out practical work in order to generate data for interpretation (enthalpy changes and rate of reaction). The emphasis is less on developing practical proficiency than in practical units, like Units 2, 4 and 19. You must give learners at all levels a good idea of the attention to detail needed in presenting calculations, the need for specificity in considering the quality of results and the breadth and depth required in descriptions, explanations, discussions and analyses. Exercises carried out to allow learners to practice their presentation and analytical skills, and ability to calculate, should not be duplicated in the assessment activities.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 18: Industrial Chemical Reactions

Introduction

Introduce the unit by showing a presentation involving photographs and videos of chemical plants relevant to the work. Introduce the need to take notes in a personally useful style from the start of the unit. Mention aspects of all learning aims briefly. Learners should have the opportunity to carry out brief research or have discussions on selected topics throughout.

Learning aim A – Investigate chemical thermodynamics in order to understand spontaneous reactions

Learners will spend considerable time on the assessment activities. Develop the ability to carry out calculations associated with enthalpy changes and the skills needed to present work well.

- Measuring enthalpy change:
 - Carry out a quiz to revise reaction profiles for enthalpy changes involving exothermic and endothermic reactions and any practical work on enthalpy changes undertaken previously.
 - Learners should discuss why knowing about enthalpy changes is important to industry.
 - Learners could do a differentiated worksheet based on $\text{heat} = m c \Delta T$.
 - Give learners a value of the standard enthalpy change for displacing copper (II) ions by iron (II) ions.
 - Lead learners through the planning of an experiment to measure the above enthalpy change by the addition of excess iron filings to a known volume copper (II) sulphate in solution.
 - Learners should carry out the practical work for the $\text{Cu}^{2+}_{(\text{aq})} + \text{Fe}$ experiment.
- Processing the results of the $\text{Cu}^{2+}_{(\text{aq})} + \text{Fe}$ displacement reaction:
 - Explain to learners how to plot temperature against time for the reaction, extrapolating back to zero time to get the accurate highest temperature on which to base their value of ΔT .
 - Learners should calculate the enthalpy change per mole for their experiment.
 - Explain how to present results clearly. Learners should comment on the strengths and weaknesses of a classmate's presentation and then improve their own presentation of calculations.
 - In small groups, learners should discuss how well results agree within the class and with the standard value, supplied by you, and comment on sources of error. Encourage learners to present the outcomes of their discussion in a specific and quantified way. Learners should calculate the results that they would get using a different value of ΔT and evaluate how likely it was that their values were inaccurate. The results should be in reasonably close agreement because the reaction is happening in the water which is absorbing the heat. Ensure that learners have considered that. You could suggest an alternative way of carrying out the experiment – in a copper beaker, sitting in a known volume of water in

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an outer vessel and get learners to speculate on whether the results would be higher or lower than their own experimental results.

- Using data to perform calculations involving enthalpy changes:
 - Learners should use standard enthalpy of formation data to calculate the standard enthalpy changes for a range of reactions. They could also calculate the standard enthalpy of formation for a substance, given the enthalpy change for a reaction and the enthalpies of formation for the other substances. Ensure that learners are using a clear and appropriate way of presenting their work. You should prepare a differentiated worksheet for calculations that the learners will find useful when carrying out their assignment work.
 - Discuss why enthalpy changes are important to industry.
- Estimation of enthalpy of formation from bond enthalpies:
 - Explain average bond enthalpies and demonstrate how to calculate enthalpy of formation from these values.
 - Discuss the reliability of these values with the learners.
 - Learners should practice the above calculations by working through a differentiated worksheet. Examples that are more complex may involve values for the enthalpy of vaporisation and comparisons with literature values or could involve finding a value of average bond enthalpy value where the enthalpy of formation was one of the pieces of supplied data.
- Entropy:
 - Introduce entropy as a measure of disorder.
 - Show learners how to calculate the standard molar entropy changes from values of standard molar entropy for individual substances. Lead learners to relate the values for the entropy for reactions to the degree of disorder in the reactants and products.
 - Learners should carry out some calculations involving
 - $\Delta S^{\circ}_{\text{reaction}} = \sum S^{\circ}_{\text{products}} - \sum S^{\circ}_{\text{reactants}}$
- Gibbs energy:
 - Introduce Gibbs energy and how change in Gibbs energy is related to changes in enthalpy and entropy changes. Explain the condition for a feasible reaction as a negative change in Gibbs energy, how to calculate ΔG° from ΔH° and ΔS° . You will need a good source of thermodynamic data.

Learners should work through a differentiated worksheet based on the equation $\Delta G^{\circ} = \Delta H^{\circ} - T \Delta S^{\circ}$, including rearrangement of the equation and calculation of the temperature at which a reaction may become feasible if ΔH and ΔS do not vary much with temperature.

- When learners have had sufficient time to acquire the knowledge, skills and understanding for this learning aim, they should attempt the assignment.

Learning aim B – Investigate factors affecting rate of reaction in order to understand collision theory

Introduce the topic in terms of industry's need to know how rate of reaction is affected by various parameters so that it can speed up or slow down reactions. Wherever possible, give examples of industrial relevance.

- Collision theory:



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- Working in pairs, learners should complete a worksheet that revises the effect of particle size, concentration, temperature and presence of a catalyst on the rate of reaction. (For example you could ask, '2 mol dm⁻³ hydrochloric acid is added to marble chips of average width 2 mm and 5 mm. Which will react faster? How could you prove this?')
- Explain collision theory in general terms and then go through each of the four factors, using collision theory, reaction profiles and the spread of energies of reacting particles to explain the effects of the factors on rate. Learners should be led through the explanations and involved throughout. For example, if you explained the effect of decrease in particle size, get the learners to give an explanation of increase in particle size. Stress the importance of presenting the explanations well. Ensure that you have explained homogeneous and heterogeneous catalysts.
- Calculating rate and order of reaction:
 - As shown, learners should calculate rate and initial rate of reaction from concentration/time graphs. Lead learners to deduce the units of rate of reaction.
 - Present learners with tables showing direct proportion between initial rate and concentration (first order), proportion between initial rate and concentration squared (second order) and constant initial rate, no matter what the concentration is (zero order). Deduce the units of the first, second and zero order rate constants from the rate expression – for example, Rate = k[A₀] for a first order reaction where k has units of s⁻¹.
 - Present a straightforward example of initial rate for reactions involving two or three reactants, where you work out the order with respect to each reagent, the overall order, the rate expression and then calculate rate constant.
 - Learners should work through a differentiated worksheet with straightforward and more complex examples of the type of problem described above.
- Arrhenius equation:
 - Explain the basis of the Arrhenius equation in both the exponential and logarithmic forms. Describe the graphical relationship between ln(k) and 1/T. Demonstrate calculations to obtain the activation energy.
- Learners should work through examples, calculating activation energy. This could also include examples of finding rate constant and temperature for very able learners who have good algebraic skills.
- When learners have had sufficient time to acquire the knowledge, skills and understanding for this learning aim, they should attempt the assignment.

Learning aim C – Investigate chemical equilibrium in order to understand the extent to which reactions go to completion

In this learning aim, ask challenging questions to ensure that learners have not picked up any misconceptions.

- Introduction to equilibrium:
 - Introduce equilibrium with a game involving coloured sticky notes. Yellow and pink together is the product of reaction of separate yellow and pink notes stuck to a whiteboard. You can begin with the separate notes. One person will be responsible for combining them, another for separating them. An equilibrium will be established. At equilibrium, there will be separate reactants and product in the mixture at any time. The rate of making the compound will be the same as

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- for breaking it up. The reaction will continue to happen.
- Use videos and animations to illustrate what happens to the concentration of reactants and products – starting with products or starting with reactants. Introduce industrial examples of equilibrium reactions.
 - Learners should make notes about the characteristics of equilibrium reactions and industrial examples.
 - Introduce equilibrium constant and how to write the expressions for K_c and K_p .
 - Learners should complete a differentiated worksheet where they write expressions for finding K_c and deduce units and substitute values for concentration into the expressions. This should include more complex examples where learners may have the total volume of the reaction vessel or solution and the number of moles of each reagent. More advanced learners should have the opportunity to rearrange expressions.
 - Show learners the equation that relates equilibrium constant to standard change in Gibbs energy: $\Delta G^0 = -RT \ln K$ which means that $K = \exp(-\Delta G^0/RT)$. (So a reaction that has a huge negative standard Gibbs energy will have a very large equilibrium constant. A reaction with a huge positive standard Gibbs energy will have a very tiny equilibrium constant.)
 - Effect of changes of concentration on equilibrium:
 - This is difficult to explain. It may be worth going back to the sticky note example – learners can discuss it and think it through. Learners need to understand that equilibrium constant stays the same at constant temperature. Adding reactants or taking product away means that the reaction is no longer in equilibrium. The forward reaction speeds up and the backward reaction speeds up and so on until equilibrium is re-established. The amounts of reactants and products will be different – but the equilibrium constant will still be the same. (It may be possible to illustrate this for buffer systems if the learners have done Unit 13. Adding hydroxide to a weak acid solution uses the small amount of hydrogen ions present due to dissociation of the acid. More acid dissociates as a result. It is possible to titrate a weak acid with hydroxide until effectively all the acid has dissociated.)
 - You should guide learners about the level of detail/clarity expected in a description of the effect.
 - Lead learners to deduce that removing product from an equilibrium reaction will cause more product to be made.
 - Effect of pressure, catalyst and temperature on equilibrium:
 - Introduce the rule that the reaction that produces fewer molecules will be favoured by high pressure/the reaction which produces more molecules will be favoured by low pressures.
 - Learners could work through a series of examples, predicting which reaction will be favoured (forward or backward) by an increase in pressure and whether increasing pressure will increase/decrease/have no effect on yield. Once that is understood, they could consider examples where they have to predict the effects of either raising or decreasing the pressures.
 - Explain the effect of catalyst on equilibrium.
 - Explain the effect of temperature in terms of the endothermic reaction (forward or backward) being favoured by increases in temperature.
 - Learners could work through examples describing increases or decreases in



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temperature of a range of reactions and predicting the change in equilibrium yield and to explain mathematically why equilibrium constant increases for reactions whose forward reaction is endothermic/decreases when the forward reaction is exothermic.

- Learners could research industrial equilibrium reactions where the conditions are altered to produce more product in a realistic time frame (Haber Process, Contact Process and hydration of ethene to produce ethanol). Learners should not be producing assessment evidence at this stage.
- When learners have had sufficient time to acquire the knowledge, skills and understanding for this learning aim, they should attempt the assignment.

Learning aim D – Understand how industry controls chemical reactions, using physical chemistry concepts

Since this learning aim is assessed by learners applying their knowledge and understanding, you should try to find a balance between leading learners into how they may apply what they have learned without giving the learners the answers to the questions that will be in the assignment.

- Explain the use of heat exchangers. Involve learners in discussions.
- Explain fluidised bed technology and outline its applications. Videos are useful here. Learners may work through a worksheet that will allow them to understand the important concepts.
- Learners should research a list of industrial reactions, taking notes as they carry out the research. Introduce the idea of control of industrial reactions by posing questions that learners may answer by carrying out research – give an example of:
 - particle size being altered
 - use of a catalyst
 - temperature being optimised
 - concentration being optimised
 - pressure being optimised
 - use of heat exchangers.
- When learners have had sufficient time to acquire the knowledge, skills and understanding for this learning aim, they should attempt the assignment.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

Unit 5: Principles and Applications of Science II gives learners an introduction to calculations involving enthalpy changes.

This unit also links to:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 4: Laboratory Skills in the Workplace.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Curtis, C., Scott, D. and Murgatroyd, J., *Edexcel AS/A Level Chemistry Student Book 2 + Activebook: Student Book 1*, Pearson Education Limited, 2015 (ISBN: 978-1447991168).

Curtis, C., Scott, D. and Murgatroyd, J., *Edexcel A Level Chemistry Student Book 2 + Activebook*, Pearson Education Limited, 2015 (ISBN: 978-1447991175). Both of these student books cover some of the topics in Units 13 and 18.

Hill, G. and Holman, J., *Chemistry in Context: Laboratory Manual*, 5th edition, Nelson Thornes Publishers Ltd, 2001 (ISBN: 978-0174483076). This contains details of practical work that will be useful, not only for Unit 18 but also for Units 13 and 19.

Hill, G. and Holman, J., *Chemistry in Context*, 6th revised edition, Nelson Thornes Ltd, 2011 (ISBN: 978-1408514962). Excellent reference for harder topics which need more detail and explanation.

Lister, T. and Renshaw, J., *AQA Chemistry A Level Year 1*, 2nd edition, Oxford University Press, 2015 (ISBN: 978-0198351825). Contains material on enthalpy changes and equilibrium.

Lister, T. and Renshaw, J., *AQA Chemistry A Level Year 2*, 2nd edition, Oxford University Press, 2015 (ISBN: 978-0198357711). Contains material on kinetics, equilibria and thermodynamics.

Videos

<http://www.ineos.com/intv>

This is a series of videos about the operation of a company heavily involved in the chemical industry. Learners will get the chance to see the chemical plant that is featured in these videos.

<https://www.youtube.com/watch?v=MLJizTuwqVA>

This is quite a good introduction to heat exchangers.

https://www.youtube.com/watch?v=cmm5R_km4Kk

This explains fluidised bed combustion.



<https://www.youtube.com/watch?v=8n78CDI3GoU>

This video shows a fluidised bed combustor on a laboratory scale.

https://www.youtube.com/watch?v=uMkzxV_y7tY

This video outlines ammonia production at a BASF plant.

<https://www.youtube.com/watch?v=8LriocEzpC0>

This video about an ammonia plant has many views of the plant, although it is quite old.

<https://www.youtube.com/watch?v=Z9nfbVh5Wzk>

This video presents an introduction to the use of thermodynamics in the chemical industry.

Websites

<http://www.nationalstemcentre.org.uk/dl/74a55fcae715c96c0b84940ceb72a0235ff8619e/31413-10545-Nuffield%20Advance%20Science%20Book%20of%20Data.pdf>

National STEM Centre and Nuffield Foundation. The website has links to lots of science resources. This particular resource is a collection of standard thermochemical data which is very useful for learning aim A. Despite the standard state involving a pressure of 1 atmosphere rather than 1 bar, the data are self-consistent and useful.

<http://www.chemguide.co.uk>

Chemguide: Jim Clark. Although this website is aimed at AS and A level learners, it contains explanations of the topics that are broader than required for particular syllabi and thus targets the BTEC content effectively.

<http://www.essentialchemicalindustry.org/index.php?start=1>

CIEC, Chemistry Department, University of York. The central resource is a book about the chemical industry which is updated and is available online. This site explains how the material may be used and gives links to all the chapters (Introduction, Industrial Processes, Materials and Applications, Basic Chemicals, Polymers, Metals). It contains a great deal of material which learners will find relevant to the research for their assignments.

<http://www.rsc.org/learn-chemistry>

Learn Chemistry: Royal Society of Chemistry – links to resources relevant to the topics in the unit.

<http://preparatorychemistry.com>

Preparatory Chemistry: An Introduction to Chemistry by Mark Bishop. This contains links to eBook chapters on acids and bases and on oxidation and reduction.



Unit 19: Practical Chemical Analysis

Delivery guidance

Approaching the unit

This unit will extend learners' knowledge of analytical techniques and the expertise gained will prove to be useful in laboratory careers and in higher education courses. Learners will learn more about sample preparations, the use of standards, titration and ultraviolet/visible analysis at a fixed wavelength. Learners will use a range of spectroscopic and chromatographic techniques. You should try to relate the topics to practice in industrial, university and health service laboratories where possible.

Delivering the learning aims

Samples, analysed in industrial or in hospital laboratories, are not simple compounds or solutions. The analytes are present along with a range of other components – in a matrix. The examples of analyses selected in **learning aim A** are of analytes (Cu , HCO_3^- , Fe^{2+}) within relatively simple matrices (brass, bottled water and iron tablets respectively) which therefore enables learners to discuss the extent to which the presence of other matrix components may affect the analysis and the greater range of sources of error. Learners will standardise titrants against primary standards and explore the reasons for using secondary, rather than primary standards in analyses.

Learners used simple colourimetry, involving coloured transition metal solutions, in Unit 2. As part of **learning aim B**, you will select at least two applications of the Beer-Lambert Law that will extend the learners' knowledge. All centres are likely to be able to give learners the experience of an analysis involving addition of a colour reagent to a colourless reagent and of the greater sensitivity to be gained when ammonia solution is added to solutions containing Cu^{2+} . Learners may carry out these two types of Beer-Lambert Law application using simple colourimeters if your centre does not have an ultraviolet-visible spectrometer. Ultraviolet-visible spectrometers have become more affordable, however. It is possible to determine the concentration of a number of organic analytes and of nitrate using the Beer-Lambert Law with wavelengths in the ultraviolet region. If your centre does not have an ultraviolet-visible spectrometer, it should be possible to obtain specimen results from another centre or from a local university. Similarly, you may also use quantitative infrared spectroscopy, using a solution cell, at your own centre if you have the equipment or team up with another centre or a university laboratory to obtain results.

Learning aim B also includes joint structure elucidation of organic compounds. However, some level 3 learners, operating at pass level, may not be able to combine the information from the different techniques. You should introduce each of the techniques, used in joint structure elucidation of organic compounds, separately to allow learners to explore the information that may be obtained from each. You should carefully select simple examples that give pass learners the opportunity to apply the required knowledge for each type of information. All learners should be able to use % elemental composition and a mass spectrum to work out the empirical and molecular formulae of simple compounds. Given the infrared spectra of an alkane, alkene, alcohol, ester, aldehyde, ketone and

carboxylic acid, all learners should be able to work out which is which from the key peaks. Introduce learners to the practical aspects of infrared spectroscopy that they are likely to encounter at work or on a higher education course. Focus on the interpretation of NMR spectra, rather than the instrumentation. All learners should be able to identify the number of protons or carbon atoms in chemically equivalent environments and therefore be able to predict the number of unresolved peaks, their relative areas and approximate chemical shift. This will allow them to match simple spectra to displayed chemical formulae. Explain simple splitting patterns.

You could work through some examples of joint structure elucidation with learners, leading them through the process of determining empirical and molecular formulae and possible displayed formulae. Lead them to rule out some possibilities by using infrared spectroscopy and lead them to predict the appearance of the ^1H and ^{13}C NMR spectra and therefore rule out other possible structures. Merit and distinction learners will be able to correctly identify structures or identify possibilities, between which it is not possible to distinguish further. Distinction learners will be able to explain the structure elucidation process in detail.

To deliver **learning aim C** effectively, you should have links with an organisation/organisations that use gas chromatography (GC) and high performance liquid chromatography (HPLC). You should arrange for your learners either to use these instruments themselves or to see the instruments in operation. You will need to have examples of GC and HPLC chromatograms for the learners to interpret. You should have available a range of analytical chemistry textbooks which either include GC and HPLC or target the techniques specifically. Learners should use these and the internet in order to research the instrumentation and the applications of the techniques. Learners must know how to obtain qualitative and quantitative data from chromatograms and how to optimise retention time.

Visiting industrial, hospital and university laboratories will show learners the importance and relevance of the analytical techniques included in this unit. Prepare the host for these visits by discussing the unit and optimising what the learners are able to see and experience. It should be possible for learners to gather information to help with the assignments for other units on their visit(s).

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Investigate quantitative analysis on the components of matrices to determine their composition	A1 Quantitative analysis of three products	Portfolio of method sheets and calculated results for the three analyses. Report comparing 'primary and secondary titrimetric standards', analysis of specific errors and how accuracy may be affected by analytes being part of a matrix.



<p>B Investigate spectroscopic techniques to identify compounds and determine concentrations</p>	<p>B1 Beer-Lambert applications</p> <p>B2 Organic structure elucidation</p>	<p>Portfolio of method sheets, calibration graphs and calculated results. Completed exercises on use of percentage composition and mass spectrometry to determine molecular formula, evidence of identification of the class of compound, giving rise to particular infrared spectra, matching ^1H and ^{13}C NMR spectra to structural formulae of simple organic molecules. An account of how two unknown organic compounds have been identified from their percentage composition, mass spectra, infrared spectra and ^1H and ^{13}C NMR spectra.</p>
<p>C Investigate chromatographic techniques to identify components and determine the amounts present in samples</p>	<p>C1 Gas chromatography (GC)</p> <p>C2 High-performance liquid chromatography (HPLC)</p>	<p>Description of how the techniques GC and HPLC work. A portfolio of qualitative and quantitative interpretation of chromatograms and peak area results for HPLC and GC. A report describing how an HPLC method would be developed and how either an HPLC or GC procedure would be modified to give optimum separation of peaks.</p>

Assessment guidance

Give learners the opportunity to gain the required knowledge and competence before the assessment activities take place. Learners will require several teaching sessions in order to complete the assessment activities. Plan these sessions so that learners have enough time and opportunity to achieve all the criteria, of which they are capable.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 19: Practical Chemical Analysis

Introduction

Learners should be familiar with the need to record potentially useful notes and experimental details. Issue a laboratory notebook and explain that it has to be used to keep a record of facts, discussions and experiments carried out that may prove to be useful for the assessment activities. Outline the three learning aims.

Learning aim A – Investigate quantitative analysis on the components of matrices to determine their composition

You could develop the key concepts that the learners will need as individuals in the assessment activities by using a different example of analysis of a matrix, e.g. the salt content of potato crisps. Learners should then be well placed to carry out the assessment activities individually.

- Introduction to the problem of finding the salt content of potato crisps:
 - Introduce the problem of how to determine the salt content of potato crisps.
 - Learners should discuss whether measuring either Na^+ or Cl^- concentrations will allow the salt concentration to be determined.
 - Learners may research ways to measure salt content, e.g. silver nitrate titration of the chloride, use of a chloride selective electrode, use of a sodium selective electrode, use of flame emission spectroscopy.
 - Lead learners towards silver nitrate titration, with potassium chromate indicator, as a possible analytical tool for chloride.
 - Facilitate a discussion about whether and how the salt could be extracted. Learners should discover practically that it is not easy to dissolve the salt and to filter the solution. Lead learners to considering direct titration of a water/crisp mush.
- Using silver nitrate as a titrant to find the salt content of potato crisps:
 - Learners should research the use of silver nitrate solution as a titrant – including safety aspects of handling the solution, safety aspects of potassium chromate as an indicator and the need to standardise the silver nitrate.
 - Working in pairs, learners should follow a method to standardise silver nitrate solution and titrate the salt in crisps mixed with water.
 - Ensure learners are comfortable with the terminology of 'primary titrimetric standard' and 'secondary titrimetric standard'.
 - Learners should calculate the salt concentration of crisps and compare it with the value quoted on the packet and with other learners' results.
 - Learners should discuss the extent to which the results agree, the reliability of the method, possible specific sources of error including the matrix and why it was appropriate to use a secondary standard (silver nitrate solution). Encourage the correct use of scientific terminology.
- Give learners the opportunity to practise acid digestion of a metal, dilution, preparation and use of matched standards in colourimetry:



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- Learners could dissolve small amounts of nickel in nitric acid and make these to volume.
- Explain the preparation and use of matched nickel standards.
- Learners could prepare matched standards containing a known amount of nickel (II) ammonium sulphate hexahydrate and an appropriate amount of nitric acid, made to volume and diluted to give a suitable range of standards.
- Learners could find the absorbance of the nickel standards and the digested nickel solution, using a colourimeter and hence calculate the amount of nickel in the sample that was digested.
- Learners could discuss the quality of their results and the sources of error in the experiment, including whether nickel (II) ammonium sulphate hexahydrate was a suitable compound, from which to prepare standards.
- Learners should practice converting between nickel concentration in g dm^{-3} , mg dm^{-3} (ppm) and mol dm^{-3} .
- Give the learners the opportunity to carry out a pH titration and perform calculations:
 - Learners should research the composition of still lemonade.
 - Learners could be reminded (be seeing the equipment demonstrated briefly) how they could carry out a pH titration of the citric acid content of still lemonade using sodium hydroxide 0.1 mol dm^{-3} sodium hydroxide. (If there is time, the learners could carry this out.)
 - Learners plot pH versus volume of sodium hydroxide and $\Delta\text{pH}/\Delta\text{volume}$ versus volume of sodium hydroxide for a given set of results.
 - Learners should calculate the concentration of acid (base the calculation on the pH jump around pH 9.4, dividing the volume giving this end-point by 3 to get the citric acid concentration because citric acid is triprotic).
 - Learners should convert the concentration of acid into g dm^{-3} and mg dm^{-3} to give further practice in unit conversions.
 - Learners should discuss the sources of error in this experiment, including the need to standardise the sodium hydroxide used, why it is appropriate to use sodium hydroxide as a secondary standard in this experiment and possible errors due to there being other compounds present in the solution (not a solution of pure citric acid).
- Give an opportunity to explore manganate (VII) as a redox titrant:
 - Learners should titrate a simple iron (II) solution with potassium manganate (VII) and calculate the concentration of Fe^{2+} in the titration if they have not studied Unit 13.
 - Learners should carry out test tube reactions to show that manganate (VII) is an oxidising agent, e.g. for glucose solution, sucrose solution, starch solution, small pieces of paper soaked in water.
- Learners should discuss the colour change as a way of showing that manganate (VII) has oxidised something and been reduced to Mn^{2+} .

Learning aim B – Investigate spectroscopic techniques to identify compounds and determine concentrations

Learners should not require much additional input with respect to the Beer-Lambert Law Applications having used colourimetry in learning aim A. Learners should respond



Unit 19: Practical Chemical Analysis

well to taking time to use a logical approach to using spectra to identify the structure of organic compounds.

- Beer-Lambert Law Applications:
 - Deliver a presentation about Beer-Lambert Law Applications to include addition of colour reagents to solutions of colourless analytes, addition of ammonium ions to copper (II) solutions to intensify the colour and improve sensitivity, quantitative ultraviolet spectroscopy and quantitative infrared spectroscopy.
 - Learners should, at appropriate points in the presentation, add colour reagents to different concentrations of analyte, add ammonium hydroxide to different concentrations of copper (II) sulfate solution and plot calibration graphs, and calculate sample concentrations for an ultraviolet spectroscopy and a quantitative infrared spectroscopy application.
- Using % elemental composition and mass spectroscopy to find the empirical and molecular formulae of organic compounds:
 - Following an explained example, learners should use a differentiated worksheet to work out the empirical formulae for organic compounds.
 - Explain the operation of a mass spectrometer and the format of the output (relative abundance versus mass/charge ratio). Explain how the molecular ion peak may be used to determine molar mass and hence molecular formula for an organic compound.
 - If possible, visit an organisation which uses mass spectrometry.
 - Learners should use mass spectra from the compounds whose empirical formulae they have determined in order to determine molecular formula.
 - Introduce simple fragmentation patterns.
- Displayed structural formulae for alkanes, alkenes and functional group compounds:
 - Revise the structures of alkanes and alkenes and introduce a range of functional group compounds (to include primary, secondary and tertiary alcohols, alkenols, ethers, aldehydes, ketones, carboxylic acids and esters).
 - Learners should carry out a matching exercise/game to ensure that they can draw and recognise the different types of organic compounds, with the help of their notes.
 - Explain general formulae to learners and ensure that they know the general formulae of the different compound types (e.g. C_nH_{2n+2} for alkanes, C_nH_{2n} for alkenes and cycloalkanes, $C_nH_{2n+2}O$ for alcohols and ethers, $C_nH_{2n}O$ for aldehydes, ketones and enols, $C_nH_{2n}O_2$ for carboxylic acids and esters).
 - Learners should draw the displayed structural formulae for the compounds whose molecular formulae they found using their % composition and mass spectrum.
- Infrared spectroscopy:
 - Explain infrared spectroscopy in terms of the radiation causing bends and stretches of bonds at characteristic frequencies/wavenumbers. Describe the instrumentation (including FTIR having replaced grating instruments), sample preparation, and the need to exclude moisture. Explain the format of an infrared spectrum. Ensure that learners have a good correlation chart to use to help them identify peaks corresponding to C-H, C=O, O-H, N-H, C-O, C=C.



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- If possible, visit an organisation which uses infrared spectroscopy and give learners the opportunity to run spectra for themselves or see them run.
- Learners should label the main peaks (e.g. O-H stretch) of known examples of the infrared spectra of the compound types so that they become familiar with their appearance.
- Proton (^1H) NMR:
 - Explain NMR as being a technique using radiofrequency radiation in the presence of a strong magnetic field. Instead of varying frequency (as with ultraviolet-visible and infrared), the magnetic field is changed to make protons in different environments flip their spin (resonate). Explain the concept of shielding in terms of shielded protons having a very good share of the electrons in covalent bonds. Tetramethylsilane (TMS) is set to have a chemical shift of 0, while the deshielded aldehyde proton has a chemical shift of about 10. Ensure that the learners have a good correlation chart to use.
 - Learners should complete a worksheet on the number of main peaks expected in a low-resolution spectrum (without resolution of splitting patterns). Learners should base their judgements on the proximity to electronegative atoms and on molecular symmetry. Benzene rings may be included.
 - Learners should match simple spectra to displayed formulae.
 - Explain simple splitting patterns for the more able learners.
- Carbon 13 (^{13}C) NMR:
 - Explain that about 1% of natural carbon is ^{13}C and that it is also possible to run ^{13}C NMR spectra (due to the development of modern pulse FTIR instruments). Explain that the principles are similar. Different carbons in molecules have different shares of bonding electrons. Chemical shifts are high for carbons bonded to electronegative atoms and low for those with a good share of bonding electrons. The value of chemical shift is higher for ^{13}C . Ensure that learners have a good correlation chart to use.
 - Learners should identify the number of chemically equivalent carbons and hence the number of low resolution peaks in a molecule.
 - Explain the n+1 rule for the multiplicity of peaks, split by bonded protons.
 - Learners should match extended structural formulae to ^{13}C NMR spectra.
- Joint structure elucidation:
 - Prepare some examples of % composition, mass spectrum, infrared spectrum, ^1H and ^{13}C for several and work through some examples. Lead the learners to suggest what to do: work out the empirical formula, use the mass spectrum to determine the molecular formula; draw all the possible displayed formulae corresponding to the molecular formula; use the infrared spectrum to rule out some possibilities; work out the number of main, unresolved peaks expected in the ^1H and ^{13}C NMR spectra for the remaining possibilities and rule out more possibilities; use NMR splitting patterns and the fragmentation pattern from the mass spectrum to confirm the identity of the structure. There may be more than one structure that matches the evidence.
 - Learners should work through examples independently and practice explaining the logic they have used.

Unit 19: Practical Chemical Analysis**Learning aim C – Investigate chromatographic techniques to identify components and determine the amounts present in samples**

Prepare the learners sufficiently well for them to be able to undertake the assessment activities.

- Instrumentation and application for GC and HPLC:
 - Prepare a presentation to introduce GC and HPLC and then give a framework for researching the principles, instrumentation and operation of GC and HPLC, making useful notes for subsequent independent assignment work. (Learners will carry out focused research in the session but they may carry out much more research independently.)
- Visit an organisation to use GC and HPLC instrumentation or to see the instrumentation in operation:
 - Learners should see for themselves how chromatograms are produced following sample injection. Ideally, they should have the opportunity to inject samples for themselves. The host of the visit should explain what the instrumentation is used for and reinforce what the learners have found out about the mobile and stationary phases, columns, modes of injection, detectors, how to alter the temperature (GC) or the composition of the mobile phase (HPLC) and why that might be done. The host should explain the use of stored methods and why an alternative column may be used.
- Qualitative and quantitative GC:
 - With the help of an organisation that uses GC routinely, prepare a bank of chromatograms that will allow learners to identify components of a mixture from the retention time and 'spiking'. Ideally, there should be chromatograms run at different temperatures to allow learners to see the effect of increasing/decreasing temperature on retention time and separation of the peaks. Prepare chromatograms or collate data that allow learners to use peak area to determine the amount of a substance present. This may include use of a standard.
 - Learners should work through a differentiated worksheet to identify components of a mixture and to draw conclusions about the effect of temperature.
 - Learners should work out the amount of a substance present in a mixture from its peak area in relation to a standard.
- Qualitative and quantitative HPLC:
 - With the help of an organisation that uses HPLC routinely, prepare a bank of chromatograms that will allow learners to identify components of a mixture from the retention time and 'spiking'. Ideally, there should be chromatograms run at different solvent compositions to allow learners to see the effect of changing solvent composition on retention time and separation of the peaks. Prepare chromatograms or collate data that allow learners to use peak area to determine the amount of a substance present. This may take the form plotting the peak areas against the concentrations of standards and using the sample peak area to determine the amount of analyte present.
 - Learners should work through a differentiated worksheet to identify components of a mixture and to draw conclusions about the effect of solvent composition.
 - Learners should work out the amount of a substance present in a mixture from its peak area in relation to those of standards.



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- Method development and optimisation:
 - Learners should work through a differentiated worksheet which allows them to appreciate how an HPLC method could be developed and optimised (e.g. initial research to identify a suitable column and solvent mixture and detector setting, trying out the method, altering the solvent mixture to get a better – more timely or greater – separation, reducing background noise etc.) Learners could also consider how to optimise a GC method.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 3: Science Investigation Skills*
- *Unit 4: Laboratory Practice in the Workplace*
- *Unit 10: Applications of Inorganic Chemistry.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Christian, G.D., Dasgupta, P. and Schug, K., *Analytical Chemistry*, 7th edition, Wiley Global Education, 2013 (ISBN: 978-0470887578).

This advanced textbook includes chapters on titration, spectroscopy and chromatography as well as information on good practice in industry.

Skoog, D.A., West, D.M., Holler, F.J. and Crouch, S.R., *Fundamentals of Analytical Chemistry*, 9th edition, Brooks/Cole, 2014 (ISBN: 978-0495558286).

Advanced textbook with chapters on titration, spectroscopy and chromatography.

Websites

<http://www.aazea.com/book/analytical-chemistry-by-gary-d-christian/#download>

Analytical Chemistry, 6th edition, Christian, G.D. Online textbook with chapters on titration, spectroscopy and chromatography.

<http://www.rsc.org/learn-chemistry/collections/spectroscopy>

Organic spectroscopy and chromatography: Royal Society of Chemistry. This explains the information to be gained from spectroscopic techniques and gives practice exercises. It also contains an introduction to GC and HPLC with videos and animations.

http://sdb.sdb.aist.go.jp/sdb/cgi-bin/cre_index.cgi – organic spectroscopy: *National Institute of Advanced Industrial Science and Technology (Japan)*. This is an extensive database of spectra (mass, infrared, ^1H NMR, ^{13}C NMR) which may be used to construct worksheets and assignments for learning aim B.



Unit 20: Biomedical Science

Delivery guidance

Approaching the unit

This is an introductory unit and previous knowledge assumed is in terms of your learners' experience of level 2 science. Your learners will be looking at the applications of science in some specialised areas. It is not intended to prepare them for direct entry into biomedical science but rather as an introduction so they can make a reasoned choice about which branch of biomedical science would be of interest for further study.

It is not possible to cover all the main branches of biomedical science, so in this unit, areas such as haematology, histology and cytology are chosen as exemplars. Although your learners will be familiar with these areas from possible contact with the NHS, there are a number of other industries involved in biomedical science and you should encourage your learners to consider them when doing research for this unit. It is sometimes difficult to have access to biomedical laboratories/facilities so you may have to rely on input from speakers and other sources of information.

Your learners must do laboratory work within your centre in order to meet the criteria and understand the procedures carried out in haematology and cytology. Strict adherence to COSHH and health and safety regulations is required.

Delivering the learning aims

For **learning aim A**, first see the warning below about working with human body fluids such as blood.

Although it is possible to use blood samples from scientific suppliers or to use artificial blood, check your health and safety regulations before doing so. You can use prepared microscope slides and photomicrographs of blood to introduce blood components and follow this up with research by your learners. As they do this research and look at the slides, your learners can investigate diseases and problems associated with the blood components.

Again using prepared slides, your learners can practise doing blood counts as an introduction to some of the diagnostic techniques in a haematology laboratory. Visits to such a laboratory or hearing from speakers about their work would be useful at this point.

Learning aim B requires a lot of tutor input backed up by visits to suitable laboratories and from visiting speakers. Work experience would allow some of the techniques to be observed or even practised but it will mostly be covered by research. Using prepared slides to compare normal and abnormal tissues will help your learners to appreciate histology and cytology.

For **learning aim C**, first see the warning below about working with human body fluids such as urine. Simulated samples can be bought or made up in which case a range of practical work can be done. Pre-prepared slides of urine with blood cells, micro-organisms etc. can be used as part of urine analysis. Visiting speakers, visits to analytical laboratories and work experience would add to the

vocational aspects of this aim. Using case studies concerning patients with symptoms, their laboratory results etc. will help your learners put the work into context. Remember that it is the doctor who interprets and does the diagnosis, but the results give the material for the doctor to work with.

Generally, you should make sure of COSHH and health and safety regulations if you are doing practical work of any kind. In the criteria for this unit practical work is assessed only for a simple urine analysis as part of C.P8.

For practical work, you must follow all relevant COSHH and health and safety regulations some of which will vary depending on the county you teach in. Always check first before doing any work with body fluid products.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the principles of haematology and its use in medical diagnosis	<p>A1 The components of blood</p> <p>A2 Disease and the consequences for blood composition</p> <p>A3 Diagnostic techniques used in haematology</p>	<p>Practical work to investigate microscopically the components of blood and use of diagnostic techniques to identify disease. Observation records will be required.</p> <p>Report explaining blood component structure and function along with causes and consequences of dysfunction.</p> <p>Analysis of the use of diagnostic blood tests for different diseases.</p>
B Examine the use of histology and cytology in medicine	<p>B1 Accurate investigation of tissue to detect disease and dysfunction</p> <p>B2 Role of informatics and record keeping</p>	<p>Report/presentation on the implications for society, the health service and individual patients of using histology and cytology in detecting and diagnosing disease occurrence, including how information is used and communicated to key stakeholders.</p>
C Examine the use of urinalysis as an analytical and diagnostic tool	<p>C1 Urine composition and the implications of changes</p> <p>C2 Urine sampling and analysis for diagnosis</p>	<p>Practical work and report on the use of urinalysis in diagnosing changes to health status.</p>



Assessment guidance

Learning aim A includes practical work using pre-prepared blood slides to help the learners understand the components of the blood. Some prepared slides can be used that show abnormalities such as sickle cell shaped blood cells, high levels of white cells etc. The aim requires your learners to be able to carry out diagnostic haematology tests. Any practical work done must be observed and your learners should record what they see under the microscope. The practical work can be filmed for the verifier to view.

You can approach some of learning aim B using practical work so your learners appreciate the work done in histology and cytology. Again, use pre-prepared slides and materials to avoid any health risks. Your learners will need to do some research about how cytology and histology are used for detecting and diagnosing disease. Making your learners aware of the huge increase in data being handled is important and input from a specialist in informatics would be useful. Your learners will be aware of reports going missing etc. but they need to know how this vast amount of data is handled and cross-referenced so best use can be made of it from a patient and practitioner point of view.

For learning aim C, your learners should have access to a suitable laboratory where they can carry out urine analysis and write up reports on their findings. Observation of their practical work is expected and this could be recorded to help in verification later on. Your learners will also need to do some research so they can include in their report how results are used in the diagnosis of any health changes in the patient. Visits to suitable laboratories, work experience and talks from visiting speakers will all help put this aim into a vocational context.

General comment: learning aims A and C require your learners to be observed doing practical work so they can meet the criteria with the key words being 'Correctly carry out ...'. The funnelling to merit concentrates on the key words of 'discuss', and 'analyse' while at distinction level 'evaluation' is the key word.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 20: Biomedical Science

Introduction

You could start with a general brain storming session on what biomedical science means to your learners. Use this to build up a mind map/spider diagram/flow chart of the factors that make up biomedical science in terms of what the NHS supplies, and what your learners and their families may have experienced. This gives the learners some ownership of the subject matter. Make sure you include the main items such as haematology, histology, cytology and analysis and diagnosis. You will need to make sure your learners understand these terms, possibly by setting it as a quick research activity for 15 minutes, and then using it as a summary feedback to finish the session.

Learning aim A – Understand the principles of haematology and its use in medical diagnosis

Refer to your introductory session and the use of haematology as a tool in biomedical science.

- Revise the structure of blood that your learners will have covered at level 2. Do this briefly by way of a quiz or building up a chart of blood components and their functions. Make sure your learners use the correct biological terms such as erythrocytes.
- At some time during this work a visit to a laboratory or having guest speakers who work in such laboratories will put the material into context.
- Examine microscope slides or photomicrographs of these blood components. Ask your learners to explain the structure and functions of each of the main blood components.
- Give them some unlabelled prepared slides as a test of being able to identify blood components. The idea is to make sure your learners know what normal blood should be like. You could also test they know the functions of these components.
- As a class activity do a brainstorming session on what your learners know about diseases and disorders of blood. Learners should note and keep any ideas not relevant to blood, as they may be of use later on.
- Show your learners the effect of some diseases/disorders on blood components using videos/ microscope slides etc. Use this as a discussion with your learners.
- Set your learners some research work to do on the effect of diseases and disorders for a later session.
- Use some case studies to help your learners understand the signs/symptoms/effects of blood diseases/disorders. The research they have done should be of help.
- Ideally, work experience in a haematology laboratory would be vocationally relevant to correctly carrying out diagnostic tests on blood. If this is not possible then set up your laboratory to mimic a haematology laboratory where blood samples are received for analysis. You will need to observe your learners as they carry out the diagnostic tests. Make sure they record what they are doing and the outcomes. You can record their work for verification later on.

Use the practical work to discuss the basic tests and encourage them to evaluate the



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effectiveness in terms of detecting diseases.

Learning aim B – Examine the use of histology and cytology in medicine

Refer back to the terms, histology and cytology, and discuss with your learners what they decided they meant. Put them into context by setting your learners some research about the techniques used. You could give each learner an area to research, e.g. types and methods of sample removal. Be prepared to guide your learners about which websites to use and the key words to enter for a search.

- To follow up their research, give your learners a case study to discuss in small groups that will test their knowledge of tissue investigation and diagnosis. You will need to give sufficient information in the case study about symptoms etc. so your learners can decide which tissue investigations they might carry out.
- Use a class discussion to draw together what tissue investigation involves, how it is carried out and used. Conclude with discussing the need to take specimens at autopsy in order to discuss cause of death. You will need to be aware of any particular situations in the class where this may be inappropriate and an alternative way of covering the material may be needed.
- The same applies when using case studies or group discussion about the implications once a diagnosis has been made.
- Large amounts of data, not only from diagnostic tests, but general information kept in patients' files, rapidly accumulate and your learners can give you their experiences of huge files, both paper-based and electronic, that they may have seen during medical visits. This is a good starting point to a discussion about record keeping and the topic of informatics.
- Your learners will give you numerous examples of lost records etc. Use this to get them to consider examples of redacted patient information that they can study. Ask them how they would organise and store the information. Set this as a practical exercise. Remind them of certain criteria they must allow for, such as confidentiality, accuracy, completeness etc.
- If possible, find a speaker/colleague who can demonstrate to your learners the processes involved in data storage and record keeping.
- Research, as a small group activity, the different systems used to store data both paper-based and electronically. Ask your learners to summarise the basis of these data storage systems.

As a follow-up, look at how information is used and communicated in the NHS.

Learning aim C – Examine the use of urinalysis as an analytical and diagnostic tool

Learners could start this learning aim by doing practical work into urine sampling and analysis. Your learners will be observed carrying out practical work, as they must do this correctly and be able to analyse their results. You may feel that a knowledge of the composition of urine, and how this can vary in relation to health should be researched prior to practical work. Choose whichever way suits you and your learners but practical work must be observed being carried out by your learners to achieve criterion C.P8.

- Remind your learners of the urinary system they studied at level 2 and the role of the kidneys in helping to rid the body of chemicals that are not needed or are harmful.
- Use this revision to introduce the composition of urine in a normal healthy person,

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which includes variations in the constituent parts. Discuss why these variations appear, such as an increase in hormone levels or sodium or potassium.

- To capture the interest of your learners refer to urine analysis carried out in all types of major sports. Encourage your learners to do some research on how samples are taken, what tests the sample undergoes and how the results are interpreted.
- Use the findings of your learners to make a flow chart of the processes and indicate where there can be problems and why there can be misinterpretation of results. Include in your discussions what indicators are used in urine analysis and relate this to how sampling is done in a hospital laboratory.
- You could supply your learners with some case studies where symptoms and results of urine analysis are given and your learners interpret them.
- Visits to relevant laboratories/visits from speakers working in such laboratories and work experience will make the aim vocationally interesting.
- Your learners are required to carry out urine analysis correctly. You must make sure you abide by the COSHH and health and safety regulations that apply to your centre. You and your learners should do risk assessments before any practical work.
- If work experience is not possible then try to make your laboratory like an area where such urine analysis would be carried out for the NHS. You can give your learners a urine sample and ask them to test for specific things, such as pH, glucose, ketone etc. Chemical test strips are readily available from suppliers.
- Using microscopes to look at urine samples for cells and micro-organisms is another aspect of practical work to be done and observed.
- Your learners should be aware that they will be observed doing practical work and they should be prepared to record their results and analyse what they mean.

As a whole-group activity, discuss how urine analysis helps in the diagnosis of health changes.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 1: Principles and Applications of Science I*
- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 5: Principles and Applications of Science II*
- *Unit 8: Physiology of Human Body Systems*
- *Unit 10: Biological Molecules and Metabolic Pathways.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Hoffbrand, V. and Mehta, A.B., *Essential Haematology*, Wiley Blackwell, 2006 (ISBN: 978-1405136495).

This book introduces the formation and function of blood cells and diseases that arise from dysfunction and disruption of these processes. Basic science, diagnostic tests and clinical features are all easily explained.

Howard, Martin and Hamilton, Peter, *Haematology: An Illustrated Colour Text*, Elsevier Health Services, 2008 (ISBN: 978-0443103629).

A reference book for tutors and learners.

Iles, Raymond and Docherty, Suzanne (eds), *Biomedical Sciences: Essential Laboratory Medicine*, Wiley, 2012 (ISBN: 978-0470997741).

This covers all the major topics for this unit. You can also use it for other units.

Luxton, R., *Clinical Biochemistry*, 2nd edition, Scion Publishing, 2008 (ISBN: 978-190842415).

This reference focuses on the areas of body function required for the maintenance of health.

Ramakrishnan, S., *Manual of Medical Laboratory Techniques*, JP Medical Ltd, 2012 (ISBN: 978-9350256343).

This manual is a complete guide to medical laboratory techniques used in medical microbiology, haematology, clinical biochemistry, histopathology, human genetics and molecular biology.

Tortora, Gerard J. and Derrickson, Bryan H., *Principles of Anatomy and Physiology*, John Wiley & Sons, 2011 (ISBN: 978-0470565100).

A very well-known book which covers in detail all the information required for human biology – a standard reference book for learners.

Journals

New Scientist

Articles from newspapers, television or radio transcripts or other scientific publications will be beneficial to aid the learning process.

Websites

www.ase.org.uk

The Association for Science Education.

www.sep.org.uk

Science Enhancement Programme.

www.societyofbiology.org

Society of Biology.

You can find many other sites using a search engine of your choice and typing in the subject required. These sites do tend to change, with new ones appearing and taking the place of existing ones. Always check the site is still active before recommending to your learners.



Unit 21: Medical Physics Applications

Delivery guidance

Approaching the unit

Learners may bring knowledge of medical physics applications through their own experiences or from knowledge of friends or family experiences.

You could give initial introductory input for your learners about radioactive sources, radioactive isotopes, radioactivity, X-rays and the electromagnetic spectrum and radioactive decay, which they may have covered in their previous studies.

Learners should be encouraged to research and learn about the uses of medical physics applications through articles in the various types of media about new techniques, new discoveries and through the National Health Service and other health services.

A number of universities and medical science industries welcome learners that have a good knowledge and understanding medical physics applications.

To complete this unit your learners will need access to the internet, CD-ROMs, journals or magazines, and books.

The delivery methods proposed for this unit are, for example:

- discussions – class and small group discussions on case studies and new techniques/discoveries and applications
- visits to radiography departments
- visiting/guest speakers from radiography departments or from health and safety organisations
- tutor presentation/guidance – briefing and monitoring learners about individual research and valid appropriate websites and references
- group and individual learner activity – where learners can research relevant materials and case studies
- video and YouTube clips – where learners can learn and reinforce their knowledge and understanding of underlying physics concepts and through demonstrations of various medical physics techniques in a medical health scenario.

Delivering the learning aims

For **learning aim A**, introduce the unit by informing the learners about the sections in the unit, how it fits within the qualification and how it relates to other units. Inform the learners about the assignments that they need to complete. Give some input on different types of non-ionising instrumentation radiation techniques and then discuss with the learners any previous experiences they have had to engage and motivate them. You could follow this with a general discussion on how each of the techniques relates to screening, diagnosis, and

treatment of patients, and the benefits, advantages and disadvantages of each of the techniques.

You could invite a guest speaker through STEMNET ambassadors to inspire learners about non-ionising instrumentation radiation techniques. It is important for learners on an applied science programme of study to understand the fundamental physics concepts that enable the different techniques to function reliably and effectively for screening, diagnosis and treatment of patients.

Give an initial input with regard to fundamental physics of magnetic resonance imaging, covering an outline of the instrumentation used to scan for protons in different environments within the body. Learners will need to understand the underlying theory of energising hydrogen nuclei (high-energy state) when they absorb a certain radio frequency pulse input which resonates with the strength of the magnetic field and the relaxation of the hydrogen nuclei (low-energy state) to emit a radiofrequency signal output pulse. This can be captured by a powerful computer and produce high-resolution images of soft tissues in the body. You could ask learners, in small groups or individually, to investigate magnetic resonance imaging and its application in the health service. You could repeat the delivery method above for the other three non-ionising instrumentation radiation techniques shown in the content.

For **learning aim B**, give some input on different types of ionising instrumentation radiation techniques and then discuss with the learners any previous experiences they have had to engage and motivate them. This could include some of the latest current media articles on 'Proton Beam Therapy' or 'Gamma Knife Surgery'. Follow this by having a general discussion on how each of the techniques relates to screening, diagnosis and treatment of patients, and the benefits, advantages, disadvantages of each of the techniques.

A guest speaker through STEMNET ambassadors or from the local hospital could be asked in to inspire learners about ionising instrumentation radiation techniques. It is important for learners on an applied science programme of study to understand the fundamental physics concepts that enable the different techniques to function reliably and effectively for screening such as use of mammograms for screening purposes, diagnosis and treatment of patients.

Give an initial input with regard to fundamental physics of X-rays covering an outline of the instrumentation used, where the X-rays are generated in a vacuum tube by producing high-energy electrons from a metal cathode which accelerate to a positively charged tungsten anode. The resulting X-rays are directed to pass through the patient's body on to a photographic plate or digital recorder to produce an image. You could also cover how the X-ray intensity and penetration is increased.

You could ask learners, in small groups or individually, to investigate X-rays and their application in the health service. You could repeat this delivery method for the other three ionising instrumentation radiation techniques shown in the content.

For **learning aim C**, introduce the topic by enabling learners to share any stories they have about ionising radiation techniques. Give input for your learners about health and safety, associated risks and side effects with reference to both patients and operators, and include legislative requirements. Discuss the subject of patient choice and consent when considering the use of radiation therapy/techniques. Learners could compare a number of well-known cases. In small groups or as individuals your learners could then carry out an investigation through various media sources such as journals, media sources, magazines, NHS leaflets, the internet and books about health and safety precautions, risks to patients and operators with reference to the use of ionising radiation for



screening, diagnosis and treatment. A guest speaker from the Health and Safety Executive or from a radiography department in a hospital could help learners understand the importance of health and safety when using ionising radiation sources and instrumentation. You could then repeat the delivery method above for the other three non-ionising instrumentation radiation techniques.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications	A1 Magnetic Resonance Imaging (MRI) A2 LASERs A3 Infrared Thermography (IRT) A4 Ultrasound	<p>A research report showing the different types of non-ionising and ionising radiation techniques.</p> <p>Learners could produce visual presentations for the underlying principles and production. They could produce tables and use case studies for comparisons in justifying techniques used for diagnosis and treatment.</p>
B Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications	B1 X-rays B2 Computerised tomography (CT) or Computerised axial tomography (CAT) B3 Gamma Ray Imaging B4 Radiotherapy, Gamma Knife Surgery and Proton Beam Therapy	<p>A report showing the health and safety and risk implications for operators and patients with the use of case studies, reference to legislative requirements and associated articles.</p> <p>Information from visits or visiting speakers.</p>
C Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications	C1 Safety precautions, side effects and risks for operators and patients of ionising radiation C2 Safety precautions, side effects and risks for operators and patients of non-ionising radiation	<p>A report showing the health and safety and risk implications for operators and patients with the use of case studies, reference to legislative requirements and associated articles.</p> <p>Information from visits or visiting speakers.</p>

Assessment guidance

This unit is internally assessed by a number of independent tasks. Each task should cover at least one entire learning aim and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion.

There are two suggested summative assignments for this unit as shown in the assessment criteria, each covering one or two learning aims. All learners must independently generate individual evidence that can be authenticated; this also applies to learners who have completed their assignments in a group. The main sources of evidence are part of each assignment.

Learners should incorporate research that is corroborated by a referenced bibliography. Learners need to produce their assignment reports in a style that allows assessors to assess the evidence presented for each individual criterion and to ensure that three assignment themes are present. Learners could produce evidence using diagrams, tables, presentations, technical scientific posters or leaflets. The assessment plan and recommended approach is funnelled to give a thematic approach for learners to give progressive evidence that is coherent and to allow for higher command words/verbs to be used when moving from pass to merit to distinction grade.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 21: Medical Physics Applications

Introduction

Introduce the unit, learning aims and assessment criteria. You could then brief the learners how the unit fits within the qualification and relates to other units.

Revise some underlying relevant concepts about radioactivity, radioactive decay and the electromagnetic spectrum that learners should have covered previously.

Learning aim A – Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications

- Brief learners about non-ionising instrumentation techniques and then have a discussion where learners can contribute and share experiences of the techniques used for screening, diagnosis or treatment. You could also use case studies of patients and the consideration of patient choice and consent.
- Invite a guest speaker to come in and discuss non-ionising radiation, its importance in medical applications and any new developments taking place or being available in the future.
- Give a presentation to learners about the fundamental physics concepts underlying magnetic resonance imaging, covering the instrumentation, the process of nuclear magnetic resonance and the production of high-resolution images.
- Brief learners about carrying out an investigation into Magnetic Resonance Imaging, and give guidance about reliable and valid sources of information. Ask learners to carry out an investigation into Magnetic Resonance Imaging.
- Use the same sequence as above to deliver Magnetic Resonance Imaging, to cover instrumentation, the underlying physics concepts and uses of Lasers, Infrared Thermography and Ultrasound and where applicable the types of images produced.
- Ensure learners carry out research into Lasers, Infrared Thermography and Ultrasound.

Discuss with the learners the different medical applications of non-ionising radiation for screening, diagnosis and treatment purposes. Discuss which technique would be a suitable choice for different medical conditions.

Learning aim B – Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications

- Brief learners about ionising instrumentation techniques and then have a discussion where learners can contribute and share experiences of the techniques used for screening, diagnosis or treatment. You could also use case studies of patients and the consideration of patient choice and consent.
- Invite a guest speaker to come in and discuss ionising radiation, its importance in medical applications and any new developments taking place or being available in the future.
- Give a presentation to learners about the fundamental physics concepts underlying X-rays, covering the instrumentation, the process of producing X-rays and the production of images.

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- Brief learners about carrying out an investigation into X-rays, and give guidance about reliable and valid sources of information. Enable learners to carry out research into X-rays in preparation.
- Use the same sequence as above to deliver X-rays, to cover computerised tomography, gamma ray imaging and radiotherapy techniques for instrumentation, the underlying physics concepts and uses of them and where applicable the types of images produced.
- Discuss with the learners the different medical applications of ionising radiation for screening, diagnosis and treatment purposes. Discuss which technique would be a suitable choice for different medical conditions.

Ask learners to comment on a number of different medical conditions and the type of non-ionising or ionising radiation they would select for that condition in terms of advantages, disadvantages and side effects.

Learning aim C – Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications

- Brief and discuss with learners the need for health and safety for both operators and patients when using ionising instrumentation techniques during screening, diagnosing and treatment. Learners could be encouraged to share their experiences and from members of their family and friends.
- Learners could also read and discuss a number of well-known health and safety case studies with regard to ionising radiation that you have given.
- Invite a guest speaker from a local hospital or from the Health and Safety Executive to talk about health and safety, side effects and associated risks with ionising and non-ionising radiation and health and safety legislation.
- Enable learners to investigate ionising radiation and health and safety issues.
- Brief and discuss with learners the measures in place for health and safety for both operators and patients when using non-ionising instrumentation techniques during screening, diagnosing and treatment. Learners could be encouraged to share their experiences and/or from members of their family and friends.
- Learners could also read and discuss a number of well-known health and safety case studies with regard to non-ionising radiation that you have given.
- Ask learners to investigate non-ionising radiation and health and safety issues.

Discuss with learners the implications of unsatisfactory health and safety measures to patients and operators.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

The unit in the new NQF Level 3 BTEC Applied Science qualification that links to this unit is as follows:

- *Unit 1: Principles and Applications of Science I.*

The previous QCF Level 3 BTEC National in Applied Science also has a Medical Physics Techniques unit and other units that link to this unit and resources produced or purchased for those units may be partially suitable for use in this unit.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Foal, S., Hocking, S., Llewellyn, R., Musa, I., Patrick, E., Rhodes, P. and Sorensen, J., *BTEC Level 3 Applied Science Student Book*, Pearson, 2010 (ISBN: 978-1846706800).

This book contains Unit 20 Medical Physics Techniques material for the 2010 specification.

Journals

Nature

An international journal covering research spanning all areas of science.

New Scientist

Covering the latest news and articles about science and technology.

Scientific American

Latest science stories, articles and news.

Physics World

Institute of Physics – latest news about physics articles and stories.

Videos

www.youtube.com/watch?v=0-ewpwwcxK0

CT scan: what happens.

www.youtube.com/watch?v=MS590Xtq9M4

How does proton therapy work?

www.youtube.com/watch?v=9GsrIARpTms

Medical physics gamma imaging.

www.youtube.com/watch?v=tVNHZKxK0Us

Medical thermography training.

www.youtube.com/watch?v=AwXJNXnCLNs

MRI scan: what happens?

www.youtube.com/watch?v=C23cRCZ2J98

Production of lasers.

www.youtube.com/watch?v=kpJBfN4W0ng

Ultrasound tutorial video.

www.youtube.com/watch?v=wbbbsbE2mQuA

X-rays work.

Websites

www.ase.org.uk

Association for Science Education – science resources for tutors, journals, textbooks, useful links.

www.bbc.co.uk/schools/gcsebitesize/science/triple_aqa/medical_applications_physics

GCSE Bitesize Science – medical applications of physics – background information.

www.HSE.gov.uk

Health and Safety Executive – information about health and safety.

www.HSE.gov.uk/coshh

Health and Safety Executive – information about the ‘Control of Substances Hazardous to Health’ regulations.

www.iop.org

Institute of Physics – background information on medical physics resources.

www.nationalstemcentre.org.uk

National STEM centre – resources for science, technology, engineering and mathematics.

www.nationalstemcentre.org.uk/elibrary/collection/565/teaching-medical-physics

National STEM centre – Teaching Medical Physics.

www.nhs.uk/conditions/ct-scan/pages/introduction.aspx

CT Scans from NHS Choices.

www.rsb.org.uk

Royal Society of Biology – resources about theoretical and practical biology, journals, textbooks, useful links.

www.stemnet.org.uk/ambassadors

STEM ambassadors – central hub for allocation of speakers to schools/colleges.

www.nhs.uk/conditions/Ultrasound-scan/Pages/Introduction.aspx

Ultrasound from NHS Choices.



Unit 22: Materials Science

Delivery guidance

Approaching the unit

Learners may bring knowledge of materials science with them from Unit 5 and previous studies about metals, carbon and polymers/plastics.

You could give initial introductory input for your learners about how important materials are in everyday usage and the need to find new materials because we are running out of certain materials in the earth's crust for which there is a high demand.

Learners should be encouraged to research and learn about different types of materials and investigate some of the more recent discoveries/innovations in the use of new materials such as graphene, carbon-fibre and the use of materials in applications to reduce carbon emissions.

A number of universities and industries producing material products welcome learners that have a good knowledge and understanding of materials science and its applications.


To complete this unit your learners will need access to the internet, CD-ROMs, journals or magazines, and books.

The delivery methods proposed for this unit are, for example:

- discussions – class and small group discussions on case studies and new techniques/discoveries and applications
- visits to a university or manufacturer producing materials
- visiting/guest speakers from a university or manufacturer
- tutor presentation/guidance – briefing and monitoring learners about individual research and valid appropriate websites and references
- group and individual learner activity – where learners can research relevant materials and case studies
- video and YouTube clips – where learners can learn and reinforce their knowledge and understanding of materials and their uses.

Delivering the learning aims

For **learning aim A**, introduce the unit by informing the learners about the unit introduction, aims and assessment criteria and assignments that will need to be covered. Discuss with the learners how it relates to Units 1 and 5 and describe how it fits in with other units in the qualification. It would be useful to ask them about their previous knowledge and experience with regard to materials science and using group work enable them to investigate how materials are classified into different categories. Discuss with the learners their findings and how materials are classified into different categories. It is important that learners have some practical experience of what a lot of the materials look and feel like; it could be a good idea to have a number of the different materials in a



laboratory/room for learners to inspect and write down their category and their use/application. You could invite a guest speaker through STEMNET ambassadors to inspire learners about the uses and applications of materials, and careers in materials science.

For **learning aim B**, it is important for your learners to have an understanding of scale and an understanding of the definition of nanotechnology. Give input with reference to the size of nanoscale particles and that they are made up of clusters of atoms and molecules about 1 nm long, which for example is equivalent to 3.5 atoms of gold and 8 hydrogen atoms. One molecule of glucose is about 1 nm in size. You could show some photographs of images at the nanoscale level and inform learners about the types of microscope that are used to give such images. Show some images where individual atoms have been manipulated using a Scanning Tunneling Microscope and Atomic Force Microscope. Inform learners that properties of materials are size dependent and materials often have different properties at the macroscale compared to that at the nanoscale level due to quantum mechanical effects and their unique structures. Some examples have different electrical properties as conductors and semi-conductors; optical properties such as colour (a colloid of gold nanoparticles is ruby red in colour), carbon nanotubes are 100 times stronger than steel but six times lighter. These are some of the unique opportunities for scientists to explore and utilise properties of materials at the nanoscale level. Ask learners to investigate the types of nanoparticles as defined by their shapes and produce diagrams of the different shapes, and investigate some other examples of the difference in properties at the nanoscale level. Discuss with learners their findings about the types of nanoparticles and the relationship to their properties and potential uses. Introduce learners to the topic areas where nanoparticles are used and ask learners to investigate their uses/applications on the internet and any case studies from magazines/journals. Discuss with learners their findings and how the uses can be structured into different topic areas for example medicine with regard to gene therapy, biochips, scratch-proof eyeglasses; food packaging and the use of antimicrobial coatings; computing and electronics using nanoscale semiconductors; chemistry as in cosmetics, dyes, sunscreens; energy uses such as ceramic coatings for solar cells.

For **learning aim C**, you could introduce the topic of polymers and plastics by asking learners about their previous knowledge. Show them some different types of natural and synthetic polymers and ask them what they are used for in everyday life and either demonstrate or ask learners to make some molecular models of some monomers, polymers and co-polymers. Demonstrate plasticity and elasticity, and ask learners what the difference is between thermosetting and thermoplastics. This could be followed by asking the learners to investigate some starting materials used to make polymers and examples that make biodegradable polymers/plastics. With regard to additives use the models of polymers to demonstrate the use of cross-linking agents and plasticisers, and explain the use of other additives to improve the properties of polymers. Ask learners to write down all uses/benefits of polymers/plastics, what they are used for and discuss their advantageous properties compared to the use of more traditional materials. You could then ask learners to investigate media articles and case studies on the internet to include broadsheets, tabloids and any scholarly articles about the disadvantages and environmental impact of polymers/plastics. Discuss their findings and ask them to justify the uses of plastics/polymers and the risk assessment paradigm.

For **learning aim D**, introduce this by asking learners to discuss in groups the different ways individuals, authorities, non-government organisations and governments are trying to reduce carbon emissions. Discuss with the learners the importance of using different and often innovative materials in relevant



technologies to reduce carbon emissions, one way of doing this is by use of case studies/articles from a number of tabloid/broadsheet newspapers and scientific magazines/journals and include the benefits and limitations of relevant technologies. At this stage ask a guest speaker in to talk about reducing carbon emissions and the important part materials have to play. Follow this up by showing a number of YouTube video clips of the benefits of wind turbines, how they use the electromagnetic effect to produce electricity and how wind turbines are produced. Introduce and demonstrate a model of a wind turbine and its component parts and/or get learners to build their own wind turbine. Ask learners to investigate the materials used to make wind turbine blades, the useful properties and any limitations of the materials. Introduce the method of using photovoltaic cells to reduce carbon emissions by showing a number of YouTube video clips of the use of photovoltaic cells. You could also demonstrate a model of a photovoltaic cell and its component parts. Discuss with the learners solar photovoltaic cells, how they change light energy into electricity and their benefits and limitations. Ask learners to investigate the materials that make up solar photovoltaic cells, their useful properties and any limitations. Another method of reducing carbon emissions is by the use of LEDs. Introduce the topic of LEDs by asking learners about their previous knowledge and discuss the uses of LEDs in the home and any advantages/benefits they have compared to other types of lighting. Demonstrate a variety of LEDs, their component parts, and discuss their voltage and power output. Ask learners to calculate how much energy you would save by replacing traditional incandescent light bulbs with LEDs.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the classification and properties of different materials	A1 Classification of materials A2 Macroscopic properties A3 Microscopic structure	An investigative report showing the different types of materials. Learners could then produce a classification visual presentation using microscopic and macroscopic pictures, diagrams and data for the different materials and their properties.
B Examine the uses, benefits and limitations of developing nanotechnology materials	B1 Defining nanotechnology B2 Uses of nanotechnology B3 Benefits of nanotechnology B4 Environmental impact and health and safety risks of nanotechnology	Learners could produce a report based on case studies, internet searches and class discussions about the benefits and risks of nanotechnology materials.

<p>C Investigate the benefits and limitations of polymer technology</p>	<p>C1 Polymers and their sources</p> <p>C2 Benefits of polymers</p> <p>C3 Limitations and environmental risks of polymers</p>	<p>A research report showing the different types of polymers, benefits and risks to the environment.</p>
<p>D Examine materials used in applications in order to reduce carbon emissions for a sustainable future</p>	<p>D1 Wind turbine blades</p> <p>D2 Solar photovoltaic cells</p> <p>D3 Light-emitting diodes (LEDs)</p> <p>D4 Fuel cells</p>	<p>Learners could research sources of information and compose a portfolio of case studies with reference to examples of everyday uses.</p>

Assessment guidance

This unit is internally assessed through a number of given independent tasks. Each task should cover at least one entire learning aim and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion.

There are four suggested summative assignments for this unit as shown in the assessment criteria, each covering one learning aim. All learners must independently generate individual evidence that can be authenticated; this also applies to learners who have completed their assignments in a group. The main sources of evidence are part of each assignment.

Learners should incorporate research that is valid and has a referenced bibliography. Learners need to produce their assignment reports in a style that allows assessors to assess the evidence presented for each individual criterion and to ensure that four assignment themes are present. Learners could produce evidence such as using diagrams, tables, presentations, technical scientific posters or leaflets. The assessment plan and recommended approach is funnelled to give a thematic approach for learners to give progressive evidence that is coherent and to allow for the use of higher command words/verbs when moving from pass to merit to distinction grade.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 22: Materials Science
<p>Introduction</p> <p>Begin by introducing the unit to learners by informing them about the introduction, learning aims, assessment criteria and the assignments they need to complete. You could then brief the learners how the unit fits within the qualification and especially Unit 5 and previous studies about metals, carbon and polymers/plastics.</p> <p>Revise some underlying relevant concepts about atomic and molecular structure and bonding, electromagnetic theory, energy transformations, energy calculations, polymers and graphite.</p>
Learning aim A – Understand the classification and properties of different materials
<ul style="list-style-type: none"> • Brief learners about the classification of materials and then discuss how materials are classified into different categories based on their properties at the macroscopic level. • Display a number of different materials in the laboratory or workshop and ask learners to inspect the materials and classify them into different categories, and what they are used for. • Invite a guest speaker to come in and discuss the importance of materials and, for example, the search for new materials to replace the rare earth metals that are in short supply and very expensive. • Give a presentation to learners about the macroscopic properties of materials and ask learners to carry out some practical work to establish the properties of a number of materials such as density, strength and thermal conductivity etc. • Ask learners to carry out an investigation into a number of given materials and ask them to classify them in decreasing or increasing order of their macroscopic physical properties. • Discuss with learners their experience of studying atoms, molecules and bonding at the microscopic level. <p>Use molecular models to demonstrate the microscopic effect on macroscopic properties such as with graphite and diamond, metals and their alloys and cross-linking agents and plasticisers in polymers.</p>
Learning aim B – Examine the uses, benefits and limitations of developing nanotechnology materials
<ul style="list-style-type: none"> • Discuss with learners what they understand by the term nanotechnology and display some images at the nanoscale level. • Invite a guest speaker to come in and discuss the importance of nanotechnology, its benefits, risks and future. • Brief learners about how the properties of materials at the macroscopic level can be very different at the nanoscale level. Give examples of electrical conductivity, optical properties and strength. • Enable learners to investigate given types of nanoparticles defined by their shape

**Unit 22: Materials Science**

and discuss with the learners their findings.

- Ask learners to investigate the uses of nanoparticles and their benefits.

Discuss with the learners the benefits of nanotechnology and the potential risks to the environment, and health and safety risks to the general public and employees who manufacture and work with nanoscale materials.

Learning aim C – Investigate the benefits and limitations of polymer technology

- Begin by discussing with learners their previous experience about plastics and polymers and general usage in everyday life.
- Demonstrate a number of different solid or liquid polymers and plastics and what their uses are, to include clothing, sports equipment, furniture and in engineering and construction materials etc.
- Invite a guest speaker from the polymer/plastics industry, university or IMO³ to discuss their benefits and limitations.
- Demonstrate or ask learners to make a number of molecular models of monomers, polymers and co-polymers and use them to demonstrate what are meant by plasticisers and cross-linking agents.
- Ask learners to find out what is the difference between thermo- and thermosetting plastics and list some everyday examples. Discuss with learners their findings.
- Learners should investigate different starting materials to make polymers/plastics to include sources to make biodegradable plastics, and the additives used to improve the properties of polymers/plastics.
- Use case studies or articles to enable learners to investigate the beneficial properties of a number of well-known polymers/plastics. Ask learners to compare the use of polymers/plastics to some conventional materials such as those used in the home/construction.
- Discuss with the learners their findings about the improved properties.

Ensure learners investigate the disadvantages and environmental impact of plastics/polymers by looking at a number of articles in broadsheets, tabloids and scholarly articles. Discuss with the learners their findings, how they fit with risk assessment and management, and a change in approach required to fit in with a risk assessment paradigm.

Learning aim D – Examine materials used in applications in order to reduce carbon emissions for a sustainable future

- Introduce this aim by asking learners to discuss in groups the ways different individuals and organisations are trying to reduce carbon emissions and then discuss the important part played by using traditional and new materials.
- You could ask learners to investigate articles about the benefits and limitations of technologies used to reduce carbon emissions and then discuss their findings.
- Invite a guest speaker from the energy industry or from a university to discuss ways of reducing carbon emissions.
- Follow this up by showing learners YouTube clips of wind turbines, their component parts and the materials used to make the wind turbine blades; also show them a model of a wind turbine and/or ask them to make one and revise the electromagnetic effect.
- Ensure learners investigate the materials making up wind turbine blades, their

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useful properties and their limitations.

- Introduce solar photovoltaic cells and demonstrate how they convert light energy into electricity.
- Discuss with the learners the use and benefits of solar photovoltaic cells.
- You could follow this up by showing learners YouTube clips of photovoltaic cells, their component parts and the materials used to make them. You could also show them a model of a photovoltaic cell and/or ask them to make one.
- Ask learners to investigate the materials that make up solar photovoltaic cells, their useful properties and any limitations of the materials.
- Introduce the concept of LEDs and discuss with the learners the use and benefits of LEDs.
- You could follow this up by showing learners YouTube clips of LEDs, their component parts and the materials used to make them. You could also show them a model of a LED and/or ask them to make one.
- Ask learners to investigate the materials that make up LEDs, their useful properties and any limitations of the materials.

Discuss with the learners the use and benefits of fuel cells such as in transport.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

Units in the new NQF Level 3 BTEC Applied Science qualification that link to this unit are listed below:

- *Unit 1: Principles and Applications of Science I*
- *Unit 3: Science Investigation Skills*
- *Unit 5: Principles and Applications of Science II.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Journals

Chemistry World

Royal Society of Chemistry – latest news and articles.

Materials World

The Institute of Materials, Minerals and Mining.

Nature

An international journal covering research spanning all areas of science.

New Scientist

Latest news and articles about science and technology.

Physics World

Institute of Physics – latest news about physics articles and stories.

Scientific American

Latest science stories, articles and news.

Videos

www.bbc.co.uk/programmes/p01pz6yx

Elemental Business Carbon Materials – BBC iPlayer.

<https://www.youtube.com/watch?v=x2zjdtxrisc>

How Photovoltaic Solar Cells Work.

www.youtube.com/watch?v=WYqCnEvTRUQ

Introduction to composites.

<https://www.youtube.com/watch?v=xufi4RuFjnM>

Material-efficient LED production in Germany.

www.youtube.com/watch?v=0_UDX21rPSE

Metals and their corrosion.

www.youtube.com/watch?v=YCpGQ_aMb7I

Wind turbines: How do they work?



www.en.wikipedia.org/wiki/Wind_turbine_design

Wind turbine design and materials for blades.

www.youtube.com/watch?v=MoDbzxUdV70

What are the major types of material PV cells are made of?

Websites

www.ase.org.uk

Association for Science Education – science resources for tutors, journals, textbooks, useful links.

www.extremetech.com/extreme/183690-ceramic-fuel-cells-could-be-the-future-of-green-at-home-power-and-heat-generation

Ceramic Fuel Cells.

www.bbc.co.uk/programmes/p02rncvm

Elements: Carbon(C) – Materials – BBC iPlayer.

www.bbc.co.uk/schools/gcsebitesize/design/resistantmaterials/materialsmaterialsrev2.shtml

GCSE Bitesize Metals and their corrosion.

www.cleapss.org.uk

Supporting practical science and technology with regard to health and safety.

www.HSE.gov.uk/coshh

Health and Safety Executive information about the 'Control of Substances Hazardous to Health'.

www.HSE.gov.uk

Health and Safety Executive – information about health and safety.

www.howstuffworks.com

How stuff works – resources on different materials and properties.

www.auto.howstuffworks.com/fuel-efficiency/alternative-fuels/fuel-cell.htm

How fuel cells work.

<http://www.explainthatstuff.com/windturbines.html>

How wind turbines work.

www.iop.org

Institute of Physics – resources about theoretical and practical physics, journals, textbooks, useful links.

www.iom3.org/materials-world-magazine

Materials World Magazine.

www.madehow.com/Volume-1/Light-Emitting-Diode-LED.html

Light Emitting Diode.

www.nationalstemcentre.org.uk

National STEM centre – resources for practical experiments and projects.

www.nationalstemcentre.org.uk/elibrary/resource/2726/it-s-a-material-world

National STEM centre – 'It's a Material World'.

www.fuelcells.org/base.cgim?template=teachers

National STEM – Fuel Cells 2000 – resources and lesson plans.

www.nationalstemcentre.org.uk/elibrary/list/10907/fuel-cells-and-biofuels

STEM – fuel cells and biofuels.



www.rsb.org.uk

Royal Society of Biology – resources about theoretical and practical biology, journals, textbooks, useful links.

www.rsc.org.uk

Royal Society of Chemistry – resources about theoretical and practical chemistry, journals, textbooks, useful links.

www.stemnet.org.uk/ambassadors

STEM ambassadors – central hub for allocation of speakers to schools/colleges.

www.iom3.org

The Institute of Materials, Minerals and Mining – resources, journals, magazines and articles.



Unit 23: Forensic Evidence, Collection and Analysis

Delivery guidance

Approaching the unit

As this is an optional unit, no previous knowledge of forensic evidence collection or analysis is assumed. Learners may bring their knowledge of forensic evidence collection from watching different forensic science television programmes and documentaries.

You should encourage learners to research how investigators preserve, identify and gather evidence from a range of crime scenes, which will enable them to piece together the crime itself. They should look at how to gather forensic evidence using appropriate methods to maintain the integrity of the forensic evidence and demonstrate the importance of health and safety when collecting and analysing forensic evidence. Learners must also understand the importance of documentation methods to forensic investigation.

You should also encourage learners to research different types of forensic evidence that may be collected from crime scenes and the information this can give about the suspect and victim.

Learners will conduct scientific analysis of physical, biological and chemical evidence left at a crime scene to draw rational and balanced conclusions from observations of analysis.

Learners must be given the opportunity to practise the techniques of identifying, recording and gathering evidence as part of the investigation process. They should also look at the importance of presenting the evidence in court.

To complete this unit your learners will need access to a range of research materials, which could include the internet, journals or magazines, and books.


You can use a range of delivery methods in this unit, for example:

- discussions – class and small group discussions on types of forensic science evidence found at a scene
- scenario and mock crime scene – for example, a mock crime scene car to carry out search and recovery
- practical work – for example, chemical presumptive tests to analyse bodily fluids (blood, semen, saliva)
- research – government legislation relating to road traffic.

Delivering the learning aims

Group work is an acceptable form of delivery but you must ensure that learners individually produce evidence that is sufficient for assessment.

For **learning aim A**, learners need to be introduced to the practices and procedures involved in evidence collection and the roles of authorised personnel at the crime scene. Learners will need to understand who would have access to



crime scenes and why. Learners should also be able to identify the who (victim, perpetrator, witnesses), when (timeline), where and what (motive and modus operandi) of the crime scene. You could deliver a short presentation and demonstration on the preservation and recovery of evidence at crime scenes. This should include restriction of access, observation and recording of the scene and identifying evidence. Learners should understand the prevention of contamination, and how to collect, package, store and transport evidence. You will need to address legislation including the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health (COSHH) Regulations 2002 and the Management of Health and Safety at Work Regulations 1999.

For **learning aim B**, learners need to investigate a simulated crime scene using forensic procedures. You will need to discuss the collection of biological evidence, such as blood, hair, saliva, semen, bones and fingerprints. You can then go on to look at the collection of chemical evidence, including drugs, poisons, and firearm discharge residue (FDR). For collection of physical evidence, you should cover footprints, tool marks, firearms, ammunition, documents and technology (such as phones or computers). Other important investigative considerations that learners should be made aware of include prevention of contamination, security, records and full documentation of procedures and methods.

For **learning aim C**, learners will need to conduct scientific analysis of physical, biological and chemical evidence. You could introduce the sub-topics by a presentation that describes and explains the different analyses that learners can carry out on evidence collected from a crime scene. You should give a demonstration of appropriate techniques. The aim is for learners to conduct analysis on the forensic evidence they collected from the mock crime scene. You will also need to explain roles in other areas of forensic science, including entomologists, forensic anthropologists, forensic profilers and palynologists.

For **learning aim D**, learners will need to be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis. You could introduce the topic via a short presentation on reporting methods. Learners will need to be able to justify all the methods used, assess their findings, draw conclusions and include aspects of probability from their investigations, while evaluating the techniques used. They should be able to give evidence of good practice and areas for improvement. Learners may find learning aim D particularly challenging when trying to write an expert witness statement to conclude their results. It would be worthwhile giving learners examples of witness statements to model structure and content.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand how to gather forensic evidence, the integrity to forensic investigation and the importance of health and safety	A1 At the crime scene A2 Preservation and recovery of evidence A3 Search patterns A4 Health and safety	A written report that demonstrates understanding of how to gather forensic evidence. The report should display a high level of presentation.
B Investigate a simulated crime scene using forensic procedures	B1 Collection of biological evidence B2 Collection of chemical evidence B3 Collection of physical evidence B4 Other important investigative considerations	Process a simulated crime scene. Learners should be given a simulated crime scene with a forensic scenario. They should preserve the scene and process the scene, documenting their practical work. They should include photographs of their evidence. Supported with an observation document, completed by the assessor.
C Conduct scientific analysis of physical, biological and chemical evidence	C1 Physical evidence techniques C2 Chemical evidence techniques C3 Biological evidence techniques C4 Other areas of forensic science	Portfolio of laboratory examination forms, that includes drawings and photographs where appropriate, method sheets and results of analysis carried out. Supported with an observation document, completed by the assessor. A report, explaining the scientific techniques and the conclusions drawn from analysis.
D Be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis	D1 Interpretation of evidence D2 Presentation of evidence D3 Provisions of forensic service	An appropriately structured expert witness statement that includes conclusions, explanations and aspects of probability.

Assessment guidance

This unit is internally assessed through a number of assignments that will include independent tasks. Each assignment should cover at least one entire learning aim and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion. There are a maximum of three suggested assignments for this unit, with learning aims C and D combined to one summative assessment.

All learners must independently generate individual evidence that can be authenticated. The main sources of evidence are likely to be written reports, portfolios and observation documents to authenticate work. Learners should incorporate in-depth research that is corroborated by a fully referenced bibliography.

Learners could also produce presentations. Suitable forms of evidence for a presentation are, for example, slides, preparation notes, script, cue cards, peer assessment records and an observation record. Observation records alone are not sufficient sources of learner evidence; the original learner-generated evidence must also support them. Assessors should remember that they are assessing the content of the presentation against the learning aim and not the skill with which the learner delivered the presentation.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 23: Forensic Evidence, Collection and Analysis

Introduction

Begin by introducing the unit to learners through a discussion explaining forensic science as a specialist branch of science in relation to law. This can be followed by outlining the learning aims of the unit.

Learning aim A – Understand how to gather forensic evidence, the integrity to forensic investigation and the importance of health and safety

- Give learners pictures of authorised and non-authorised personnel to provoke their thoughts. Learners should contribute their thoughts about who would have access to crime scenes and why. From this discussion, you should draw up a list with the learners of the personnel who can access a crime scene.
- Give a short presentation and demonstration on the preservation and recovery of evidence at crime scenes.
- You could divide your learners into small groups and give some of them scenarios of different crime scenes. Ask them to produce lists of evidence they would collect and methods of collection. Learners could use the internet to research and make notes on the relevant health and safety legislation's importance when entering and processing a crime scene. The use of a visiting speaker could help learners understand forensic science evidence collection and the importance of health and safety.
- In small groups, your learners could carry out research into search patterns using peer-reviewed websites. They could produce information posters, with pictures and descriptions of the search pattern, explaining the science behind it. Learners should give examples of crimes where each search pattern would be appropriate. They could then share these resources with the rest of the class, and use the resources to collect the relevant information needed for their assessment.
- Use the learners' research to lead a discussion on search patterns.
- You should give learners appropriate parts of the Health and Safety at Work Act 1974 (and subsequent updates), Control of Substances Hazardous to Health (COSHH) Regulations 2002, Management of Health and Safety at Work Regulations 1999. You should also introduce learners to the Use of Disposable Personal Protective Equipment (PPE). You could lead a discussion on these health and safety considerations in relation to given scenarios.
- Encourage the learners to come to a conclusion about the significance of health and safety considerations in relation to the integrity of evidence and discuss consequences of not adhering to health and safety standards.
- When the assessor is satisfied that learners are familiar with policies and procedures, importance of documentation methods, health and safety and preservation and integrity of evidence required when investigating a crime scene, learners will need to carry out the assessment for this learning aim.

Unit 23: Forensic Evidence, Collection and Analysis

Learning aim B – Investigate a simulated crime scene using forensic procedures

- Introduce different types of biological, chemical and physical evidence. You could ask learners to work in groups to discuss the most suitable ways to collect and package evidence, and justify why they are the most appropriate.
- You should give demonstrations of all the collection methods and packaging methods most appropriate to the evidence that is being recovered. You should also give the learners opportunities to practise methods of collection and packaging before they carry out their simulated crime scene.
- You could model the examination process by demonstrating a forensic examination on a mock crime scene in the classroom and give out exemplar crime scene notes/records. You could ask the learners to take notes of your examination by documenting the order of the techniques you carry out and the method you use.
- For assessment, learners will need to carry out a forensic examination of a simulated crime scene with a given scenario. You should therefore give learners the opportunity to practise this before assessment, but this should not be the same activity. The scenario could be, for example, a mock crime scene car containing biological, chemical and physical forensic evidence such as a bloodstained t-shirt, suspect white powder, ransom note. They could work in groups and should use appropriate forensic procedures to gather biological, physical and chemical evidence. Group work is acceptable, but for assessment it must be clearly identified how each learner achieved the targeted criteria. Learners must have the opportunity to understand how to document the scene including taking photographs of the scene and each piece of evidence. They are required to make full crime scene notes. It is important to give learners samples of contemporaneous crime scene notes as a model of what is expected.
- Learners should be encouraged to take into account and demonstrate health and safety considerations and you should ask learners to complete a risk assessment, indicating potential hazards, risks, controls and emergency procedures.
- Learners could work in groups after the mock crime scene to discuss their examination and justify all the procedures used. They could then feed this back to the class via a mind map central for all to use to gather the information.
- Learners should be encouraged and taught how to evaluate all the procedures they used to process their simulated crime scene; they should draw conclusions about their ability to carry out each procedure and suggest ways in which they could improve their practical work. Learners should evaluate how they maintained safety and how they ensured the integrity of evidence.
- When learners have had the opportunity to practise and refine their skills in carrying out a forensic examination of a crime scene, and collect and process evidence, they will be assessed for this learning aim following the directions in the assignment brief.

Learning aim C – Conduct scientific analysis of physical, biological and chemical evidence

- You could begin by introducing biological analysis techniques appropriate to the evidence collected from the simulated crime scene and the techniques listed in the unit content.
- Learners should research each technique either in a group or independently. Research should include the scientific theory behind the technique. They could

**Unit 23: Forensic Evidence, Collection and Analysis**

produce flip cards for each technique with a description of the technique and how it is carried out on one side and the scientific explanation of how the test works and the results that can occur from the analysis, on the other side.

- You should demonstrate each technique and equipment involved where possible, and give learners the opportunity to practise the techniques they may use when analysing their forensic evidence.
- You could present learners with an exhibit room/box, which holds forensic evidence of interest. They should produce a plan of what evidence they are going to analyse, the equipment they will need, the techniques they are going to perform stating what they hope to achieve. Once this has been agreed by you, they should start their analysis as an opportunity to practise the skills required for assessment. They must include photographs, sketches and laboratory examination documentation to record their practical work. Learners should have opportunities to discuss and draw valid conclusions from the analysis of physical, chemical and biological evidence. You should give learners exemplar conclusions from different practical investigations and encourage them to produce appropriate conclusions from their practical investigations.
- When learners have acquired the necessary skills for analysing and explaining techniques in analysis of evidence, assessment will be undertaken using the assignment brief.

Learning aim D – Be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis

- You could begin by enabling learners to discuss the process through from the crime scene to preparation of the case for court, as this is what the assessment criteria and guidance require. You should introduce the role and expectations of an expert witness in court. You could show learners videos of experts presenting evidence in court. Learners need to understand how comprehensive documentation from the evidence gathering and scientific analysis process can be brought together, interpreted and compiled in a case file.
- You should supply the learners with two examples of expert witness statement, one exemplary practice and one less adequate example. You could ask them to work in groups to identify which is better and why.
- Learners could base their report around these models. The expert witness statement report should enable the learners to present valid conclusions, evaluate the techniques used in forensic science to analyse the physical, chemical and biological evidence gathered and evaluate the findings, including aspects of probability.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 25: Forensic Fire Investigation*
- *Unit 26: Forensic Traffic Accident Investigation.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/en/support/published-resources.html>) for more information as titles achieve endorsement.

Textbooks

Flanagan, R.J., Taylor, A., Watson, I.D. and Whelpton, R., *Fundamentals of Analytical Toxicology*, Wiley-Blackwell, 2008 (ISBN: 978-0470319352). This book contains details of techniques used in organic chemistry in relation to poisons and drugs of abuse.

Jackson, A.R.W. and Jackson, J.M., *Forensic Science*, 2nd edition, Prentice Hall, 2007 (ISBN: 978-0131998803). This book is both comprehensive and accessible.

Langford, A., Dean, J., Reed, R., Holmes, D., Weyers, J. and Jones, A., *Practical Skills in Forensic Science*, Prentice Hall, 2005 (ISBN: 978-0131144002). This book contains details of forensic practical evidence collection skills.

Moore, P., *The Forensics Handbook*, Eye Books, 2004 (ISBN: 978-1903070352). This book contains information about securing and processing crime scenes.

Pepper, I.K., *Crime Scene Investigation: Methods and Procedures*, Open University Press, 2005 (ISBN: 978-0335214907). This book contains information about taking photographs and the recording, recovery and comparison of evidence.

White, P.C., *Crime Scene to Court: The Essentials of Forensic Science*, The Royal Society of Chemistry, 2004 (ISBN: 978-0854046560). This book details how crime scene and forensic examinations are conducted in the UK, the principles of crime scene investigations and the importance of this work in an investigation.

Journals

Biological Sciences Review

Chemistry Review

Chemistry World

Journal of Forensic Sciences

New Scientist

Physics Review

Science and Justice



Websites

www.biozone.co.uk

Biology resources for learners and tutors.

www.chemsoc.org

Royal Society of Chemistry.

www.fbi.gov

Federal Bureau of Investigation.

www.forensic.gov.uk

The Forensic Science Service.

www.forensic-science-society.org.uk

The Forensic Science Society.

www.hsegov.uk/pubns/indg342.pdf

Health and Safety Executive guidance for employers and employees on blood-borne viruses in the workplace.



Unit 24: Cryogenics and Vacuum Technology

Delivery guidance

Approaching the unit

This unit gives you great opportunities to introduce your learners to the realities of modern practical applied science. You will be helping them: to experience how physics principles guide equipment and experiment design; to understand and to match industrial standards of safety and cleanliness; and to be motivated by the value that their technical science expertise can add for competitiveness in industry, for better human health and comfort, and for broadening the horizons of new research.

The physics principles elements build on the topics 'thermal physics' and 'fluids' from *Unit 5: Principles and Applications of Science II*, or alternatively on the 'materials' and 'thermodynamics' topics in A level Physics.

Wherever possible, you should make initial learning happen through practical, hands-on experience. Most of the physics principles can be explored through creative use of a fairly limited set of cryogenics and vacuum equipment. With a good practical understanding of basic principles, you will then be able to use site visits and video resources to extend learners' interest into much larger or high-tech applications, beyond the scope of a school or college laboratory.

Delivering the learning aims

Learning aim A should extend learners' understanding of physics principles just sufficiently for them to come to grips with the practicalities of achieving and holding cryogenic temperatures and rough or high vacuum pressures.

Use practical investigations to help learners become very familiar with graphical representation of the state of a gas or vapour and to introduce the usefulness of logarithmic scales (e.g. pump-down time vs. pressure). From these you can lead into the interpretation of phase diagrams and psychrometric charts, and you can illustrate the possibility of refrigeration using a closed cycle, such as the Carnot cycle.

Starting from the kinetic theory model of matter, introduce the concept of entropy, both in terms of a measure of random disorder and as the indicator for the direction of natural processes like heat transfer (i.e. the Second Law of Thermodynamics). Also introduce the relationship $T = dQ/dS$, discovered independently in the 19th century through the study of the efficiency of heat engine and refrigeration cycles. Point out how at very low temperatures tiny heat inputs will make significant changes in entropy and it becomes increasingly difficult to remove heat and lower the temperature of a system. Hence, you can deduce the existence of an absolute zero for temperature (the Third Law of Thermodynamics) and move on to the definition of practical temperature scales, using the concept of thermal equilibrium (the Zeroth Law).

You can directly link heat transfer both by conduction and by radiation to practical work on cryogenics – see learning aim B below. You should reference the different types of convective heat transfer to the mean free path, and

learners can then explore them through observing the changing efficiency of a high vacuum diffusion or turbomolecular pump as pressure changes.

By linking at every step the physics principles with their applications in vacuum technology or cryogenics, you can help the learners to gain a practical feel for the subject.

Textbooks for **learning aim B** tend to be written at quite an advanced level, but an accessible introduction, written by a senior scientist at CERN and suitable for use by learners, is available via the internet – see Resources below.

The use of liquid nitrogen (LN₂) will be your main and perhaps only way of carrying out cryogenic experiments in your school or college laboratory. This is intrinsically hazardous, so you should teach the safety aspects at the outset. All practical work, and particularly the initial filling of other vessels with LN₂ from a Dewar storage vessel must always be closely supervised. Nevertheless, in this unit learners should get hands-on experience with using cryogenic fluids such as LN₂. Good safety awareness and corresponding responsible behaviour and confidence are important learning outcomes.

Learners may only be able to gain experience of mechanical methods of cryogenic cooling by visits to external establishments, but you can use an ordinary domestic/laboratory refrigerator to introduce the principle of cooling by using a vapour compression cycle.

Point out that the temperature differences we are inducing in cryogenics are extreme compared with those normally experienced. Hence, you can help learners to appreciate the large changes that occur in properties like thermal conductivity, which we normally consider to be fairly constant. Introduce learners to searching for data on material properties at low temperatures and to using them both in design calculations and to check against their own measurements.

Thermometry at low temperatures will give good opportunities for quantitative practical work. Use thermometer calibration work to help learners understand and apply the principles of temperature scales (from learning aim A). A platinum resistance thermometer is an appropriate standard instrument against which to calibrate, and boiling LN₂ can give a useful fixed point of temperature. Learners can calibrate thermocouples or carbon resistor sensors that they then use for more dynamic temperature measurements – e.g. the gradual warming of a LN₂ cooled sample and measurement of one of its physical properties at various temperatures or, in the case of thermal conductivity, over a temperature range. Designing investigations of this kind will give you and the learners practical contexts for discussing and applying techniques for heat-sinking, insulation and radiation shielding.

A good place to start **learning aim C** might be for you to show learners the right procedure for using a rotary backing pump to pump down a system to rough vacuum. This can enable you to cover all the main safety issues and to introduce some gauges (e.g. capsule and Pirani). There is a widely used and accessibly written textbook on vacuum technology – see Resources below – which you should try to make available to learners, at least for reference. The catalogues of the major vacuum equipment manufacturers also make excellent learning reference materials.

Because pumping a vacuum is not at all like piping water, it is important that learners develop a new 'common sense' about vacuum systems from practical experience. So, it is worthwhile for them to spend time on apparently simple practical tasks like measuring pump-down time against pressure achieved for different pumps, and with different arrangements and sizes of pipes and



chambers. This means that they can gain a lot of valuable experience using only a limited collection of vacuum kit.

In high vacuum experiments, leak detection becomes a particularly important feature. Ideally, you should try to give learners experience of using both a spark (Tesla) tester, which works well on glass pipes and chambers, and a helium leak detection method. You will probably not have access in your own laboratory to an expensive mass-spectrometer helium leak detector, but because helium travels so much more quickly through a leak than does air you can still demonstrate the principle by looking for sudden movements in pressure indication on a Penning or ionisation gauge when helium is released over the suspect location. You (and any technician supporting you) will certainly need some way of identifying leaks if you are to achieve regular success in high vacuum experiments.

You will almost certainly not be able to have examples of every type of pump and gauge working in your own laboratory. But, once learners have grasped the fundamentals of vacuum then visits to or videos of larger and more specialist installations will usefully extend their vision and understanding. When explaining the functioning of equipment, old second-hand pumps, gauges etc. that can be opened and looked at inside are very good learning aids, which you may be able to source through your local industrial partners.

Learning aim D has a dual purpose:

- to introduce learners to the wide and exciting range of career opportunities associated with cryogenics and/or vacuum technologies
- to develop learners’ skills in critically evaluating the value and the financial viability of a specific application of technology.

Each learner will need, as well as gaining a good overview of the whole range of applications of these technologies, to focus on one specific application and to research and evaluate it in some detail. You should therefore aim to open up a number of differing research opportunities for them through links with industry and research organisations and by carrying out your own research into internet resources and publications. One very useful resource is the Cryogenics Impact Report – see Resources below.

Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Understand the principles of gases and vapours, temperature and heat (thermal energy) transfer that underpin cryogenics and vacuum technology	A1 Gases and vapours A2 Temperature A3 Heat-transfer mechanisms	Reports on items of cryogenic and vacuum equipment which correctly apply physics principles to explain aspects of design or performance. (Some or all of these could be directly linked with equipment used for investigations in learning aims B and C.)



<p>B Investigate the properties of materials at very low temperatures using cryogenic equipment</p>	<p>B1 Cryogenic equipment B2 Investigations of material properties at low temperatures B3 Awareness of hazards and safety</p>	<p>Research reports in which equipment function and design is explained, and selection justified.</p>
<p>C Explore common vacuum components so as to inform appropriate component selection and the use of correct operating procedures</p>	<p>C1 Vacuum measurement C2 Pumping principles C3 System design C4 Awareness of hazards and risks</p>	<p>Data and interpretation of results from practical investigations.</p> <p>Risk assessments that consider the major hazards arising from the technologies used.</p>
<p>D Explore the impact and potential of cryogenics and vacuum as enabling technologies in industry and research</p>	<p>D1 Industrial applications D2 Research applications D3 Cost benefit analysis</p>	<p>Research reports that include examples from each of the major areas of industrial and research application.</p> <p>A critical cost benefit study that uses both financial and outcome-based indicators.</p>

Assessment guidance

You should try to enable learners to give all or at least most of their assessment evidence from practical situations that they have witnessed – either through their own practical work, through visits or through high quality images or video material.

For learning aim A, the emphasis is practical application of principles. Evidence for the pass criterion can draw on explanations of a wider range of equipment as well as those items actually used by the learner during the course of study. However, in order to fulfil the learning aim A merit and distinction criteria, learners must make significant and valid use of physics principles in justifying elements of their experimental design and when analysing risks and sources of error for their own investigations related to learning aims B and C. When setting the brief for those practical investigations, you should therefore make this clear and explicit: e.g. by including prompt questions such as, 'How has your experimental design and choice of equipment been guided by physics principles?'

Note that, while they use similar criteria, the pass and merit for learning aims B and C are assessed separately. But the distinction criterion covers both these learning aims, and you should be looking for evidence of learners' consistent good practice in evaluating risks and accuracy across the reports from both investigation assignments.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 24: Cryogenics and Vacuum Technology

Introduction

Begin with some simple practical demonstrations using the equipment in your own laboratories – e.g. 1) cooling rubber, plastics and vegetable samples by immersion in liquid nitrogen (LN₂), and 2) using a rotary vacuum pump to evacuate a glass vessel in which a high voltage discharge can be produced. Use question and answer to highlight the key risks and the precautions you take for each. Explain to learners that the aim is for each of them to become proficient and confident in working with these technologies, and that because of the hazards they must first gain a good understanding of the physics principles involved.

Lead on to a brief discussion of the range of industrial and research applications you aim to cover together and highlight the industrial visits and other resources you will use in the coming programme.

Learning aim A – Understand the principles of gases and vapours, temperature and heat (thermal energy) transfer that underpin cryogenics and vacuum technology

- Start from learners' prior grasp of Kinetic Theory and introduce them to some online animations and/or laboratory models. Ask them in small groups to explore and explain, using those tools, what might happen to the behaviour and measurable properties:
 - of a gas or vapour as the number of particles in a chamber is reduced by the action of a vacuum pump? And as the temperature is increased or decreased?
 - of liquids or solids in a vacuum chamber?
 - of various types of solids at very low temperature? (Relate back to the demo of cooling in LN₂.)
- Start from learners' everyday experience of natural processes like mixing and cooling, and give some examples on video that can be played both backwards and forwards. Ask them in small groups to identify factors that determine the direction in time that natural processes follow, and to explain why we can so easily tell when the videos are being played backwards.
- Use discussion to introduce the concept of entropy and to develop learners' concepts of pressure and temperature, all at a molecular level.
- Introduce a short cycle of practical investigations (to be undertaken in groups of two or three) including Gas Law measurements and graph-plotting, thermometer calibrations, rough vacuum pump-down times and gauge comparisons.
- In each learning session, couple a practical time with a short whole class didactic and discussion time, in which knowledge of physics principles is taken deeper to cover all the remaining theory content.
- Conclude the learning in this section of the course with a discussion of how extreme low temperatures and sudden changes of pressure can create hazardous conditions; give a careful briefing and demonstration of key precautions.
- Assessment for this learning aim will mostly arise from the applications of physics

Unit 24: Cryogenics and Vacuum Technology

principles that learners explain in their reports on investigations undertaken for learning aims B and C.

Learning aim B – Investigate the properties of materials at very low temperatures using cryogenic equipment

- If possible, start with a visit to an industrial or research site that regularly uses LN₂ or other cryogenic fluids, or to the local depot of a cryogen supplier. Otherwise, use good video materials. Highlight and discuss with learners the safety issues surrounding the storage, transport and transfer of cryogens.
- Use demonstrations to illustrate the less obvious dangers of working with LN₂ – in particular the huge and rapid expansion and generation of pressure due to its boiling off; and the condensation of atmospheric oxygen on cold metal surfaces forming liquid oxygen drops and thus causing flammability and explosion hazards. Also, demonstrate how LN₂ moves and spreads rapidly when spilled, due to the Leidenfrost effect.
- Demonstrate how to safely decant LN₂ from your own laboratory storage Dewar into a smaller Dewar vessel, and then under close supervision allow each learner to carry out the operation. Use this process to initiate a familiarisation with each of the cryogenic experimental laboratory set-ups that learners will be using in this course. These could include:
 - thermometer calibrations (if not already covered practically within learning aim A)
 - measuring electrical resistance of metal wires cooled in LN₂ against temperature as they slowly warm
 - estimation of LED band gap energy by measuring and plotting resistance on a logarithmic scale against 1/T
 - Meissner effect (levitation) demonstration showing strong friction-free bearing performance
 - measuring the transition temperature for a high temperature superconductor sample
 - devising impact resistance or other strength tests for LN₂ cooled samples.
- Ensure learners' grasp of safety issues by insisting on a written method statement and risk assessment from each before they start independent work on any cryogenic experiment.
- For each of the listed types of cryogenic equipment that learners cannot directly experience in your own laboratory, use further industrial or research centre visits and/or video resources to illustrate both their functioning and application. (Encourage learners to take notes that will help with their upcoming research for learning aim D.)
- Hold discussion sessions around the design of experiments and processes seen – both in your own laboratory and those witnessed through visits and videos – identifying elements of thermal design and pointing out where compromises have had to be made.
- When learners carry out their own independent assessed investigations, ensure that at all times they have adequate supervision and access to technical safety advice from you or another experienced tutor or technician.

Depending on the size of the teaching group and availability of specialist equipment, it may be advisable to teach learning aims B and C in parallel so that learners can



Unit 24: Cryogenics and Vacuum Technology

simultaneously use experimental equipment for both topics on a carousel basis.

Learning aim C – Explore common vacuum components so as to inform appropriate component selection and the use of correct operating procedures

- Introduce vacuum practice with a step-by-step demonstration of using a backing pump to evacuate a chamber down to rough vacuum and then carefully letting it up to atmosphere again. Familiarise learners with mechanical and Pirani type vacuum gauges. Emphasise the precautions taken, e.g. against accidental overpressure due to a blocked outlet (or to incorrect rotational direction if a three-phase motor), filtering or piping away of oil-mist from the pump exhaust.
- Explain the theory of gas transport and show learners how to calculate conductance values and pumping speeds. Couple this with descriptions of the functioning of the various types of mechanical pump and their usual applications.
- Discuss with learners the challenges of accurately determining vacuum pressures, and introduce them to all the main types of gauge. Explain the properties often used as proxy for pressure, and the corrections needed with different gases.
- Enable learners to explore these pumping and measurement concepts through practical investigations that could include:
 - effect of different-sized pumps and different bore connecting pipes on pump-down time – to show that pipe conductance is more important
 - comparison of tube conductance for various lengths and diameters of pipe by measuring pump-down speeds
 - effects of known introduced contamination (e.g. air, nitrogen, dirty O-rings, solvent-cleaned O-rings, single drop of water) on pump-down times
 - comparison of rough vacuum gauges (e.g. Capacitance manometer, Pirani, Strain, Capsule Dial), controlling pressure by using a needle valve bleed
 - calibration of a Pirani gauge against a mechanical gauge for gases with differing thermal characteristics – e.g. air, argon, helium.
- Explain the functioning of both diffusion and turbomolecular pumps. Introduce learners to the practical use of your own high vacuum system(s) and to the extra precautions needed to ensure safe operation – especially the need to ensure adequate backing pump capacity and function at all times. Teach them how to carry out leak detection and how to achieve the highest possible vacuums by avoiding contamination.
- High vacuum investigations that you set learners could include:
 - comparison of high vacuum gauge readings – Penning and hot cathode ionisation types – at a range of pressures and with different gases
 - creation and observation of plasmas using various gases
 - thin-film coating using either resistance evaporation (e.g. of Aluminium) or sputtering techniques
 - freeze-drying of samples
 - measuring the impact of using a cold trap in conjunction with a diffusion pump
 - measuring the compression ratio of a turbomolecular pump over a range of backing pressure values.

**Unit 24: Cryogenics and Vacuum Technology****Learning aim D – Explore the impact and potential of cryogenics and vacuum as enabling technologies in industry and research**

- Your programme of industrial site and research centre visits for learners to see equipment and applications in use, and your use of high-quality video material to complement this, will ideally have been interspersed throughout the course so as to integrate with learners' growing knowledge of equipment and techniques. Conclude this programme, making sure that you have covered all the major areas.
- Give learners a case study in which cost and outcome data are presented to justify investment in cryogenics or vacuum technology for a particular industrial application or research project. This is an ideal opportunity to draw on expertise from local employers. A presentation from an industrial or research expert and/or access to real-life case-study data from a known local source will greatly enhance learners' experience.
- Guide learners in working through calculations and re-presenting the given case-study data so as to clearly lay out the arguments for and against the use of the technologies in this case.
- Complete the learners' preparation for undertaking their own case-study research by introducing them to an appropriate range of information sources and employer contacts. Also, rehearse with them how to reference and record in a bibliography all the sources they will use in their assignment report.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

The physics principles developed in this unit build on learning that can have been gained through prior study of the following:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 4: Laboratory Techniques and their Application*
- *Unit 5: Principles and Applications of Science II.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Harris, N., *Modern Vacuum Practice*, 3rd edition, McGraw-Hill, 2007 (ISBN: 978-0955150111).

A wide-ranging guide to vacuum practice and source of data for learners and tutors.

Pobell, F., *Matter and Methods at Low Temperatures*, 3rd edition, Springer, 2007 (ISBN: 978-3540463566).

A cryogenics practice reference text for tutors.

Official publications

WECD, *Cryogenics Impact Report*, Science & Technology Facilities Council, March 2015.

Websites

<http://www.montanainstruments.com/docs/An%20Introduction%20to%20Cryogenics.pdf>

CERN Laboratory for Particle Physics, Departmental report AT 2007-1, An Introduction to Cryogenics, Lebrun, Ph. An accessibly written and well-illustrated introduction for non-specialists, written by a senior scientist at CERN.

<http://cas.web.cern.ch/cas/Spain-2006/PDFs/Lebrun.pdf>

The above report as a presentation slide show.

<http://members.mrtc.com/anvk/cryogenics/cryogenics.html>

Alan Kuehner, Science Fun demonstration experiments with liquid nitrogen. Clear safety warnings with instructions, photos and videos.

<https://www.euro-fusion.org/fusion/jet-tech/vacuum-pumping-of-the-torus>

EUROfusion, Vacuum pumping – research for tomorrow's energy supply. A summary with photos of the large vacuum pumps used to evacuate the JET torus at Culham Centre for Fusion Energy in Oxfordshire.



Unit 25: Forensic Fire Investigation

Delivery guidance

Approaching the unit

As this is an optional unit, no previous knowledge of forensic fire investigation is assumed. Learners may bring their knowledge of forensic evidence collection through their experiences from Unit 23 and from watching different forensic science television programmes.

Learners should be encouraged to research and learn about how investigators gather evidence from a fire scene, which will enable them to piece together the sequence of events that led to the fire. They should also be encouraged to research different factors that may be involved in fire scenes and the interrelationships between these factors.

They should look at how fires are started and the phases a fire goes through; they will also study the behaviour of fire and heat transfer and how knowledge of these can aid a fire scene investigation.

Learners will study methods of processing a fire scene to determine the origin of the fire; they will understand the health and safety implications associated with a fire scene. They will study possible evidence at a fire scene that will help determine the origin of the fire. Learners will need to gain an appreciation of the importance of witnesses and documentation during the investigation. Learners will recognise the importance of other agencies involved in fire investigation and how the interactions between the different agencies will lead to successful conclusions about the circumstances that led to the fire.

To complete this unit your learners will need access to a range of research materials, which could include the internet, journals or magazines, and books.

You can use a range of delivery methods in this unit, for example:

- discussions – class and small group discussions on major factors that cause fires
- practical work – for example, combustion and extinction
- case studies – for example, roles of different agencies and how they interact
- research – for example, different ways to extinguish a fire.

Delivering the learning aims

Group work is an acceptable form of delivery, but you must ensure that learners individually produce evidence that is sufficient for assessment.

Learning aim A should cover sources of ignition and the chemistry of combustion and extinction. This learning aim should involve formal lectures, input from specialist speakers and learner research, accompanied by experimental work carried out in the laboratory on combustion and extinction of fires. It is important that both primary and secondary sources are covered and heat transfer, conduction, convection and radiation.



For **learning aim B**, you could introduce with a presentation, the causes of a fire. Present the learners with the phases of a fire and, in groups, they could research each phase and present the work back to the class. This could then be fed back to the class via a mind map central for all to use to gather information. You could cover the behaviour of fire through a visual presentation and with the use of video clips.

For **learning aim C**, the aim is for learners to understand methods used to process a fire scene. This learning aim should involve formal lectures, input from specialist speakers and learner research, accompanied by experimental work. Where appropriate, learners could carry out an investigation into a mock fire scene or picture-based mock fire scene. This learning aim should be as practical as it can be depending on the resources available. Once learners have conducted their investigation they should describe and justify all the methods used, they should assess their findings and draw conclusions as to the cause of the fire. You could introduce the topic of other agencies via a short lecture and the other agencies involved should be listed. The learners could brainstorm in small groups the interactions between each agency. They should research each agency and explain its importance in forensic fire investigation.

Where learners are carrying out practicals involving the chemistry of combustion and fire, they must adhere strictly to health and safety guidelines. Completion of a risk assessment is essential.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Explore the chemistry of combustion and methods for extinction and heat transfer	A1 Chemistry of combustion A2 Methods used for extinguishing a fire A3 Heat transfer	Portfolio of method sheets and results, supported with an observation document completed by the assessor. A report containing conclusions of experimental work, relating it to the theory of combustion that is being investigated. The report should also include the justification of extinguishing methods.
B Explore the cause, phases and behaviour of fire	B1 Causes of a fire B2 Phases of a fire B3 Fire behaviour	A visual presentation including a description of how fires are caused and the phases of a fire. A report explaining the behaviours of fire and how behaviour is influenced by the cause and surroundings.
C Understand methods involved in processing a fire scene and the role played by agencies in fire prevention and investigation	C1 Fire scene C2 Witness evidence C3 Documentation C4 Agencies involved in fire prevention and investigation	Learners should be given a mock scene or a vocational scenario. They should describe how they processed the scene in the way they did, justifying all of the methods used. A visual presentation, including a description of all the agencies involved, explaining and evaluating their role in the process of investigating a fire.

Assessment guidance

This unit is internally assessed through a number of assignments that will include independent tasks. Each assignment should cover at least one entire learning aim and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion. There are three suggested assignments for this unit, each covering one learning aim.

All learners must independently generate individual evidence that can be authenticated. The main sources of evidence are likely to be written reports, portfolios and observation documents to authenticate work. Learners should incorporate in-depth research that is corroborated by a fully referenced bibliography.

Learners could also produce presentations. Suitable forms of evidence for a presentation are, for example, slides, preparation notes, script, cue cards, peer assessment records and an observation record. Observation records alone are not sufficient sources of learner evidence; the original learner-generated evidence must also support them. Assessors should remember that they are assessing the content of the presentation against the learning aim and not the skill with which the learner delivered the presentation.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 25: Forensic Fire Investigation

Introduction

Begin by introducing the unit to learners through a discussion explaining forensic fire investigation as a specialist branch of forensic science. You can follow this by outlining the learning aims of the unit.

Learning aim A – Explore the chemistry of combustion and methods for extinction and heat transfer

- Give learners the fire tetrahedron as a stimulus to provoke thoughts on the components needed to start a fire. You could allow learners to carry out a candle burning experiment with different-sized beakers to simulate the necessity of oxygen in the fire tetrahedron. You should use questioning to draw from the learners possible sources of ignition and then deliver a short presentation on primary and secondary sources of ignition.
- In small groups, your learners could carry out research into combustion and extinction. They should produce notes and carry out investigations into the chemistry of combustion and extinction by performing experiments in the laboratory. Examples could include heating cooking oil to demonstrate the conditions required to start combustion (you could supplement this by demonstrating boil over).
- You could burn a solid hydrocarbon and draw out the products of combustion with a pump over cobalt chloride paper in order to show the presence of water and through limewater for the presence of carbon dioxide. You could demonstrate how to extinguish a flame by starving it of oxygen.
- To cover unit content on flame colours, depending on the materials involved in the combustion you could allow the learners to carry out flame tests. They can investigate the different flame colours by also burning various coated paper, for example glossy, waxed and newspaper.
- Learners should also carry out investigations into heat transfer. They will draw conclusions for all investigations carried out, linking them to the chemistry of combustion, extinction and heat transfer.
- For assessment, learners could produce scientific reports about each experiment they carried out discussing the chemistry of combustion, extinction and methods of heat transfer, from practical observations, using scientific terminology.

Learning aim B – Explore the cause, phases and behaviour of fire

- You could begin by introducing different causes of fire. You could give the learners scenarios and ask the learners to work in groups to conclude how the fire could have been started.
- Learners could then take part in a research task about the phases of fire. They could produce information leaflets about each phase. Lead a class discussion to clarify the phases, and build a mind map to document the learners' research.
- You could show the learners pictures or video clips of a fire starting and flame propagation. You should explain that flame propagation depends on the surroundings. Learners should research the spread of fire and how it depends on



Unit 25: Forensic Fire Investigation

the materials it comes into contact with, e.g. solid materials, thermal insulators, low thermal materials conductivity, low density materials, foamed plastics, thin sheets of material.

- Using the video clips or pictures, you should identify 'U' and 'V' patterns truncated and inverted cones, hourglass, spalling of concrete and plaster, caused from flames. You could give the learners pictures and ask them to describe and explain the patterns they identified.
- You could give learners a list of terms, e.g. point of origin, plumes ventilation, hot gas layer, flame over, flashover, full room involvement/post flashover, suppression. They could select two or three and you could ask them to find out definitions and make definition cue cards. All learners could use these to gather all the information needed.
- For assessment, learners are required to discuss and analyse how fire behaviour is influenced by its cause and the surroundings. They could produce a written report, ensuring they reference correctly to ensure authenticity.

Learning aim C – Understand methods involved in processing a fire scene and the role played by agencies in fire prevention and investigation

- You could begin by introducing the role of the fire scene investigator and the scientific method approach. You could give the learners a stimulus of various fire scenes and ask them to identify possible hazards. You should use questioning to draw from the learners controls and precautions to ensure safety of personnel during the scene examination.
- You could lead a class discussion and draw information from the learners' knowledge of crime scene investigation about the processing, preservation, access to authorised personnel only.
- You should demonstrate examination methods when processing the scene. You should demonstrate packaging and preservation of samples collected from a fire scene. If it is not possible to carry out a mock fire scene, it is essential that the learners are given scenarios to help them understand the methods involved with processing a fire scene. It is important that you give learners a model Incident Recording System (IRS), fire safety documents, diagrams, floor plans, etc.
- Ask learners to work in small groups to research other agencies involved in investigating a fire scene. They should write a description and evaluate their roles in relation to fire investigation.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 23: Forensic Evidence, Collection and Analysis.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Almirall, J.R. and Furton, K.G., *Analysis of Arson Evidence (Forensic Science Techniques)*, CRC Press, 2004 (ISBN: 978-0849378850).

DeHaan, J.D., *Kirk's Fire Investigation*, 6th edition, Prentice Hall, 2006 (ISBN: 978-0131719224).

DeHaan, J.D. and Icove, D.J., *Forensic Fire Scene Reconstruction*, 2nd edition, Prentice Hall, 2008 (ISBN: 978-0132228572).

Faith, N., *Blaze: The Forensics of Fire*, St Martin's Press, 2000 (ISBN: 978-0312261283).

Noon, R.K., *Forensic Engineering Investigation*, CRC Press, 2000 (ISBN: 978-0849309113).

Quintiere, J.G., *Principles of Fire Behaviour*, Delmar, 1997 (ISBN: 978-0827377325).

Redsicker, D.R., *Practical Fire and Arson Investigation*, CRC Press, 2007 (ISBN: 978-0849321337).

Websites

www.arson-codes.com

Corporate Investigative Services gives fire analysis consultation services.

www.communities.gov.uk

Communities and Local Government for a copy of an FDR1 form.

www.fidogs.co.uk

The Association of Fire Investigation Dog Handlers.

www.firesafe.org.uk

Fire Safety Advice Centre.

www.fireservicecollege.ac.uk

The Fire Service College.

www.fmglobal.com

FM Global is an insurance company: Pocket Guide to Arson and Fire Investigation.



www.gardinerassociates.com

Gardiner Associates supplies interagency fire investigation training to police and fire authorities.

www.ife.org.uk

Institution of Fire Engineers.

www.interfire.org

Gives resources for fire services, fire insurers, law enforcement, etc.

www.nfpa.org

National Fire Protection Association.

www.thefpa.co.uk

The Fire Protection Association is the UK's national fire safety organisation.



Unit 26: Forensic Traffic Collision Investigation

Delivery guidance

Approaching the unit

As this is an optional unit, no previous knowledge of forensic traffic collision investigation is assumed. Learners may bring their knowledge of forensic evidence collection through their experiences from Unit 23 and from watching different forensic science television programmes.

You should encourage learners to research and learn about how investigators gather evidence from the site of a collision, to enable them to piece together the sequence of events that led to the collision. Learners should also be encouraged to research different factors that may be involved in road traffic collisions and the interrelationships between these factors.

They should look at how physics of forces and motion are essential to successful road traffic collision investigation.

Learners will study evidence left at a crash scene and how this can be related to the momentum of the vehicles involved, this information can then be used in the reconstruction of events. Learners will need to gain an appreciation of the extent and nature of the damage that can be done to vehicles, their occupants and pedestrians in a collision.

You need to give learners the opportunity to practise the techniques of identifying, recording and gathering evidence as part of the investigation process. They should also look at the importance of the legislation associated with road safety.

To complete this unit, your learners will need access to a range of research materials, which could include the internet, journals or magazines, and books.

You can use a range of delivery methods in this unit, for example:

- discussions – class and small group discussions on major factors that cause road traffic collisions
- practical work – for example, friction to simulate surface and tyres, speed, kinetic energy, velocity
- case studies – to use equations to calculate motion, velocity and coefficient of friction from given traffic collision scenarios
- research – government legislation relating to road traffic.

Delivering the learning aims

Group work is an acceptable form of delivery, but you must ensure that learners individually produce evidence that is sufficient for assessment.

Learners will need access to simulated car crash scenes, a forensic science laboratory, a learning resource centre equipped with collision investigation and

forensic books, periodicals, journals, CD-ROMs, computers, scanners, printers and other associated ICT equipment and software.

Learners should also have access to PDFs of the Road Traffic Act 2006 and the Road Traffic Legislation Act 1984.

For **learning aim A**, introduce the topic by sharing a stimulus to provoke thoughts. Learners should contribute their thoughts about the stimulus, from this discussion you should draw from the learners the major factors that cause road traffic collisions. You could then deliver a short presentation on all the major causes of road traffic collisions. In small groups, your learners could then carry out research into two or more given major factors and produce information leaflets about these factors. All other learners could go on to use these resources or the internet to make notes on the relevant information needed for their assessment. A visiting speaker could help learners understand major factors affecting road traffic collisions especially for information on vehicle factors.

For **learning aim B**, you could introduce the topic by a presentation that explains the physics of movement and collision. You should give learners the equations and units of measurement, and worked examples to help with given scenarios. Group research will enable learners to understand these scientific terms and they could deliver their understanding via poster presentation to the group. These posters could be photographed and uploaded onto the centre's ICT system, or presented on the wall for the duration of delivery. Case studies/scenarios could be given to small groups to discuss the factors in the study that may have affected the driver's reaction time. This could then be fed back to the class via a mind map central for all to use to gather information.

For **learning aim C**, the aim is for learners to conduct a collision investigation and collect a variety of evidence at the scene, using appropriate techniques. The learners should be given a mock or scenario-based road traffic collision. Once learners have conducted their investigation they should describe and justify all the methods used, they should assess their findings and draw conclusions as to the cause of the collision, whilst evaluating the reliability of the evidence and the techniques used. Learners could formulate a report of their work. Learners could visit a vehicle site or use a vehicle to carry out their investigation. You need to explain documentation of the scene, the collection, packaging, preservation and transportation of evidence, as well as the chain of continuity and report writing. Owing to the difficulty in obtaining a vehicle, a crash scene could be simulated with model vehicles and appropriate props. Additionally or alternatively, learners could assess and process road measurement data and exhibits from the scene in a laboratory, using appropriate techniques.

For **learning aim D**, the topic could be introduced via a short lecture and the legislation listed in the unit content could be given to the learners either through suggested websites, on the centre intranet or paper copies. This learning aim should mainly involve formal lectures and learner research. It could also involve case studies, report writing and role playing. Learners may find learning aim D particularly challenging when trying to describe and discuss the legislation that applies to road traffic collisions. It would be worthwhile directing the learners to the appropriate sections of these documents and providing additional information where necessary. Small-group discussions and leading questions would be good to focus their thoughts.

Where learners may visit a vehicle site or use a vehicle to carry out their investigation, health and safety issues must be strictly adhered to. Completion of a risk assessment is essential.



Summary of the unit

Learning aim	Key content areas	Recommended assessment approach
A Investigate factors that cause road traffic collisions and injury	A1 Human factors A2 Environmental factors A3 Vehicle factors	Visual presentations including a description of the factors that cause road traffic collisions. A report explaining the relationship between the causal factors in road traffic collisions and the significance of each cause.
B Explore how science is used in the road traffic collision investigation process	B1 Physics of movement and collision B2 Driver's reaction B3 Scientific road traffic investigation techniques	Portfolio of method sheets and results of any speed, velocity or momentum investigations carried out, supported with an observation document completed by the assessor. A report relating the scientific techniques used in road traffic collision investigation.
C Use investigative techniques for road traffic collisions	C1 Investigative techniques C2 Equipment and materials used at the scene C3 Investigation aids C4 Cost of traffic collisions	Learners should be given a mock or scenario-based road traffic collision. They should describe how and why they processed the scene in the way that they did, justifying all of the methods used. They should present the findings of any practical work carried out.
D Understand legislation that applies to road traffic collision examination	D1 Road traffic acts D2 Criminal justice system referral	A written report, including a description of the road traffic acts, explaining and evaluating them in relation to road traffic investigation.

Assessment guidance

This unit is internally assessed through a number of assignments that will include independent tasks. Each assignment should cover at least one entire learning aim, and it is essential that a learning aim is assessed as a whole and not split into tasks or sub-tasks per criterion. There are four suggested assignments for this unit, each covering one learning aim.

All learners must independently generate individual evidence that can be authenticated. The main sources of evidence are likely to be written reports, portfolios and observation documents to authenticate work. Learners should incorporate in-depth research that is corroborated by a fully referenced bibliography.

Learners could also produce presentations. Suitable forms of evidence for a presentation are, for example, slides, preparation notes, script, cue cards, peer assessment records and an observation record. Observation records alone are not sufficient sources of learner evidence; the original learner-generated evidence must also support them. Assessors should remember that they are assessing the content of the presentation against the learning aim, and not the skill with which the presentation was delivered.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 26: Forensic Traffic Collision Investigation

Introduction

Begin by introducing the unit to learners through a discussion explaining traffic collision investigation as a specialist branch of forensic science. You can follow this by outlining the learning aims of the unit.

Learning aim A – Investigate factors that cause road traffic collisions and injury

- Give learners a stimulus to provoke their thoughts on road traffic collisions. The stimulus could be a video, picture, newspaper article or case study about a road traffic collision. Learners should contribute their thoughts on the stimulus and you should use questioning to draw from the learners the major factors that cause road traffic collisions. Add these to a mind map as they are identified.
- Give learners a short presentation that covers all the major causes of road traffic collisions and ask them to make notes.
- In small groups, your learners could carry out research into two or more given major factors using peer-reviewed websites, they could produce information leaflets about these factors, giving examples where appropriate, for example, how different drugs may affect drivers in different ways. These resources could then be shared and used by the rest of the class to collect the relevant information needed for their assessment. The use of a visiting speaker could help learners understand major factors affecting road traffic collisions, especially for information on vehicle factors.
- Using the learners' research, lead a discussion on the relationships between the major factors that cause road traffic collisions and ask them to consider how any relationships identified can increase road traffic collision or injury, for example, the relationship between human factors, such as lack of experience, and environmental factors, such as weather. This relationship may be a likely cause of a road traffic collision.
- Encourage the learners to come to a conclusion about the likelihood and significance of different factors in causing road traffic collisions. Give learners examples of conclusions. Learners may research statistics about road traffic collisions locally and nationally using this to back up their conclusions on the significance of factors and those which are more prevalent than others.
- For assessment, learners should produce a written report which evaluates all the major factors – human, environmental and vehicle – and their significance in causing road traffic collisions and injury. In the evaluation, learners will discuss the relationships and describe each factor. It is important to give learners samples of written reports and the skills for successful evaluation.

Learning aim B – Explore how science is used in the road traffic collision investigation process

- You could begin by introducing the physics of movement and collision, and how this is important knowledge necessary in the investigation of road traffic collisions. You should give learners the equations and units of measurements for each term specified under B1 and give worked examples to help with given scenarios.

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- Learners could then take part in group discussions to clarify these terms further. Small groups can research and become 'experts' on one or more of the following: Newton's laws of motion, conservation of momentum, conservation of energy, kinetic energy, principles of velocity, dynamic and static forces or coefficient of friction between road surface and tyres. New groups can then be formed containing an 'expert' from each of the earlier groups; knowledge should then be shared with their peers.
- You could give learners scenarios where they must apply their knowledge on physics of movement and collision, using the equations and correct units of measurement. Learners could be given differentiated scenarios based on their mathematical ability, taking into consideration other courses they may be studying simultaneously. Formative feedback should be given here to ensure that the learners can complete the assessed scenarios in the assignment task successfully.
- You could give learners method sheets to carry out practical investigations into speed, velocity and momentum and any other practical investigations that enhance the learning of the unit content. Learners could produce a portfolio of method sheets and present their results. They could draw short conclusions that relate the results to road traffic investigation. This should be supported with an observation document, completed by the assessor.
- Using the learners' practical results and calculations, lead a discussion on the scientific factors and how they are associated with road traffic collisions. Build a mind map to document the learners' thoughts.
- Learners could have group discussions on factors affecting drivers' reaction times, the research could be presented back to the class. Alternatively, case studies/scenarios could be given to small groups and they should discuss the factors in the study that may have affected the drivers' reaction times. This could then be fed back to the class via a mind map central for all to use to gather the information.
- For assessment, learners are required to have calculated motion, velocity and coefficient of friction from traffic collision scenarios. They could do this by completing given scenarios in the assignment as a task or an appendix. Learners could produce a written report which analyses the relationship between scientific factors in road traffic collision investigations; through their analysis they will discuss and describe each scientific factor.

Learning aim C – Use investigative techniques for road traffic collisions

- You could begin by introducing the techniques and equipment used to examine and process a road traffic collision.
- Demonstrate the use of techniques and equipment, allowing learners the opportunity to practise the techniques also.
- You could model the examination process by demonstrating an examination on a mock collision and give an exemplar of collision scene records. You could ask the learners to take notes of your examination by documenting the order of the techniques you carry out and the method you use.
- Ask learners to work in small groups to examine a simulated crash scene and produce collision scene records, which include important interview information, photographs, sketches and any additional data collected from the scene. They should write a description of the techniques and equipment they used and why they used it.
- You should give learners exemplar conclusions from different practical

**Unit 26: Forensic Traffic Collision Investigation**

investigations and encourage them to produce appropriate conclusions from their practical investigations as to the cause or causes of the collision they investigated.

- Learners could take part in small-group work and evaluate the techniques they used to investigate the scene explaining advantages of the chosen techniques. They may use the internet to research in more detail advantages of these techniques in road traffic collision investigation.

Learning aim D – Understand legislation that applies to road traffic collision examination

- You could begin by introducing the legislation listed in the unit content. This is a difficult topic so it may be best to break this into sections of legislation. Give learners sections of legislation that you consider to be the most appropriate in terms of road traffic collisions and the criminal justice system.
- Ask learners to work in small groups to discuss the legislation and give them leading questions about the legislation to allow them to focus their discussion.
- You could ask learners to produce a mind map or presentation about their particular section of legislation and its purpose and effectiveness. Learners should assess why these laws have been formulated and how effective they are. Learners could be given or research published data to help with explaining effectiveness.
- Give learners case studies that allow them discuss the different legislations that apply. Learners could discuss which laws were broken and the impact that this had or could have had.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- *Unit 2: Practical Scientific Procedures and Techniques*
- *Unit 14: Forensic Evidence, Collection and Analysis.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Applied Science. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Burke, M.P., *Forensic Medical Investigation of Motor Vehicle Incidents*, CRC Press, 2006 (ISBN: 9780849378591).

Cooper, S. and Orme, M., *Blackstone's Police Manual 2008 Volume 3: Road Policing*, Oxford University Press, 2007 (ISBN: 9780199229260).

James, S.H. and Nordby, J.J. (editors), *Forensic Science: An Introduction to Scientific and Investigative Techniques*, CRC Press, 2002 (ISBN: 9780849312465).

Meloan, C.E., James, R.E. and Saferstein, R., *Criminalistics: An Introduction to Forensic Science*, 8th edition, Prentice Hall, 2003 (ISBN: 9780131126817).

Noon, R.K., *Forensic Engineering Investigation*, CRC Press, 2000 (ISBN: 9780849309113).

Van Kirk, D.J., *Vehicular Accident Investigation and Reconstruction*, CRC Press, 2000 (ISBN: 9780849320200).

Journals

Accident Analysis & Prevention

Behavioural characteristics and involvement in different types of traffic collision. This Elsevier journal is useful as it investigates driver behaviour in relation to traffic collisions.

Websites

www.bigsums.co.uk

Free software for traffic collision calculations.

<https://www.gov.uk/government/organisations/department-for-transport>

The Department for Transport issues all government policies on transport from government initiatives to laws.

<http://think.direct.gov.uk>

The THINK! Road Safety website.

<https://www.gov.uk/speed-limits>

Government website on speed limits.



https://en.wikipedia.org/wiki/Traffic_enforcement_camera

Wikipedia definition of traffic enforcement camera.

https://en.wikipedia.org/wiki/Safety_Camera_Partnership

Wikipedia definition of safety camera partnership.

www.howstuffworks.com/breathalyzer.htm

This site gives information on how breathalysers work.

www.hse.gov.uk/research/crr_pdf/2001/crr01344.pdf

Health and Safety Executive research report: Accident investigation – The drivers, methods and outcomes.

www.itai.org

The Institute of Traffic Accident Investigators, giving information and statistics on road traffic collision and injuries.

www.lawontheweb.co.uk/roadlaw.htm

Legal information on motoring and road traffic offences.

<http://www.legislation.gov.uk/ukpga/1984/27/section/1>

You can download the Road Traffic Legislation Act 1984 PDF from this site.

<http://www.legislation.gov.uk/ukpga/2006/49/contents>

You can download the Road Traffic Act 2006 PDF from this site.

www.orsa.org.uk

Occupational Road Safety Alliance.

www.pepipoo.com/Road_Traffic_Acts.htm

Road traffic legislation.

www.roadpeace.org

RoadPeace, a UK charity providing support for victims of road crashes.

www.rospa.com/roadsafety

The Royal Society for the Prevention of Accidents, road safety advice.

www.worldbank.org/transport/roads/safety.htm

Road safety around the world.