EXAM GUIDE
NATIONAL 5 AND CfE HIGHER BIOLOGY, CHEMISTRY AND PHYSICS

Unmissable resource for National 5 and CfE Higher students tackling their exams this May
Content relates to SQA course reports highlighting challenging areas of past exams
Includes an amazing 30% OFF ALL Bright Red books until 8 April
For a while they seemed far away, but this year’s SQA exams are on the horizon and coming closer every day. You have slogged hard for seven months in class and the final tests are in your sights. In six weeks it will be time to put all of your learning down on paper and show off all of your hard work.

Biology, Chemistry and Physics are three of the most popular and important subjects taken in secondary schools. Good passes at National 5 and Higher can make a big difference when it comes time to decide what you want to do next.

Multi award-winning Scottish educational publisher Bright Red is delighted to partner with Scotland on Sunday to bring you this great supplement to help tackle your National 5 or Higher Biology, Chemistry and Physics qualifications. We have combed through the SQA’s latest course reports for each qualification and tried to include the most useful information we can to support your final revision push and exam preparation.

All of the first class material contained in this supplement is extracted from Bright Red’s Learn to Learn, National 5 and Higher Biology, Chemistry and Physics Study Guides. These guides are written by our expert authors and are custom-designed for the new CfE qualifications. They have helped tens of thousands of students understand their course and prepare for their exams. If you like what you see, you can purchase these guides online with our exclusive 30 per cent off discount code BEBRIGHTSCOTS at www.brightredpublishing.co.uk.

We have also included signposts to our completely FREE Digital Zone – www.brightredbooks.net/subjects.

With almost 60,000 registered users and more than 1 million tests taken to date, it is well worth registering online for even more content and support.

We hope that you find this CfE supplement of great use and very best of luck to you in your studies and in your final exams.

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The best revision/exam preparation books I have ever seen

Biology PT

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REFLECTIVE THINKING

Reflective thinking is a simple process that helps our brain to remember and apply information. With reflective thinking, you use keywords that act as prompts to link your memory to banks of information. You can then apply this information to a range of familiar and new contexts.

The reflective thinking process promotes the use of more complex thinking skills such as applying, analysing, evaluating and creating. As you progress through school, the work becomes more complex, and you’ll need these skills to complete more challenging assignments.

THE 3RS PROCESS – REVIEW/REMEMBER/RECALL

The review/remember/recall process is key to studying successfully for exams and assessments. The 3Rs process involves:

• gathering the information you want to learn
• retaining the information
• being able to recall and use the information when you need it in exams.

By using the 3Rs, you will learn and practise new study techniques, which in turn will enable you to learn what you need to know for your exams.

Learning to use different techniques will ensure that you are able to use the best method for learning a particular piece of work, and will also keep your brain more alert, so you are less likely to get bored.

You can think about the 3Rs as a learning cycle.

ACTIVE LEARNING AND STUDY

Active learning can mean different things to different people. For example, some people think that if they read over their work again and again, it will become more familiar and they will remember it. This isn’t active learning.

Active learning and study uses a much higher degree of mental (and sometimes physical) involvement, by actually doing things with the information you are trying to learn.

‘Active learning is learning which engages and challenges children’s thinking using real-life and imaginary situations. All areas of the curriculum can be enriched and developed through active learning.’

Education Scotland (2010)

As you become active in your learning and study, the amount and quality of what you learn improves. Active study is a part of each of the 3Rs stages. For example, in the remember stage, active study involves using various techniques to check if you can remember what you are trying to learn. You can do this on your own but your parents, family and friends can be a huge help too.
 STUDY PLANNING

Study involves using a variety of skills and techniques to help you to learn and prepare for exams and assignments. All SQA assessments and exams cover a broad range of knowledge, understanding and skills. You will need to develop different study skills and techniques to handle these.

You should develop a study plan that takes into account how you think and learn, the types of assessment and exams you are preparing for and the skills and techniques you will need to prepare for them. Your study plan should be developed and reviewed frequently.

STUDY PLAN

A good study plan is the key to effective learning. It will help you to systematically plan your work and it will also help to motivate you when you see the amount of work that you’ve covered in each subject. We’ve included an exemplar study plan below, but remember that this is only a suggestion, and that you can adapt it to suit your own needs.

An important part of any study plan is the amount of time spent on study. This will vary depending on who you are and the subjects that you’re doing. An optimum time for students in the senior phase (S4, 5, 6) is around two hours per session. This gives you enough time to commit more detailed information to the long-term memory so you can do more challenging activities in class and be better prepared for assignments.

Study plans also help you to allocate time for ongoing work such as homework and revision. The first priority for each session must be to complete homework. This will determine how much time is left available for revision.

HOW OFTEN?

If you’re really serious about doing well in your exams, you should be planning about five sessions per week. It’s up to you when you do them. Some people prefer working Monday to Friday, while others prefer to have Friday and Saturday free and work Sunday to Thursday.

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GETTING READY FOR EXAMS

SUPPORT

Remember – there are lots of people who want you to do well in your exams and who can help you with your studying.

In school, you can get support from teachers and tutors, and from other students.

Out of school, you can get support from friends and family. Being able to discuss and work through issues with your friends in the more relaxed atmosphere of each other’s houses can make learning more effective and fun. When they see you working with friends in this way, parents and guardians will understand the effort you are putting in and will want to get involved to help you.

Working with a study buddy and/or study group means that you can:

• Encourage each other to study even when you're not in the mood. Studying with friends makes learning more fun. (Just be careful that you spend your time studying, not chatting.)
• Share note-taking and research. If you have a long reading list or a lot of websites to search, split the research between you. Photocopy your notes for your buddy or group. Discuss these within the group to get the full context and depth of information for your answer. In some cases, you might just need the odd quote from the notes, but you won’t need to read through them all yourself. This will leave you more time for writing your assignments. (Remember – always note the source of your information for your references and bibliography.)
• Develop new ideas by discussing work with your group or study buddy – they might have different ideas or ways of approaching an answer that you could use.
• Develop a deeper understanding of the course materials by discussing and exploring them with your group or study buddy.

USE YOUR STUDY NOTES

Once you’ve made notes during your study time, never throw them away. Use them later to check that you remember the key concepts of the course. If there are things that you can’t remember, then build them into your study programme to go over again. This ensures there are no gaps in your learning.

Your notes should be condensed to include all the key points – especially those that you have most difficulty remembering. Write any really hard-to-remember key points in the spaces at the top or bottom of the pages so they will stand out when you flick through them. Look over these notes every day from about two weeks before the exam, so the points become really familiar and you remember them easily.

If there is something you still find difficult to remember on the day before the exam, write the key points onto a large sheet of paper, hang this on your bedroom wall and look at it frequently until you feel you have got the information in your memory.

BEFORE THE EXAM

You need to go into externally marked exams with a good idea of what to expect. You obviously won’t know the exact questions, but you should know the format of the exam (whether it involves multiple choice questions, short or longer answers).

SUBJECT-SPECIFIC VOCABULARY

Subjects tend to have words or phrases specific to their key concepts and key features. During your reflective thinking and when studying and preparing for your exams make sure that you:

• learn the correct subject-specific terminology and use it in your answers (use your preferred learning styles to do this)
• give a brief definition of the term or word. Knowing the definitions will be a great help when a question asks you to describe or explain the term.

The reflective thinking process – identifying keywords, adding definitions and applying them – will help your brain to get into the habit of identifying, using and applying subject-specific vocabulary.

It can help to create a dictionary of keywords as part of your study notes. Use the look/cover/write/check method to learn these off by heart. Study books and guides can sometimes let you know exactly which words to use.

PAST PAPERS

Once you have completed all, or key parts, of the course, look over past exam papers on the SQA’s website and practise writing your own answers. This is a recognised and effective method of improving exam performance. Compare your answers with the marking instructions. This will allow you to assess what you did well and what you still need to improve upon.

When you analyse or mark your answers, highlight the areas you did well in with colour coding or with a tick or comment. This is important because it lets you see that you have learned that area well, and will only need to look over it at intervals prior to your exam.

Highlight the areas that need more work and build them into your study plan. When you next complete a past paper question, check that you have done better and flag this up accordingly.

After you have answered a few questions, you will probably find that you’re able to predict the sorts of things you are asked in an exam. This means you are starting to apply the higher order thinking questions yourself. Remember to use this in your study and reflective thinking.
EXAM TIMINGS
As you get closer to the exam, start to develop an awareness of how long it should take you to answer the paper you are sitting without your study notes. Once you have a good knowledge of the content, time yourself as you are answering past paper questions.

Each subject and each paper will be slightly different. Some might be divided into three or four equal sections. If this is the case, work out how long you should spend on each section. At the top of your question paper, write down a time plan, so you know when you have to change to the next question. Say, for example, that the exam starts at 9:00am, is one-hour long and is split into four sections. Your time plan would look like this:

Section 1 – 9:00am
Section 2 – 9:15am
Section 3 – 9:30am
Section 4 – 9:45am

If the paper doesn’t divide up easily into sections, then simply work out what half-time is and try to get halfway through the paper by that time. For example, if a paper is an hour long, begins at 9:00am and has 14 questions all with the same number of marks, you should aim to finish question 7 by 9:30am.

Remember to allow time to read through the paper. The format and number of questions will vary from subject to subject, so practice doing as many past papers as you can to familiarise yourself with the questions and how long they take.

Stick to your time plan as much as possible. If you spend extra time on one section, it might get you one or two additional marks by adding more depth and detail, but it will reduce the amount of time you have for other questions, and if you don’t have enough time to answer them all, you could lose more marks overall than you gained.

This is a skill you should practice against the clock. It will get you used to the time pressure of the exam. When practising at home, use an alarm clock or set the alarm on your mobile phone to help you pace your answers.
National 5 Biology encourages you to become:

- a more confident learner
- a responsible citizen with an informed and ethical view of complex issues, through the study of relevant areas of biology such as health, environment and sustainability
- someone who thinks analytically, creatively and independently, and is able to make reasoned evaluations.

**CELL BIOLOGY**

**CELL STRUCTURE**

**CELL ORGANELLES IN PLANT AND ANIMAL CELLS**

Powerful microscopes, called electron microscopes, show that cells are much more complex than they appear through light microscopes, such as those used in schools. The detailed structure of cells that is revealed using electron microscopes is known as the cell ultrastructure. The small structures found inside cells are known as organelles. Each type of organelle has a specific function, although not all organelles are found in all cells.

The diagrams, left, show the organelles commonly found in plant and animal cells.

All cells have a cell membrane which forms the boundary of the cell. The cell is filled with a jelly-like material called cytoplasm in which chemical reactions take place. The cytoplasm contains the organelles.

The following table describes the various organelles and their functions, as well as stating where they are found.

<table>
<thead>
<tr>
<th>Organelle</th>
<th>Function</th>
<th>Organisms that have these</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus</td>
<td>This contains the cell chromosomes which are made of DNA. These hold the genetic information which controls cell activities.</td>
<td>Plants and animals</td>
</tr>
<tr>
<td>Cell membrane</td>
<td>This consists of phospholipid and protein molecules. It is selectively permeable and controls the entry and exit of materials in and out of the cell.</td>
<td>Plants and animals</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>This is the site of aerobic respiration. Mitochondria are found in greater abundance in cells with high energy demands, such as muscle cells.</td>
<td>Plants and animals</td>
</tr>
<tr>
<td>Ribosome</td>
<td>This is the site of protein synthesis. Ribosomes are found in the cytoplasm or attached to tubular structures in the cell.</td>
<td>Plants and animals</td>
</tr>
<tr>
<td>Chloroplast</td>
<td>This is the site of photosynthesis. Chloroplasts contain the green pigment chlorophyll, which absorbs light energy.</td>
<td>Plants</td>
</tr>
<tr>
<td>Vacuole</td>
<td>This contains cell sap, which is a solution of salts and sugars. It is important in maintaining the shape of the cell.</td>
<td>Plants</td>
</tr>
</tbody>
</table>

Plant cells also have an outer cell wall which is made from a carbohydrate called cellulose. This supports the cell and gives a structure to plant tissue.
MULTICELLULAR ORGANISMS

VARIATION AND INHERITANCE

AN INTRODUCTION TO VARIATION

The members of a species are not identical, even though they all possess genetic information for the same range of characteristics. Individuals show variations which make them different from one another.

Some variations may be due to effects of the environment which influence the development of an individual. These variations are unimportant to the species as a whole because they are not passed on from parent to offspring.

Other variations are caused by differences in the genetic information of individuals and these can be inherited. Sexual reproduction involves combining genetic information from both parents. This allows mixing of genes in different ways and so contributes to variation. The photographs show some examples of variation between members of the same species.

Genes can exist in different forms, each capable of producing a variant of a particular characteristic. The different forms of a gene are called alleles.

DISCRETE VARIATION

Discrete variation of a characteristic shows only a limited number of distinct possibilities. This type of variation is found in characteristics that are coded by a single gene with a limited number of forms or alleles.

Discrete variation has been important in the study of inheritance. Characteristics which have easily recognised variants are observed in successive generations. The patterns of their inheritance have allowed researchers to work out the mechanism involved.

Examples of discrete variation in humans include:

- ear lobe shape
  
  A) Free ear lobes
  B) Attached ear lobes

- tongue-rolling ability
  
  A) Tongue-rolling ability
  B) Non-tongue rolling ability

- blood groups

There are four possible blood groups. These are:

1. Group A
2. Group B
3. Group AB
4. Group O

CONTINUOUS VARIATION

Continuous variation of a characteristic shows a continuous range of possibilities between a minimum and a maximum value. There are no distinct groups and an individual's characteristic may have a value anywhere in the overall range of possibilities.

Continuous variation occurs because several different genes influence the same characteristic. Such a characteristic is said to be polygenic. When a number of genes contribute to a characteristic, it means that there are many different combinations of the various alleles involved. This produces many possible values for that characteristic, forming a continuous range of possibilities.

Examples of continuous variation include height, weight and hand span. Most visible characteristics are polygenic.

When the values for a polygenic characteristic are collected for a large number of individuals, it is found that they always show the same pattern of distribution. Most individuals show values close to the middle of the range, in other words a value close to the average.

This type of distribution is called a normal distribution. When it is plotted as a graph or chart, it shows a typical bell-shaped curve.

The photograph below shows a small group of people, all from the same university department, standing in order of their heights (in feet and inches).

The graph which follows it shows the distribution of their heights (in centimetres). The distribution is not a perfect normal distribution but the dotted line shows the overall pattern. If the sample size had been greater (more people included) then we would expect the pattern of height distribution to be closer to the typical normal distribution.
DNA REPLICATION

DNA must be replicated before cell division can occur, ensuring daughter (new) cells have a complete set of genetic information.

STAGES OF DNA REPLICATION

Requirements for replication:

- DNA
- ATP
- DNA polymerase (enzyme)
- the four types of DNA nucleotide
- primer
- ligase (enzyme)

DIRECTION OF REPLACEMENT

DNA polymerase adds nucleotides on to the 3' end of the strand. The strands run in opposite directions, which means that one strand can be built up continuously as the molecule unwinds; exposing a 3' end nucleotide – this is the leading strand. However, the other strand ‘opens up’ the wrong way to add nucleotides to the 3' end. Synthesis using this strand lags behind until enough of the template strand is exposed to add a primer and then add nucleotides to the 3' end. This is repeated in fragments as more template becomes exposed. A complete strand is made when the fragments are joined together by the enzyme ligase. This strand is the lagging strand.

POLYMERASE CHAIN REACTION (PCR)

DNA replication occurs naturally in cells before cell division to make complete copies of DNA. However, specific DNA fragments can be targeted and artificially amplified (increased in quantity) in laboratories by a process known as the polymerase chain reaction.

STAGES OF PCR

Requirements

- an original DNA sample to provide the template
- a stock of four DNA nucleotides
- heat tolerant DNA polymerase (an enzyme)
- a thermal cycler (an automated reaction vessel)
- buffer solution (maintains an optimum pH)
- copies of a DNA primer (which targets the fragment to be amplified)

PCR process

- DNA heated to 95°C to separate the original DNA strands.
- Sample cooled to 55°C. Complementary primers can now be added and bind (anneal) to the start of each strand.
- Sample heated to 72°C and Heat tolerant (thermostable) DNA polymerase is added.
- Complementary free DNA nucleotides are added to the 3' end of the new strands.
- The number of original molecules has now doubled – this is called amplification.
- Steps 1–5 are repeated, amplifying the DNA to make many copies.
METABOLISM AND SURVIVAL

MICROORGANISMS

Microorganisms can be divided into prokaryotes and eukaryotes.

Prokaryotes
- Bacteria do not have a membrane bound nucleus.
- Archaea look similar to bacteria when viewed using a microscope, again lacking a true nucleus. However, the DNA sequences of organisms in this group are different from those of bacteria. The membranes and metabolisms of archaea are specialised to allow organisms of this kingdom to survive in extreme environments, such as thermal vents (with temperatures >100°C), extreme saline water and extremes of pH. Many produce methane gas, being found in the digestive systems of mammals such as cows and humans.

Eukaryotes
- Algae are able to photosynthesise and are found in environments with available light and moisture.
- Protozoa do not photosynthesise. Most are motile and catch other microbes as their food source.
- Fungi (e.g. yeast) do not photosynthesise. Usually non-motile; they absorb nutrients directly from the environment.

CULTURE CONDITIONS

Growth of microorganisms in the laboratory requires:
- a water-based growth medium that supplies the appropriate nutrients for synthesis of molecules and a source of energy (if the microorganism cannot use light for photosynthesis)
- a suitable environment with appropriate temperature, pH and oxygen levels.

GROWTH MEDIA

Growth media can be used in either a liquid or solid form.

Liquid media
Liquid medium can be used in Petri dishes or flasks and is the growth medium used in most industrial fermenter vessels. In a typical fermenter, the growth medium (a broth) can be stirred, allowing nutrients and heat to be distributed evenly and aerobic conditions to be maintained (if appropriate). The composition of the growth medium can also be monitored and altered by the addition of substances; the growth medium can be withdrawn from the fermenter vessel for retrieval of useful products.

Solid media
Solid medium is produced by the addition of agar (a jelly-like substance) to a liquid medium, causing the liquid to solidify. Most culture work carried out in schools uses a solid medium (poured into Petri dishes while molten).

Media are also classified by the composition of nutrients that they contain.

Complex media
The exact chemical composition of nutrients in this media is ‘undefined’ or unknown, because the source of amino acids is a complex meat or yeast extract. Complex media set with agar in Petri dishes is used routinely for the culture of microbes in schools.

Defined media
The chemical composition of the medium is known and is in a relatively pure form. Some genetic studies and nutritional studies require defined media.

ENVIRONMENT

In order to produce the maximum yield of product, it is important to maintain optimum environmental conditions (sterility, temperature, oxygen level and pH).

SUSTAINABILITY AND INTERDEPENDENCE

THE TWO STAGES OF PHOTOSYNTHESIS

The light dependent stage of photosynthesis

When light energy is absorbed, it excites electrons in the leaf pigments and these high energy electrons are transferred along an electron transfer chain. This releases energy which is used:

1. for photophosphorylation of ADP to form ATP by the enzyme ATP synthase
2. for the photolysis of water, during which light energy splits water molecules into hydrogen and oxygen.

Hydrogen binds to the coenzyme NADP to form NADPH. Oxygen is released as a by-product of photosynthesis. These events take place in the grana of chloroplasts.

Carbon fixation in the Calvin cycle

The NADPH and the ATP from the light dependent stage are required for the light independent stage which occurs in the stroma of chloroplasts. Carbon dioxide is fixed by the enzyme RuBisCO which attaches it to RuBP (ribulose bisphosphate) to form 3-phosphoglycerate. This compound is phosphorylated by ATP and joins with hydrogen from NADPH to form glyceraldehyde-3-phosphate (G3P). G3P is used to regenerate RuBP and is also used to synthesise glucose. ATP supplies the energy for the reactions to take place.

There are several possible fates for the glucose produced in the Calvin cycle:
- Some will be converted into starch (a storage carbohydrate).
- Some will be converted into cellulose for cell walls (a structural carbohydrate).
- Some is used to produce energy in respiration.
- Some passes to other biosynthetic pathways.
DNA

THE STRUCTURE OF DNA

DNA is made up of sub-units called nucleotides, joined in strands. There are four types of nucleotide, depending on the base: adenine (A), thymine (T), cytosine (C) and guanine (G). Each strand is made up of nucleotides which form strong chemical bonds between a phosphate group of one nucleotide and the deoxyribose of another nucleotide: the sugar–phosphate backbone. The DNA molecule is double-stranded due to the formation of weak hydrogen bonds between the bases: adenine always bonds with thymine (A–T) and cytosine always bonds with guanine (C–G).

The strands are anti-parallel, meaning that they run in opposite directions. Each strand has a 3’ end and a 5’ end, determined by whether the third or fifth carbon on the sugar molecule of the nucleotide is closest to the end. The double-stranded DNA molecule twists to form a double helix.

CHROMOSOMES

The DNA is located in the membrane-bound nucleus and takes the form of chromosomes. The DNA in each chromosome is extremely long and thread-like; it must, therefore, be organised into tidy spools (a bit like spools of thread), so it cannot get tangled up. Each spool is composed of proteins with the DNA tightly coiled around them. This is how 2 metres of DNA is packed into the microscopic nucleus of every cell in the human body!

DNA REPLICATION

DNA must be replicated (duplicated) before cell division can occur, ensuring daughter (new) cells have a complete set of genetic information. Mitosis is the type of division that replaces diploid body cells; meiosis is the type that produces haploid gametes.

STAGES OF DNA REPLICATION

Requirements for replication:

- DNA
- ATP
- DNA polymerase (enzyme)
- the four types of nucleotide
- primer (a short sequence of nucleotides)
- ligase (enzyme)

1. The DNA molecule unwinds.
2. Hydrogen bonds break, ‘unzipping’ the molecule and exposing the bases of both DNA strands.
3. A primer attaches to one end of each exposed DNA template strand.
4. This initiates DNA polymerase to add free complementary DNA nucleotides to the 3’ end of the growing strand.
5. Hydrogen bonds form between the bases.
6. Strong chemical bonds form between the phosphate and deoxyribose sugar of adjacent nucleotides.
7. Ligase enzyme joins the fragments to form a complete strand.
8. Each replicated DNA molecule is made of one original template strand and a newly synthesised strand.

NEUROBIOLOGY AND COMMUNICATION

DIVISIONS OF THE NERVOUS SYSTEM

STRUCTURAL DIVISIONS OF THE NERVOUS SYSTEM

The nervous system consists of:

- central nervous system (CNS) – brain and spinal cord
- peripheral nervous system – peripheral nerves.

THE CENTRAL NERVOUS SYSTEM (CNS)

The central nervous system consists of the brain and spinal cord, and contains neurons (cell bodies, axons and dendrites) and their supporting cells (glial cells).
The peripheral nervous system can be divided into two functional parts.

<table>
<thead>
<tr>
<th>Part of brain</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebrum</td>
<td>Involved with conscious activities, such as sensation. Also recalls memories and alters behaviour in light of experience. The left cerebral hemisphere receives sensory information from the right side of the body, including the visual field, and controls the right side of the body.</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>Part of the central core of the brain, the cerebellum coordinates contraction of skeletal muscles and controls balance, posture and movement.</td>
</tr>
<tr>
<td>Medulla oblongata</td>
<td>Part of the central core, the medulla oblongata controls essential body processes, such as breathing, heart rate, arousal and sleep.</td>
</tr>
<tr>
<td>Hypothalamus</td>
<td>The hypothalamus is important in maintaining homeostasis and for regulating basic drive processes, such as sexual behaviour, drinking and eating.</td>
</tr>
<tr>
<td>Limbic system</td>
<td>The limbic system is involved in processing information for memories and influencing emotional and motivational states.</td>
</tr>
</tbody>
</table>

**Cerebrum**

The cerebrum consists of two cerebral hemispheres (left and right) that are connected by a bridge of nerve fibres called the corpus callosum. The corpus callosum is the only route of communication between the hemispheres. The surface of the cerebrum is folded, allowing more cell bodies to be present and maximising the number of connections between neurons.

**Functional Areas of the Cerebrum**

- **Somatosensory area**: receives sensory information from the internal organs, skin and muscles.
- **Language areas**: involved with controlling muscles required for speech (muses of the lips, tongue and larynx) and memory of vocabulary.
- **Visual area**: receives information from the eyes through the optic nerves. Interprets colour, shape and movement.
- **Association areas**: concerned with emotions, personality, intelligence, problem solving and creativity.
- **Auditory area**: receives information from the cochlea in the inner ear, through the auditory nerve. Interprets pitch and rhythm.
- **Motor area**: Controls the contraction of specific muscles. Just like the somatosensory area, the parts of the body are organised along the motor area.

**FUNCTIONAL DIVISIONS OF THE PERIPHERAL NERVOUS SYSTEM**

The peripheral nervous system can be divided into two functional parts.

**1 Somatic Nervous System**

The somatic nervous system is responsible for:
- voluntary control of skeletal muscles
- involuntary reflexes.

**2 Autonomic Nervous System**

The autonomic nervous system regulates the internal environment (for example, heart rate, body temperature and digestion). It has two divisions: sympathetic and parasympathetic. These perform opposing functions (and are, therefore, antagonistic), the sympathetic division preparing the body for action and the parasympathetic division returning the body to the resting state. For example, sympathetic nerves speed up the heart rate, while a parasympathetic nerve (the vagus nerve) slows down the heart rate.

**IMMUNOLOGY AND PUBLIC HEALTH**

**SPECIFIC CELLULAR DEFENCE**

**IMMUNE SURVEILLANCE**

Immune surveillance is a theory which suggests that a range of white blood cells constantly circulate within the body, monitoring for damage to tissues or invasion by pathogens. They may also detect cells which have become cancerous. In response to damage or infection, some white blood cells produce cytokines which increase the blood flow to the site of damage or infection, resulting in the accumulation of white blood cells, including phagocytes (involved in non-specific defence) and lymphocytes (specific defence).

**CLONAL SELECTION THEORY**

The body has a huge number of different lymphocytes, each with a different membrane receptor that is specific for one particular antigen.

**Stages in Clonal Selection**

- **Stage 1**: An antigen binds to its specific receptor on a lymphocyte.
- **Stage 2**: The specific lymphocyte undergoes repeated division, resulting in the formation of a clone of identical lymphocytes.

**CELL-MEDiated IMMUNITY**

**T Lymphocytes**

T lymphocytes are produced in the bone marrow and then migrate through the bloodstream to the thymus gland where they mature. T lymphocytes play a major role in cell-mediated immunity. In the cell-mediated response, there is a direct interaction between the T lymphocytes and invading pathogen. T lymphocytes can be distinguished from other lymphocytes by their cell-surface receptors (T-cell receptors or TCRs) which allow them to detect specific foreign substances (antigens) that enter the body. These specific surface proteins allow the T lymphocytes to distinguish between the body’s own cells (self) and foreign cells (non-self).

1. **Cytotoxic T cells** (also called killer T cells) destroy cells which the immune system regards as foreign (infected cells and tumour cells). They recognise antigens on these foreign cells, bind to the antigen and destroy the cells by apoptosis.

2. **Helper T cells** do not destroy infected cells, but secrete cytokines which activate B lymphocytes and phagocytes.
CHEMICAL CHANGES AND STRUCTURE

WRITING EQUATIONS

When a chemical reaction occurs it can be described by an equation. The equation will show the reactants (the starting substances) and the products (the substances that are made). The reactants and products are separated by an arrow, with the reactants on the left-hand side and the products on the right-hand side.

\[ \text{reactants} \rightarrow \text{products} \]

The chemicals involved in the reaction can be represented by words or by their chemical formula.

A word equation is the simplest type of chemical equation.

Consider the reaction of hydrogen with oxygen to produce hydrogen oxide (water).

The word equation for this reaction is:

\[ \text{hydrogen} + \text{oxygen} \rightarrow \text{hydrogen oxide} \]

A formula equation shows the correct formulae of all the substances involved in the reaction. The formula equation for this reaction is:

\[ \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} \]

State symbols

Chemicals can exist as solids, liquids or gases. Often reactions take place in aqueous solution (the substance is dissolved in water). State symbols can be added to the right of a chemical formula to indicate the state of the substance.

\[ \text{(s) = solid} \quad \text{(l) = liquid} \quad \text{(g) = gas} \quad \text{(aq) = aqueous solution} \]

For example, hydrogen gas would be written as \( \text{H}_2(g) \) and solid magnesium would be written as \( \text{Mg(s)} \).

BALANCED FORMULA EQUATIONS

In a chemical reaction the atoms present at the start are rearranged into new substances. During this process no atoms are lost or gained. This means that the total mass of the atoms before the reaction must equal the total mass of the atoms when the reaction is complete. A balanced formula equation is one that has the same number and type of atoms on each side of the equation.

EXAMPLE 1

The reaction of hydrogen with oxygen

\[ \text{hydrogen} + \text{oxygen} \rightarrow \text{hydrogen oxide} \]

\[ \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} \]

This equation is not balanced as there are two oxygen atoms on the left-hand side but only one on the right-hand side. Add an extra water molecule to give two oxygen atoms on each side of the equation:

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

Unfortunately, the equation is still not balanced. There are now two hydrogen atoms on the left-hand side and four on the right. Add an extra hydrogen molecule to the left-hand side:

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

The equation is balanced as the number of atoms on each side is the same.

Always:

- Place the balancing numbers in front of the chemical symbol. For example, \( 3\text{H}_2\text{O} \) is acceptable but \( \text{H}_3\text{O} \text{ and } \text{H}_3\text{O}_3 \) are not.
- Carry out a final check to ensure the same number of atoms appear on both sides of the equation.

Never:

- Change a correct chemical formulae. For example, the formula of magnesium chloride is \( \text{MgCl}_2 \). This would not be changed to \( \text{MgCl}_3 \) or \( \text{Mg}_2\text{Cl}_3 \) for any reason.

It looks like an oxygen atom has been lost – this is not possible.
The table shows some ester structures and their corresponding names:

<table>
<thead>
<tr>
<th>Name</th>
<th>Flavour/fragrance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethyl methanoate</td>
<td>raspberry</td>
</tr>
<tr>
<td>ethyl ethanoate</td>
<td>pear</td>
</tr>
<tr>
<td>pentyl butanoate</td>
<td>banana</td>
</tr>
</tbody>
</table>

**STRAIGHT-CHAIN ALCOHOLS**

that there are only carbon-to-carbon single bonds in the molecule.

in the middle of the name tells us because there is an OH group in the molecule, which means that it is not part -ane. The alcohol in drinks is called ethanol. Its name does not end in -ane because it is a straight-chain alcohol.

Another major use for alcohols is in making esters.

**WHAT ARE ALCOHOL MOLECULES?**

Alcohols are a group of compounds based on hydrocarbons that all have a hydrogen atom replaced with the –OH group (hydroxyl). They have many uses in our everyday life including alcoholic drinks and as disinfectants. Another major use for alcohols is in making esters.

The alcohol in drinks is called ethanol. Its name does not end in -ane. This is because there is an OH group in the molecule, which means that it is not part of the alkane homologous series. The -ane- in the middle of the name tells us that there are only carbon-to-carbon single bonds in the molecule.

**STRAIGHT-CHAIN ALCOHOLS**

Let us look at the first four members of the straight-chain alcohols family.

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>Full structural formula</th>
<th>Shortened structural formula</th>
<th>Molecular formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanol</td>
<td>H-C-CH3-OH</td>
<td>CH3OH</td>
<td>CH3OH</td>
</tr>
<tr>
<td>ethanol</td>
<td>H-C-CH2-CHOH</td>
<td>C2H5OH</td>
<td>C2H5OH</td>
</tr>
<tr>
<td>propanol</td>
<td>H-C-C-CH2-CHOH</td>
<td>C3H7OH</td>
<td>C3H7OH</td>
</tr>
<tr>
<td>butanol</td>
<td>H-C-C-C-C-CHOH</td>
<td>C4H9OH</td>
<td>C4H9OH</td>
</tr>
</tbody>
</table>

The -ol ending is used to identify the presence of the –OH functional group, which characterises the alcohols.

The general formula for the straight-chain alcohols is C\text{n}\text{H}_{2n+1}OH.

**ESTER NAMES**

Ester names are made up of two parts. The first part of the ester name comes from the alcohol that was used to make the ester (parent alcohol) and the second part of the ester name comes from the parent carboxylic acid.

If we use ethyl methanoate as an example, we can now work out that the carboxyl group of the acid and the hydroxyl group of the alcohol react together to form a new ester functional group –COO–. Look (right) at the structure of the ester.

Esters are made by reacting together a carboxylic acid and an alcohol. The carboxyl group of the acid and the hydroxyl group of the alcohol react together to form a new ester functional group –COO–. The amount of carbon-14 in the atmosphere has not changed in thousands of years. Even though it decays, new carbon-14 is always being formed when cosmic rays hit atoms high in the atmosphere.

Plants absorb carbon dioxide from the atmosphere through the process of photosynthesis; animals eat plants and release carbon dioxide through the process of respiration. This means that all living things contain carbon-14.

When a living organism, like a tree, dies it stops absorbing carbon dioxide. Carbon-14 has a half-life of 5730 years and undergoes beta decay. Scientists can use this information to determine the age of fossils or other dead organic matter by comparing how much C-14 there is in the dead organisms with that found in a living sample.

Carbon-14 is considered one of the most reliable means of determining the age of artefacts containing plant or animal matter, including some prehistoric materials up to 50000 years old.

**EXAMPLE 1**

A sample of wood taken from a wooden bowl uncovered during an archaeological dig was found to contain \( \frac{1}{2} \) of the carbon-14 sample taken from living wood.

Calculate the age of the wooden bowl.

After 1 half-life the activity would be \( \frac{1}{2} \) of its original value.

After 2 half-lives the activity would be \( \frac{1}{4} \) of its original value.

After 3 half-lives the activity would be \( \frac{1}{8} \) of its original value.

Therefore 3 half-lives have passed.

The age of the wooden bowl is \( 3 \times 5730 \text{ years} = 17190 \text{ years old} \).
substances without hydrogen bonding. Substances with hydrogen bonding will tend to be much more viscous than the viscosity. The stronger the intermolecular forces in a substance are, the more slowly the liquid will move when poured and so the greater viscosities. The stronger intermolecular forces between its molecules, which makes them more viscous. Propane-1,2,3-triol is the most viscous of the molecules shown all have hydrogen bonding between their molecules, which make the propane-1,2,3-triol molecules highly polar, resulting in relatively strong intermolecular forces between its molecules.

SOLUBILITY

Substances will tend to be most soluble in solvents with the same type of intermolecular forces as themselves. Compounds with polar molecules will tend to dissolve in polar liquids, whereas compounds with non-polar molecules will tend to dissolve in non-polar liquids.

Highly polar molecules, such as water, can be strongly attracted to positively or negatively charged ions, so many ionic compounds are soluble in water. Ionic compounds are not soluble in non-polar liquids.

VISCOSITY

Viscosity is a measure of how thick a liquid is or how slow it is to move. Thick, treacle-like liquids have high viscosities, runny liquids have low viscosities. The stronger the intermolecular forces in a substance are, the more slowly the liquid will move when poured and the greater the viscosity.

Substances with hydrogen bonding will tend to be much more viscous than substances without hydrogen bonding.
CHEMISTRY IN SOCIETY

GETTING THE MOST FROM REACTANTS

PERCENTAGE YIELD CALCULATIONS

Example:
When excess ethanoic anhydride was added to 14.4 g of salicylic acid, 6.26 g of aspirin were obtained. Calculate the percentage yield of aspirin given that the balanced equation for the reaction is:

\[
\begin{align*}
& \text{C}_7\text{H}_6\text{O}_3 \quad \text{salicylic acid} \\
& \text{mass of one mole} = 138.0 \text{ g} \\
& \text{C}_4\text{H}_6\text{O}_3 \quad \text{ethanoic anhydride} \\
& \text{mass of one mole} = 102.0 \text{ g} \\
& \text{C}_9\text{H}_8\text{O}_4 \quad \text{aspirin} \\
& \text{mass of one mole} = 180.0 \text{ g} \\
& \text{C}_2\text{H}_4\text{O}_2 \quad \text{ethanoic acid} \\
& \text{mass of one mole} = 60.0 \text{ g}
\end{align*}
\]

Answer:

We must first calculate the theoretical yield of aspirin assuming a 100% conversion of reactants into products. We can do this in the usual way using the balanced equation for the reaction.

Although the mass of one mole of all the reactants and products are given in the question, we really only need the mass of one mole of salicylic acid and aspirin in the calculation.

\[
\begin{align*}
& \text{C}_7\text{H}_6\text{O}_3 + \text{C}_4\text{H}_6\text{O}_3 \rightarrow \text{C}_9\text{H}_8\text{O}_4 + \text{C}_2\text{H}_4\text{O}_2 \\
& \text{1 mol} \quad \text{1 mol} \\
& \text{138.0 g} \quad \text{102.0 g} \\
& \text{14.4 g} \quad \text{180.0 g} \\
& \text{18.78 g}
\end{align*}
\]

The theoretical yield of aspirin is 18.78 g and the actual yield is 6.26 g. So by substituting these values into the percentage yield expression we obtain:

\[
\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{6.26}{18.78} \times 100 = 33.3\%
\]

RESEARCHING CHEMISTRY

LABORATORY APPARATUS

Familiarise yourself with diagrams of laboratory apparatus and techniques. Here are a selection of the ones you should learn:

- A diagram showing an evaporating basin being heated to boil off the solvent.
- A diagram showing the collection of gas over water.
- A volumetric flask and its sectional diagram.
- A diagram showing filtration which is used to separate a solid from a liquid.
- A diagram showing how to accurately read the volume of liquid in a burette.
- A diagram showing a pipette with a safety filler.
- A diagram showing safe heating using a water bath.
- A diagram showing filtration which is used to separate a solid from a liquid.
ENGLISH TYPYCATYCAPCTY

ATOMS, MOLECULES AND ENERGY
The atoms and molecules which make up every substance are continually moving at different speeds and with different kinetic energies. The temperature of a substance is proportional to the average value of these kinetic energies.

When heat energy is transferred to these atoms and molecules, they gain more kinetic energy.

When a substance is heated and its temperature rises, this is because the average value of the kinetic energy of all of the atoms or molecules has increased.

TEMPERATURE CHANGE AND HEAT ENERGY
To be able to determine accurately the amount of heat energy required to change the temperature of different materials a detailed study is needed.

When heat energy is added to or removed from a material, causing its temperature to rise or fall, the change in temperature depends on:

- the type of material
- the amount of heat energy added or removed.

The effect of changing each of these quantities is shown in the following experiments.

Experiment 1 - heating different materials
In the following experiment, equal masses of aluminium, water and iron were given the same amount of heat energy and the temperature change (ΔT) was recorded in each case. The results are shown in the table.

<table>
<thead>
<tr>
<th>Material</th>
<th>Heat energy added (J)</th>
<th>Temperature change ΔT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminium</td>
<td>37500</td>
<td>42</td>
</tr>
<tr>
<td>water</td>
<td>37500</td>
<td>9</td>
</tr>
<tr>
<td>iron</td>
<td>37500</td>
<td>78</td>
</tr>
</tbody>
</table>

The results show that when the same amount of heat energy is added to, or removed from, the same mass of different materials, the temperature change is different. The temperature change, ΔT, depends on a quantity called the specific heat capacity for the material (given the symbol, c).

The units for specific heat capacity are J kg⁻¹ °C⁻¹.

WAVES AND RADIATION
TYPES OF WAVES
There are two types of waves.

Sound energy is transferred by longitudinal waves. Light energy is transferred by transverse waves. Water and sound waves require particles to vibrate in order for energy to be transferred.

Water waves, when viewed from above, can be represented by a series of lines that are straight or curved depending on the wave pattern. Each line represents the crest of a wave. The distance between two lines is one wavelength.

<table>
<thead>
<tr>
<th>Wave type</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal wave</td>
<td><img src="image" alt="Longitudinal wave diagram" /></td>
</tr>
<tr>
<td>Transverse wave</td>
<td><img src="image" alt="Transverse wave diagram" /></td>
</tr>
</tbody>
</table>

WAVE DEFINITIONS

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>λ (lambda)</td>
<td>The shortest distance before the wave pattern repeats</td>
<td>metre, m</td>
</tr>
<tr>
<td>Frequency</td>
<td>f</td>
<td>Number of waves that pass a point in one second</td>
<td>hertz, Hz</td>
</tr>
<tr>
<td>Wave speed</td>
<td>v</td>
<td>The distance travelled in unit time</td>
<td>metres per second, m/s</td>
</tr>
<tr>
<td>Amplitude</td>
<td>a</td>
<td>Distance from the rest position to the top of a crest or the bottom of a trough</td>
<td>metres, m</td>
</tr>
<tr>
<td>Period</td>
<td>T</td>
<td>The time for one wave to be produced</td>
<td>second, s</td>
</tr>
</tbody>
</table>

The National 5 Physics course covers many of the major areas of physics. It will give you an insight into the underlying nature of our world and its place in the universe. From the sources of power that we use, to the exploration of space, it covers a range of applications and relationships that have been discovered through experiment and calculation, including those used in modern technology.
Newton’s Laws of Motion

The three Newton’s laws explain how forces act on objects and cause them to move or to stay still. Forces occur in many situations. A car engine provides the force which moves the car forward. Our weight is the force which keeps us on the ground.

Force of friction

Friction is a force which is present whenever an object moves or tries to move. The force of friction opposes the motion of an object. Air resistance, or drag, is a form of friction and also acts in the direction opposite to the motion. The frictional force of air resistance increases as the velocity of the vehicle increases.

Friction can be decreased by streamlining the shape of a vehicle’s bodywork so the air passes over it more smoothly. The forward force of the engine can be reduced accordingly, which reduces fuel consumption and improves the fuel economy of the vehicle.

The friction on a vehicle is deliberately increased when the vehicle brakes. Brake pads grip part of the wheel during braking, creating friction. When work is done against friction, kinetic energy is transformed into heat energy, thus causing the brake pads of the vehicle to heat up.

Newton’s First Law of Motion

Balanced forces

When the forces acting on an object are equal and opposite we say the forces are balanced.

Newton’s first law states that, when the forces acting on an object are balanced,

- if the object is moving, its velocity remains constant
- if the object is at rest, it will remain at rest.

An example of balanced forces is a car moving at constant velocity

Some examples of balanced forces

A space probe which has accelerated to extremely high velocity, perhaps 25000 km h⁻¹, will continue at this velocity when the rocket engine is switched off. There is no air to produce air resistance and no gravitational forces from planets or stars to slow it down. So, the space probe continues at constant velocity. This saves fuel and could make long distance space travel possible for future manned space exploration.

Newton’s Second Law of Motion

Unbalanced forces

When the forces acting on an object are unbalanced, the object no longer moves at a constant velocity, but will accelerate.

Consider the situation shown in this diagram where the forces on an object are not balanced. The resultant or unbalanced force on the object is 5 N (13 N – 8 N) to the right.

Newton’s second law states: \[ F = ma, \]

where \( F \) = the unbalanced force on the object (in N)
\( m \) = the mass of the object (in kg)
\( a \) = the acceleration of the mass (in m s⁻²)

When an unbalanced force acts on an object, its acceleration is directly proportional to the unbalanced force and inversely proportional to the object’s mass.

Example 1

Calculate the unbalanced force applied to a London bus of mass 1.7 × 10⁴ kg when it has an acceleration of 1.21 m s⁻².

\[ F = ma = 1.7 \times 10^4 \times 1.21 = 2.06 \times 10^4 N \]

Example 2

Calculate the acceleration of a 7.5 kg object when an unbalanced force of 52 N is applied to it.

\[ a = \frac{F}{m} = \frac{52}{7.5} = 6.9 \text{ ms}^{-2} \]

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The Higher Physics course is split into four mandatory units:

- Researching physics
- Our dynamic universe
- Particles and waves
- Electricity

**SKILLS, RESEARCH AND INVESTIGATIONS**

**SKILLS, KNOWLEDGE AND UNDERSTANDING**
As you study and carry out practical research and investigations in physics, you will develop skills as well as knowledge and understanding. Here are some skills you should aim for:

- **demonstrate** knowledge and understanding of physics by making statements, describing information, providing explanations and integrating knowledge
- **apply** physics knowledge to new situations, interpreting information and solving problems
- **plan and design** experiments or practical investigations to test given hypotheses
- **undertake** experiments competently and **safely**, recording detailed observations and collecting data
- **use** a variety of methods to select and present information **appropriately**
- **process** information using the correct **significant figures** and **units**
- **make estimates** and **predictions**
- **draw valid conclusions** and explanations backed up by evidence or **justification**
- **evaluate** experimental procedures, identifying sources of error and suggesting improvements
- **communicate** findings or information **effectively**.

**RESEARCH**
When researching unfamiliar areas of physics, either for a topic you are studying, or for an assignment, you should start with some written questions which you want to find out about. You can use printed resources, video or audio materials, websites or key phrases to enter into a search engine. When studying the topics in this book, you will find online and video references to develop your understanding of the topic.

You may wish to pursue further links to deepen your knowledge or understanding. You will be aware that not all sources are reliable and so you should collect and synthesise information from different sources. Take note of the sources used and also note key phrases or pieces of information as you go so that you can draw up explanations and conclusions in your own report later. List any justification of your findings.

**INVESTIGATIONS**
During your course you should gain experience of planning and carrying out practical investigative work. When you carry out a formal investigation you should use standard laboratory equipment if possible. Any unfamiliar equipment required should be researched or demonstrated to you.

When carrying out a formal investigation you should **report** it to a standard appropriate for a ‘Higher’, taking account of the following:

- **Numerical results** should be recorded in tables and graphs as appropriate. Headings and axes must be labelled and appropriate scales used.
- Lines of **best fit** to curves or straight lines should be drawn.
- Consider how relationships should be expressed. Straight lines could be expressed in the form \( y = mx + c \) and the gradient and intercept on the y-axis used to find \( m \) and \( c \). Or relationships could simply be stated as direct or indirect variation.
- **Measurements** should be **repeated** as appropriate and a mean value calculated.
- **Scale-reading uncertainties** should be estimated and expressed in absolute or percentage form.
- When measuring more than one physical quantity, the quantity with the **largest percentage uncertainty** should be identified and this can be used as an estimate of the percentage uncertainty in the final result.
- The **final** numerical result of an experiment should be expressed in the form: **final value ± uncertainty**.

**ESTIMATES AND OPEN-ENDED QUESTIONS**

**Estimates**
In this course you will study ranges of scale from sub-atomic particles to the largest expanse of the universe. You will be able to make an intelligent estimate of not only distances but quantities from other topics in physics. It helps to have your own mental list of familiar items to provide a mental ruler.

**Open-ended questions**
An open ended question is typically of the form **Use your knowledge of physics to explain ...**

You should make a statement of **principle(s)** involved, and/or a relationship or **equation**, and apply these to respond to the problem/situation. Develop and justify your argument. You will gain more marks for **breadth** and **depth** of understanding. Be aware you may have to correct a false statement. **Explain** how the physics applies.
THE DYNAMIC UNIVERSE

THE EXPANDING UNIVERSE

THEORIES ON THE EXPANDING UNIVERSE

Is the universe finite or infinite? Has it always existed or did it begin at some point in the past? Can we work out its size or age? These are the types of questions that astronomers have pondered for hundreds if not thousands of years.

Newton, having discovered the law of gravity, realised that it was always an attractive force, and so a finite universe would collapse in on itself.

Olbers thought that the universe must be finite or the sky would be filled with light everywhere.

Einstein's equations, from his General Theory of Relativity about gravity, told him the universe should either be expanding or collapsing, which contradicted his view that the universe was static.

Hubble, studying the redshift from galaxies, came to the explanation that the universe is expanding. Most scientific studies tend to reinforce this idea.

The expanding universe is finite in both time and space.

If the universe has always been expanding, will it continue to expand forever, will it expand at a constant rate or will it cease expanding and collapse in again?

It is thought that what happens to the universe can be determined by measuring how fast the universe expands relative to how much matter the universe contains. For the last 80 years, astronomers have been making increasingly accurate measurements of:

- the rate at which the universe expands
- the average density and mass of matter in the universe.

MASS OF A GALAXY

We can estimate the mass of a galaxy by the orbital speed of the stars within it.

Stars in a more massive galaxy will orbit faster than those in a lower mass galaxy. The greater gravity force of the massive galaxy will cause larger accelerations of its stars. Star speeds tell us how much gravity there is in the galaxy. As gravity depends on mass and distance, the size of the star orbits allow us to derive the galaxy’s mass.

We find that although most light and other radiation emit from near the centre, most mass is calculated as being near the edge of a galaxy. What is happening?

DARK MATTER

The stars and gas in most galaxies are moving much quicker than their luminosity predicts, so something must be adding to gravity that we cannot see. Does a new type of matter exist? Astronomers consider it may be made of planets, brown dwarfs, white dwarfs, black holes, or neutrinos but as it does not seem to emit any radiation we can detect (telescopes do not see it) it is assumed to be made of a new type of matter or exotic particles which we do not yet know about.

The overall mass of this new dark matter must be about five times the mass of matter we do know about.

DARK ENERGY

Gravity is the force which slows down the expansion of the universe. However not only does the universe appear to be expanding but the rate of expansion appears to be increasing.

That acceleration implies an energy that acts in opposition to gravity, which would cause the expansion to accelerate. Just like dark matter, this energy has never been detected directly through observation, and it has been given the name dark energy.

Dark energy is assumed to exist throughout the universe. Where galaxies are grouped together, gravitational force may predominate but distant galaxies are driven apart by this unknown energy.

INTERFERENCE OF LIGHT

YOUNG’S DOUBLE-SLIT EXPERIMENT

Thomas Young’s famous double-slit interference experiment from 1801 showed that light had wave properties. He concluded that light energy travelled as a wave motion. Using a single light source with the double slits he saw an interference pattern of a series of light and dark fringes. The single light source produces coherent waves. Diffraction at each slit produces circular wavefronts, which spread out so that they meet and produce interference.

Coherent waves have the same frequency, with a constant phase relationship (either they are in phase or have a constant phase difference).

PATH DIFFERENCE

Constructive interference takes place when the two light waves are in phase. The waves are in phase when the path difference, PD, is an integer number of wavelengths.

Constructive interference for a maxima or bright fringe occurs when PD = mλ.

m = 0 gives central maximum
m = 1 gives 1st maximum etc.
i.e. PD = 0, 1λ, 2λ, 3λ

Destructive interference takes place when the two light waves are out of phase. The waves are out of phase when a crest meets a trough.

Destructive interference for a minima or dark fringe occurs when
Δ = (m + 1/2)λ

m = 0 gives 1st minimum
m = 1 gives 2nd minimum etc.
i.e. Δ = 1/2λ, 5/2λ, 9/2λ

MEASURING THE WAVELENGTH OF LIGHT

The equation mλ = d sin θ can be used to calculate the wavelengths of light. The slit separation d and the angle θ to the mth-order maxima first needs to be measured.

For a maxima, the path difference = mλ.

Using trigonometry mλ = d sin θ.

THE RANGE OF VISIBLE LIGHT

The wavelength of visible light ranges from about 4 × 10⁻⁷ m to about 7 × 10⁻⁷ m.

Here are some spectral colours emitted from cadmium, given in nanometres (10⁻⁹ m):

- blue 480 nm
- green 509 nm
- red 644 nm

You can often find wavelengths on the exam data sheet.
EXAM TIMETABLES AND TIPS

EXAM TIMETABLES

<table>
<thead>
<tr>
<th>Monday 8 May</th>
<th>Morning</th>
<th>Course</th>
<th>Level</th>
<th>Time</th>
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<tr>
<td>Chemistry</td>
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<tr>
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<td>Human Biology</td>
<td>Higher</td>
<td>13:00 - 15:30</td>
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IN THE EXAM

THE EXAM CHECKLIST

You have worked really hard during the build-up to the exam, so now it’s time to put everything you have learned into practice. Do this, and you can be confident that you will perform well.

The following exam checklist can help you to gain marks in the exam. Make this part of your routine when you are practising past paper questions.

1. Read the instructions carefully.
2. Read the whole question first.
3. Note how many marks are to be awarded.
4. Which instruction words are used?
5. Underline the keywords in the question.
6. Answer your strongest section first.
7. Write the times.
8. Use diagrams.
9. If you are running out of time – prioritise.
10. If you are running out of time – use bullet points.
11. If you have time left at the end of the exam:
   ● Go back to any sections that you missed out or feel you didn’t answer as well as you could. Try to complete the answer or add more depth and detail into your work.
   ● Read over your answers. Make sure that what you have written is what you meant and will be understood by the examiner. You can also correct any spelling or grammatical errors.
   ● If you find you have made a mistake, correct it by using the space in the margin if necessary. If you don’t have space, then draw a line through the incorrect part and put the amendment at the end of the answer paper. Write a comment to tell the examiner to look for the correct answer at the end of the paper – for example:

   Please note: 2b is continued at the end of the answer paper.

   At the end of the paper, clearly mark which question the amendment is for – for example:

   Question 2b continued.

   THINGS TO REMEMBER

As you go into the exam room, your adrenalin will probably be pumping and you will feel nervous. That’s natural. Take a deep breath, start to read the paper and focus on the techniques and knowledge you have used in your preparation to give you the confidence to produce great answers.

After the exams, sit back, relax and look forward to your results – you’ve worked for them!

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