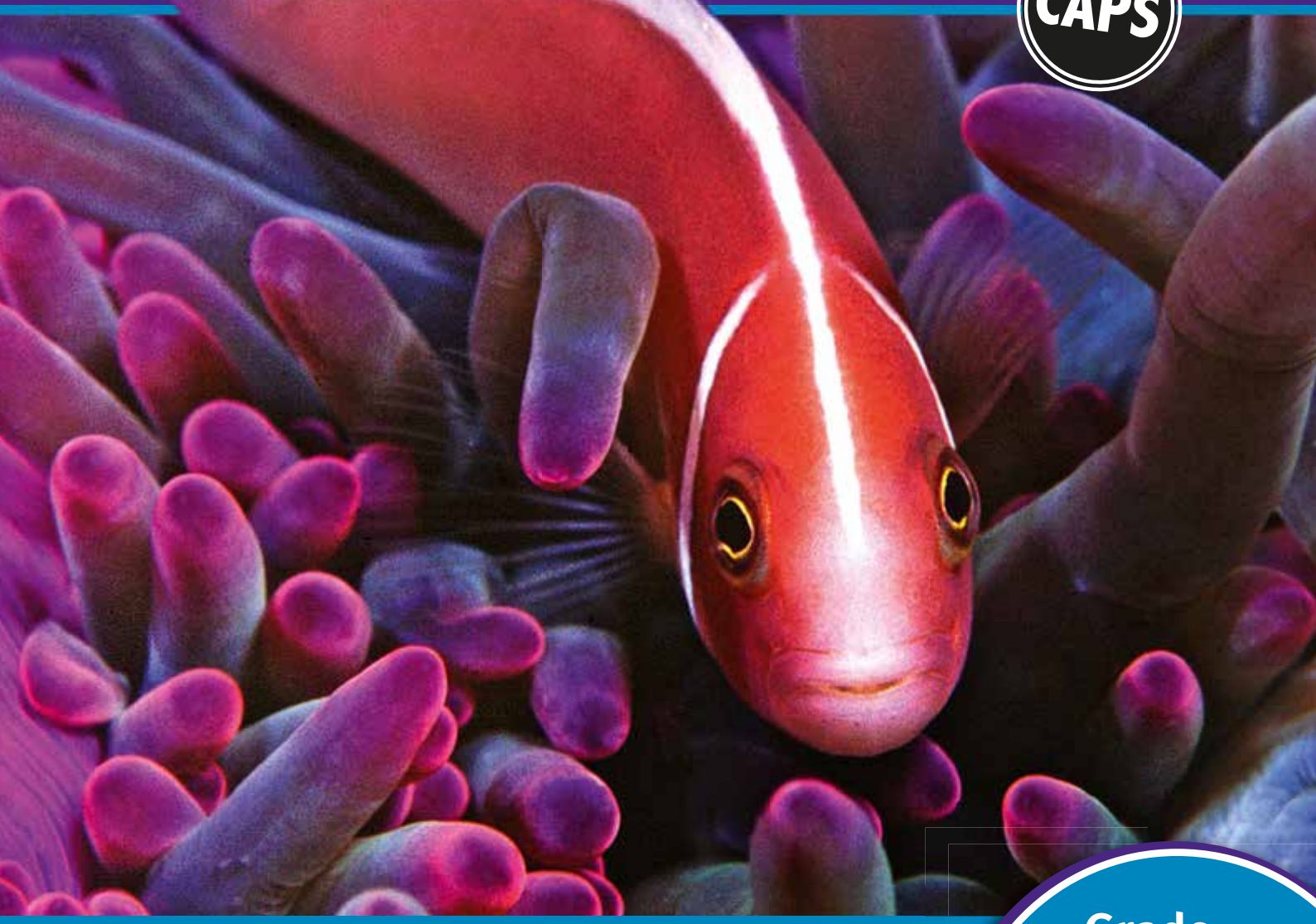
Study & Master

Physical Sciences

CAPS



Teacher's Guide

Grade 12

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Contents

Welcome to *Study & Master Physical Sciences* Grade 12. This course includes a Learner's Book and Teacher's Guide that provide the core material you need to cover the contents required by the Curriculum and Assessment Policy Statement for Grade 12 Physical Sciences.

In the Introduction you will find information about the core features of the National Curriculum and detailed advice on the Physical Sciences course in particular. Assessment is covered in Section B and explains how and when assessment should be done. Section B also contains two control tests with memoranda that can be used at the end of each term. Section C (Planning) contains a detailed phase plan, work schedule and lesson plan. The answers to all activities can be found in Section D. These include rubrics and checklists for formal and informal assessment of prescribed practical work. Section E contains photocopiable rubrics and sheets to record marks, and in Section F you can file your copy of the Curriculum and Assessment Policy Statement. You can also file your own documents in this section.

As a teacher at the Further Education and Training (FET) level, your two main resources are:

- your expertise in the subject
- your teaching experience – knowing how to help learners master the skills and knowledge of this subject.

The new Curriculum and Assessment Policy Statement (CAPS) makes two core demands on you as the teacher:

- to follow a learning programme that enables learners to develop all the skills, knowledge, values and attitudes relevant to Physical Sciences
- to have a sound, up-to-date knowledge of the content and methods of your subject, and a clear understanding of its social relevance, so that you can act as a guide, facilitator and subject expert in the classroom.

This handbook helps you to meet these demands in the following ways:

- it provides a structure for your teaching programme for the year and a work schedule that is in line with the CAPS requirements
- it provides solutions to all the activities in the Learner's Book
- it explains all the assessment requirements of the curriculum and provides practical activities with their rubrics and checklists that are required by CAPS
- it contains examples of generic rubrics, checklists and assessment sheets that you can use or adapt for your assessment work throughout the year.

SECTION A

INTRODUCTION

The National Curriculum Statement Grades R to 12 (NCS), which stipulates policy on curriculum and assessment in the schooling sector, was amended, and the amendments came into effect in January 2012. A single comprehensive **National Curriculum and Assessment Policy Statement** (CAPS) was developed for each subject to replace the old Subject Statements, Learning Programme Guidelines and Subject Assessment Guidelines in Grades R to 12.

General aims of the South African Curriculum

The National Curriculum Statement Grades R to 12 gives expression to knowledge, skills and values that are regarded to be worth learning. This statement will ensure that children acquire and apply knowledge and skills in ways that are meaningful to their own lives. In this regard, the curriculum promotes the idea of grounding knowledge in local context, while being sensitive to global imperatives.

The purpose of the National Curriculum Statement Grades R to 12

The National Curriculum Statement aims to:

- equip learners, irrespective of their socio-economic background, race, gender, physical ability or intellectual ability, with the knowledge, skills and values necessary for self-fulfilment and meaningful participation in society as citizens of a free country
- provide access to higher education
- facilitate the transition of learners from education institutions to the workplace
- provide employers with a sufficient profile of a learner's competences.

The principles of the National Curriculum Statement Grades R to 12

The principles of the National Curriculum Statement are:

- social transformation
- active and critical learning
- high knowledge and high skills
- progression
- human rights, inclusivity, environmental and social justice
- valuing indigenous knowledge systems
- credibility, quality and efficiency.

These principles can be applied to your school context in the following way.

Social transformation

What does this mean in your classroom? Your learners will come from families and communities that have been affected in diverse ways by South Africa's past. They will have many different ideas about the kind of future career they want and the kind of society they want to live in. In the learning programme that you plan for the year, you need to provide opportunities for the learners to analyse, research and come to understand the role that this particular subject plays in shaping the kind of society we want to create in South Africa and in offering them possibilities for their future.

For example: Create opportunities for learners to research and discuss questions, such as how many people in their families have studied Physical Sciences, and to what levels. How does access to Physical Sciences education relate to access to different kinds of employment? What factors influence people's access to and success in the subject?

Active and critical learning

What does this mean in your classroom? Many of the laws and principles in Physical Sciences have been developed and formulated over centuries. You need to explain the background of how these laws and principles were developed and the meaning and application of their formulation. Make the learners aware that scientific models are man-made ideas to explain scientific phenomena. These models can change when new discoveries are made.

For example: Newton's Laws makes more sense when it is explained in terms of the forces that act on the occupant of a car wearing a seatbelt.

High knowledge and high skills

What does this mean in your classroom? You, as a subject expert, should inspire your learners with relevant knowledge and activities that will encourage them to want to explore science in depth. Encourage them to relate what they learn to their lives outside school, and to possible future career paths. Strive to develop a high level of knowledge and skills in this subject in all your learners.

For example: Relate the study of particular Physical Sciences topics to future career paths such as electrical, chemical, and mechanical engineering; astronomy; medical sciences; electrical and telecommunications technology and agriculture. Where possible, create opportunities for learners to meet professional practitioners in these and other relevant fields. Set projects that challenge learners to apply their science skills outside the school context. Inform them about what they can expect to learn if they enrol for higher education in related scientific subjects.

Progression

What should this mean in your classroom? This Physical Sciences course contains material at the appropriate level to meet the criteria required for Grade 12. If you plan a learning programme using this course, you will ensure that your learners progress appropriately through the levels of knowledge and skills that the curriculum requires.

Human rights, inclusivity, environmental and social justice

What should this mean in your classroom? In all activities that you organise and facilitate, create opportunities to relate Physical Sciences to the broader social goal of promoting human rights, inclusivity, and environmental and social justice. Take into account that some of your learners might grapple with issues such as poverty, language and disability in their daily lives. Encourage them to explore these issues in ways that relate to this subject.

For example: Identify a social issue of relevance in the learners' community and help them design a small research project to gather and analyse information about this issue. This could relate to the availability of safe commuter transport (Newton's Laws) or the plastics pollution (Matter and materials).

Valuing indigenous knowledge systems

What should this mean in your classroom? This Physical Sciences course contains material that draws on indigenous knowledge systems and encourages learners to take these systems into account in their research and practical work. You should also draw on the expertise in your subject that may be available in your local community. Compile information about individuals and organisations in your region that can support your classroom work by means of relevant indigenous knowledge to which they have access.

Encourage learners to recognise sources of relevant indigenous knowledge in their own communities, and to include these sources in their research and practical project work.

For example: People from indigenous cultures have found ways to make beer and porridge from sorghum wheat.

Credibility, quality and efficiency

What should this mean in your classroom? The content of the Physical Sciences course has been reviewed by experts in their fields of chemistry and physics and covers all facets required to prepare learners to go on to study science at university and compete with the best in the world.

Qualities and skills of learners

The National Curriculum Statement aims to produce learners who are able to:

- identify and solve problems and make decisions using critical and creative thinking
- work effectively as individuals and with others as members of a team
- organise and manage themselves and their activities responsibly and effectively
- collect, analyse, organise and critically evaluate information
- communicate effectively using visual, symbolic and/or language skills in various modes
- use science and technology effectively and critically, showing responsibility towards the environment and the health of others
- demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

Inclusivity

Inclusivity should become a central part of the organisation, planning and teaching at each school. This can only happen if all teachers have a sound understanding of how to recognise and address barriers to learning and how to plan for diversity. We have included some guidelines below on how teachers can achieve the above.

Inclusive education and training should:

- acknowledge that all children and youth can learn, and that all children and youth need support
- accept and respect the fact that all learners are different and have different learning needs, which are equally valued
- enable education structures, systems and learning methodologies to meet the needs of the learner
- acknowledge and respect differences in children, whether due to age, gender, ethnicity, language, class, disability, HIV status, or any other reason.
- maximise the participation of all learners in the culture and the curriculum of educational institutions, and uncover and minimise barriers to learning.

What should this mean in your classroom? In this series of books the learners work together in groups and pairs, which gives them the opportunity to learn from each other, as well as at their own pace. The learning methodologies cater for learners with different learning abilities. Gender is also addressed as both

boys and girls are able to participate in all the activities. Learners also have the opportunity to learn about diversity within the subject matter covered.

Learners with physical barriers can work in groups or with a partner so they can be assisted where necessary. The teacher must therefore group learners with disabilities together with learners with other disabilities or no disabilities so they can support each other.

Special needs

In many classrooms, learners with special needs require additional attention; some learners require very little attention while others need more extensive help. As a teacher, be especially sensitive towards these learners without drawing too much attention to the learners' possible barriers to learning. Discretely make the fellow learners aware of the need to treat each other with respect without exception. This vital life skill should be engrained in all young people so that it becomes part of their personalities for the rest of their lives. The information that follows will assist you in addressing some of these special needs in your classroom in an inclusive way. Be aware of these and other special needs of learners in your classroom.

Partial sight or blindness: For partially sighted learners who find it difficult to read text, you could enlarge the text by using a photocopy machine. Also, ensure that these learners sit in the middle at the front of the class so that their poor eyesight does not become a barrier to their learning.

Alternatively – and especially in group work – read the text aloud to these learners. Remind the learners to read loudly, clearly and slowly as partially sighted and blind learners rely heavily on their memories. When doing experiments, these learners might not be able to see results. Train a few fellow learners with excellent social skills to convey results to their peers. It is also a good idea to let these learners stay in the groups where there are learners you have trained specially to help their challenged classmates.

Hard of hearing: Once again, these learners should sit in the front of the class. When giving instructions, or when reading text to these learners, the speaker or reader should face the learner directly and speak loudly and clearly, but without exaggerating. Learners who are hard of hearing learn to lip-read very early in life.

Impaired social skills: The nature of these difficulties varies, but could, in some cases, become a serious barrier to learning.

- Learners who are very shy or highly-strung might find class presentation extremely stressful. Although you should encourage them to develop this life skill, remember that you can never change someone's nature completely. Work gently with these learners – their shyness or nervousness may be the result of negative circumstances at home. Let them present their 'class presentations' in written form at first, and then move slowly as the year progresses, at first letting them present their work to one classmate only, then to a small group, and finally to the whole class.
- Children with ADS (Attention Deficit Syndrome, also known as ADD – Attention Deficit Disorder) will find it extremely difficult to work in groups or to sit still and concentrate for very long – in some cases having to listen for two minutes is too long. Learners with ADS could affect the class atmosphere and class discipline in a negative way, and although

everyone will agree that the deficiency is no fault of their own, they should not be allowed to ruin their fellow learners' education.

The school should have a policy that parents must inform the school confidentially if their child suffers from ADS. If learners have been diagnosed, they could be on medication. It is essential that teachers are informed; otherwise the learner could be branded as 'extremely naughty', which would be unfair and result in inappropriate handling. Teachers should be very careful not to judge a 'naughty' learner too soon. ADS is quite common, and in some cases may not have been diagnosed.

Look out for a learner who:
- finds it difficult or even impossible to concentrate
- frequently interrupts the teacher with irrelevant or seemingly 'stupid' questions
- fidgets all the time to the point of irritating peers
- jumps up frequently and asks to go to the bathroom (or somewhere else) at inappropriate times
- shouts out answers or remarks when the class has been asked to put up their hands
- is unable to deal with group work or pair sessions – these periods are interpreted as a 'free for all'
- shows signs of aggression when fairly disciplined
- argues with the teacher when asked to keep quiet.

Please note that:
- the disorder is more prolific among boys than among girls
- diet could play role in controlling the disorder – fast foods and junk foods should be kept to a minimum.

Extreme poverty: This barrier to learning requires extreme sensitivity from the teacher. If you know that there are one or more learners in your class who come from poverty-stricken backgrounds, you could handle the situation as follows: Learners are often required to bring resources from home, especially in practical learning areas like Physical Sciences. Some learners may be unable to afford additional resource materials: magazines for research; rulers; calculators and mathematical sets. Keep a supply of these items in your classroom without informing your learners and unobtrusively give them to those learners you know have difficulty in acquiring them. Be careful not to encourage 'forgetters' to make use of this offer! You could ask community groups in your area, such as churches, to provide support in collecting supplies of materials for you to keep in your classroom.

The key to managing inclusivity is ensuring that barriers are identified and addressed by all the relevant support structures within the school community, including teachers, District-based Support Teams, Institutional-level Support Teams, parents and Special Schools as resource centres. To address barriers in the classroom, teachers should use various curriculum differentiation strategies such as those included in the Department of Basic Education's *Guidelines for Inclusive Teaching and Learning* (2010).

Time allocation

The instructional time in Grade 12 is shown in this table.

Subject		Time allocation per week (hours)
I	Home Language	4,5
II	First Additional Language	4,5
III	Mathematics	4,5
IV	Life Orientation	2
V	Three electives	12 (3 × 4 h)

The allocated time per week may only be used for the minimum required NCS subjects as specified above. Should a learner wish to take additional subjects, these will have to be done outside this time.

Physical Sciences

Physical Sciences investigate physical and chemical phenomena. This is done through scientific inquiry, application of scientific models, theories, and laws to explain and predict events in the physical environment.

This subject also deals with society's need to understand how the physical environment works to benefit from it and responsibly care for it. All scientific and technological knowledge, including Indigenous Knowledge Systems (IKS), is used to address challenges facing society. Indigenous knowledge is knowledge that communities have held, have used or are still using. This knowledge has helped protect the environment for millennia. Physical Sciences examines and challenges aspects such as the safe disposal of chemical waste, responsible utilisation of resources and the environment, and addresses alternative energy sources.

Specific aims of Physical Sciences

Physical Sciences aims to equip learners with investigative skills that relate to physical and chemical phenomena such as investigating friction or solubility.

Skills required for the study of Physical Sciences:

- classifying
- communicating
- measuring
- designing an investigation
- drawing and evaluating conclusions
- formulating models
- hypothesising
- identifying and controlling variables
- inferring
- observing and comparing
- interpreting
- predicting
- problem solving
- reflective skills.

Physical Sciences aims to promote knowledge and skills in these fields:

- scientific inquiry and problem solving
- the construction and application of scientific and technological knowledge
- an understanding of the nature of science and its relationships to technology, society and the environment.

These three specific aims are aligned to the three Physical Sciences Learning Outcomes with which teachers are familiar. Within each aim, specific skills or competences have been identified. It is not advisable to try to assess each of the skills separately, nor is it possible to report on individual skills separately. However, well-designed assessments must show evidence that, by the end of the year, all of the skills have been assessed at a grade-appropriate level. There must be a clear link between the aims and the outcomes of learning. The processes of teaching, learning and assessment will provide the links between the specific aims and the achievement of the outcomes.

Physical Sciences also prepares learners for future learning, specialist learning, employment, citizenship, holistic development, socio-economic development, and environmental management. Learners choosing Physical Sciences as a subject in Grades 10 to 12 will have improved access to academic courses in Higher Education, as well as to professional career paths related to applied science courses and vocational career paths. The Physical Sciences plays an increasingly important role in the lives of all South Africans owing to their influence on scientific and technological development, which are necessary for the country's economic growth and the social well-being of its people.

The six main knowledge areas in the subject Physical Sciences are:

- Mechanics
- Waves, sound and light
- Electricity and magnetism
- Matter and materials
- Chemical change
- Chemical systems.

Developing language skills: Reading and writing

Teachers of Physical Sciences should be aware that they are also engaged in teaching language across the curriculum. This is particularly important for learners for whom the language of learning and teaching is not their home language. It is important to provide learners with opportunities to develop and improve their language skills in the context of learning Physical Sciences. It will therefore be critical to afford learners opportunities to read scientific texts, to write reports, paragraphs and short essays as part of their assessment, especially in the informal assessments for learning.

Assessment taxonomy

Application exercises should be done at all cognitive levels in all knowledge areas. (The cognitive levels will be discussed in Section B: Assessment.)

Recommended informal assessment

- Give learners at least two problem-solving exercises on a frequent basis (every day, as far as possible). These should collectively cover all cognitive levels and could be done as homework and/or class work.
- Learners should do at least one practical activity per term.
- Learners should be given at least one informal test per term.

Time allocation of Physical Sciences in the curriculum

The teaching time for Physical Sciences in Grade 12 is 4 hours per week, with 40 weeks in total. The time allocated for teaching of the content, concepts and skills includes the practical work. These are an integral part of the teaching and learning process.

Number of weeks allocated	Content, concepts and skills (weeks)	Formal assessment (weeks)
40	29	11

Overview of topics

Topic	Grade	Content
Mechanics	Grade 10	**Introduction to vectors and scalars. Motion in one dimension** (reference frame; position; displacement and distance; average speed; average velocity; acceleration; instantaneous velocity; instantaneous speed). **Description of motion** (in words, diagrams, graphs and equations). **Energy** (gravitational potential energy; kinetic energy; mechanical energy; conservation of mechanical energy (in the absence of dissipative forces)) **30 hours**
	Grade 11	**Vectors in two dimensions** (resultant of perpendicular vectors; resolution of a vector into its parallel and perpendicular components). **Newton's Laws and application of Newton's Laws** (Newton's First, Second and Third Laws and Newton's Law of Universal Gravitation; different kinds of forces: weight, normal force, frictional force, applied (push, pull), tension (strings or cables); force diagrams, free body diagrams and application of Newton's Laws (equilibrium and non-equilibrium)) **27 hours**
	Grade 12	**Momentum and impulse** (momentum; Newton's Second Law expressed in terms of momentum; conservation of momentum, and elastic and inelastic collisions; impulse). **Vertical projectile motion in one dimension (1D)** (vertical projectile motion represented in words, diagrams, equations and graphs). **Work, energy and power** (work; work-energy theorem; conservation of energy with non-conservative forces present; power). **28 hours**
Waves, sound and light	Grade 10	**Transverse pulses on a string or spring** (pulse; amplitude; superposition of pulses). **Transverse waves** (wavelength; frequency; amplitude; period; wave speed). **Longitudinal waves** (on a spring; wavelength; frequency; amplitude; period; wave speed; sound waves). **Sound** (pitch; loudness; quality (tone); ultrasound). **Electromagnetic radiation** (dual (particle/wave) nature of electromagnetic (EM) radiation; nature of EM radiation; EM spectrum; nature of EM as particle; energy of a photon related to frequency and wavelength). **16 hours**
	Grade 11	**Geometrical optics** (refraction; Snell's Law; critical angles and total internal reflection). **2D and 3D Wavefronts** (diffraction). **13 hours**
	Grade 12	**The Doppler effect** (either moving source or moving observer) (with sound and ultrasound; with light – red shifts in the universe). **6 hours**

Topic	Grade	Content
Electricity and magnetism	Grade 10	**Magnetism** (magnetic field of permanent magnets; poles of permanent magnets; attraction and repulsion; magnetic field lines; Earth's magnetic field; compass). **Electrostatics** (two kinds of charge; force exerted by charges on each other (descriptive); attraction between charged and uncharged objects (polarisation); charge conservation; charge quantisation). **Electric circuits** (emf; potential difference (pd); current; measurement of voltage (pd) and current; resistance; resistors in parallel). **14 hours**
	Grade 11	**Electrostatics** (Coulomb's Law; electric field). **Electromagnetism** (magnetic field associated with current-carrying wires; Faraday's Law). **Electric circuits** (Ohm's Law; energy; power). **20 hours**
	Grade 12	**Electric circuits** (internal resistance and series-parallel networks). **Electrodynamics** (electrical machines (generators, motors); alternating current). **12 hours**
Matter and materials	Grade 10	Revise **matter and classification** (materials; heterogeneous and homogeneous mixtures; pure substances; names and formulas; metals and non-metals; electrical and thermal conductors and insulators; magnetic and non-magnetic materials). **States of matter and the Kinetic Molecular Theory**. **The atom** (the atomic model; atomic mass and diameter; structure of the atom; isotopes; electron configuration). **Periodic Table** (position of the elements; similarities in chemical properties in groups; electron configuration in groups). **Chemical bonding** (covalent bonding; ionic bonding; metallic bonding). **Particles making up substances** (atoms and compounds; molecular, ionic and metallic substances).
	Grade 11	**Molecular structure** (a chemical bond; molecular shape; electronegativity and bond polarity; bond energy and bond length). **Intermolecular forces** (chemical bonds revised; types of intermolecular forces; states of matter; density; kinetic energy; temperature; three phases of water (macroscopic properties related to sub-microscopic structure)). **Ideal gases** (motion and kinetic theory of gases; gas laws; relationship between T and P). **24 hours**
	Grade 12	**Optical phenomena and properties of materials** (photo-electric effect; emission and absorption spectra). **Organic chemistry** (functional groups; saturated and unsaturated structures; isomers; naming and formulae; physical properties; chemical reactions (substitution, addition and elimination). **Organic macromolecules** (plastics and polymers). **16 hours**

Topic	Grade	Content
Chemical change	Grade 10	**Physical and chemical change** (separation by physical means; separation by chemical means; conservation of atoms and mass; Law of Constant Composition; conservation of energy). **Representing chemical change** (balanced chemical equations). **Reactions in aqueous solution** (ions in aqueous solutions; ion interaction; electrolytes; conductivity; precipitation; chemical reaction types). **Stoichiometry** (mole concept). **24 hours**
	Grade 11	**Stoichiometry** (molar volume of gases; concentration; limiting reagents; volume relationships in gaseous reactions). **Energy and chemical change** (energy changes related to bond energy; exothermic and endothermic reactions; activation energy). **Types of reactions** (acid–base; redox reactions; oxidation numbers). **28 hours**
	Grade 12	**Reaction rate** (factors affecting rate; measuring rate; mechanism of reaction and of catalysis). **Chemical equilibrium** (factors affecting equilibrium; equilibrium constant; application of equilibrium principles). **Acids and bases** (reactions; titrations; pH; salt hydrolysis). **Electrochemical reactions** (electrolytic and galvanic cells; relation of current and potential to rate and equilibrium; standard electrode potentials; oxidation and reduction half-reaction and cell reactions; oxidation numbers; application of redox reactions). **28 hours**
Chemical systems	Grade 10	**Hydrosphere. 8 hours**
	Grade 11	**Lithosphere.** (mining; energy resources). **8 hours**
	Grade 12	**Chemical industry.** (fertiliser industry). **6 hours**
Skills for practical investigations	Grade 12	Skills for practical investigations in physics and chemistry. **4 hours**

Overview of practical work

Integrate practical work with theory to strengthen the concepts you are teaching. These may take the form of simple practical demonstrations or even an experiment or practical investigation. There are several practical activities in the Learner's Book. Some of these practical activities will be done as part of formal assessment and others can be done as part of informal assessment.

Overview of formal assessment and recommended informal experiments

For Grade 12 three prescribed experiments are done as formal assessment per year – there is one physics/chemistry experiment in Term 1 and one chemistry/physics experiment in Term 3. In Term 2 there is a choice between a chemistry or a physics experiment. Learners must also do three practical activities for informal assessment, one in each term. There is a choice between a chemistry and physics experiment in each term.
The table lists prescribed practical activities for formal assessment as well as recommended practical activities for informal assessment.

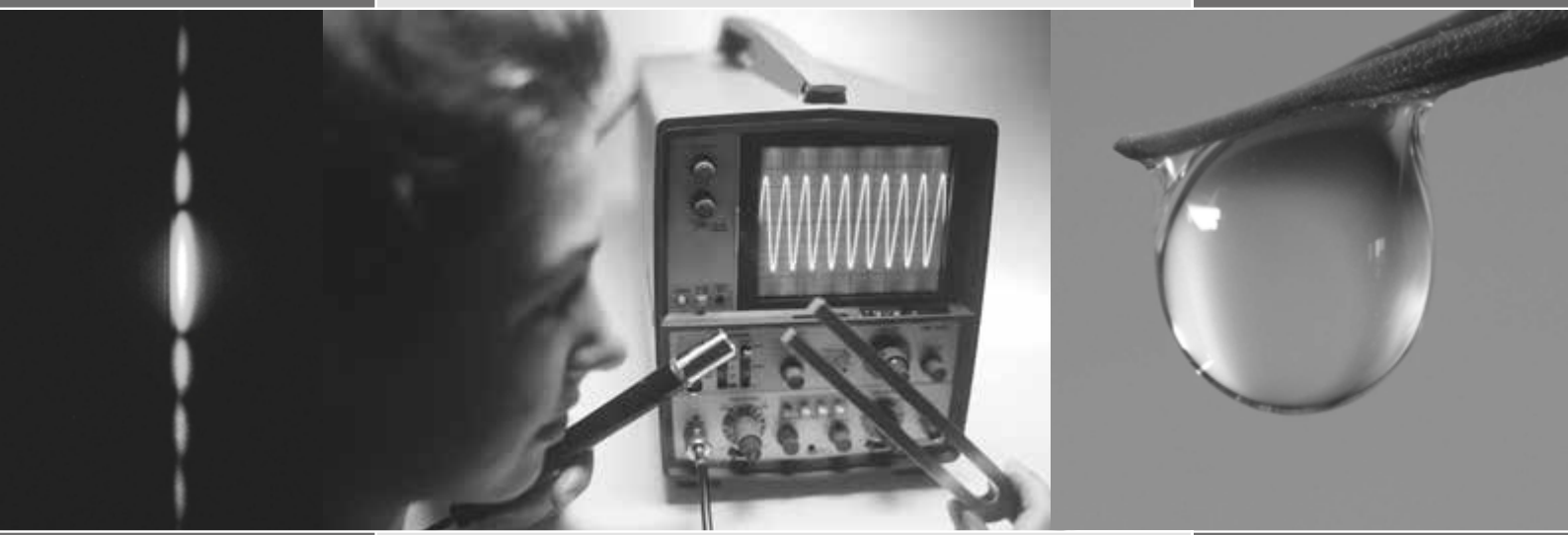
Term	Prescribed practical activities for formal assessment	Recommended practical activities for informal assessment
1	Experiment (Chemistry): Prepare different esters Experiment (Physics): Verify the conservation of linear momentum	Experiment (Physics) Investigate the conservation of momentum and energy using Newton's cradle OR Investigate the motion of a falling body OR Experiment (Chemistry) Investigate saturated and unsaturated molecules OR Make 'slime' and 'Silly Putty'.
2	Experiment (Chemistry) Use acid–base titration in neutralisation reactions	Investigation (Physics): Determine the work done in climbing up a flight of stairs. OR Experiment (Chemistry): Determine the quantitative reaction rate in the thiosulfate reaction OR Investigate reactions in equilibrium
3	Experiment (Physics) Part 1 Determine the internal resistance of a battery Part 2 Determine the equivalent resistance of a series-parallel network with known resistors using an ammeter and a voltmeter and compare with the theoretical value	Investigation (Physics): Investigating short circuits and open circuits in a series-parallel network of resistors OR Experiment (Chemistry): Investigate the electrolysis of water OR Find the galvanic cell with the highest potential OR Investigate the reduction of metal ions and halogens

Weighting of topics (40 week programme)

Mechanics	17,50%
Waves, sound and light	3,75%
Electricity and magnetism	7,50%
Matter and materials	11,50% chemistry + 3,75% physics
Chemical change	17,50%
Chemical systems	3,50%
Total teaching time (Theory and practical work)	65,00%
Total time for examinations and control tests	35,00%

SECTION B

ASSESSMENT



Assessment is a continuous planned process of identifying, gathering and interpreting information about the performance of learners, using various forms of assessment. It involves four steps.

1. Generating and collecting evidence of achievement.
2. Evaluating this evidence.
3. Recording the findings.
4. Using this information to understand and thereby assist the learner's development in order to improve the process of learning and teaching.

Assessment should be both informal (assessment for learning) and formal (assessment of learning). In both cases regular feedback should be provided to learners to enhance the learning experience.

Assessment is a process that measures individual learners' attainment of knowledge (content, concepts and skills) in a subject by collecting, analysing and interpreting the data and information obtained from this process to:

- enable the teacher to make reliable judgements about a learner's progress
- inform learners about their strengths, weaknesses and progress
- assist teachers, parents and other stakeholders in making decisions about the learning process and the progress of the learners.

Assessment should be mapped against the content, concepts, skills and aims specified for Physical Sciences and in both informal and formal assessments it is important to ensure that in the course of a school year:

- all of the subject content is covered
- the full range of skills is included
- a variety of different forms of assessment are used.

Informal or daily assessment

Assessment for learning has the purpose of continuously collecting information on learners' achievements that can be used to improve their learning. Informal assessment is a daily monitoring of the learners' progress. This is done through observations, discussions, practical demonstrations, learner–teacher conferences, informal classroom interactions, etc. Informal assessment may be as simple as stopping during the lesson to observe learners or to discuss with learners how learning is progressing. Use informal assessment to provide feedback to the learners and to inform planning for teaching. Do not view informal assessment as separate from learning activities taking place in the classroom. The results of the informal daily assessment tasks are not formally recorded unless the teacher wishes to do so. Learners or teachers can mark informal assessment tasks. Self-assessment and peer assessment actively involves learners in assessment. This is important as it allows learners to learn from and reflect on their own performance. Informal assessment also helps learners to take responsibility for their own learning and for the learning of their peers. In this way they develop a sense of self-discipline and commitment to each other's wellbeing.

The results of daily assessment tasks are not taken into account for promotional and certificate purposes. Use informal, ongoing assessments to structure the acquisition of knowledge and skills and as a precursor to formal tasks in the Programme of Assessment.

Using group and pair work

Many teachers in South Africa work in overcrowded classrooms, which make learning difficult. You can overcome some of these problems by getting a class to work in groups. Practical work is normally done in groups, while many activities lend themselves to work in pairs. Smaller groups are easier to handle and learners will also start to feel more positive about themselves.

Teamwork is an important aspect of learning skills and constructing knowledge. Sharing the workload and being aware of personal contributions to the community is important for every learner. In a group, the different roles and responsibilities people take on are essential to the success of the activity. At the FET level, learners should become aware of the roles and responsibilities that are likely to be combined in 'professional' teams working in your particular subject areas in the real working world.

Setting up

Certain learning tasks are better approached through a whole class session; others lend themselves to group work. Working in pairs and in groups of three to six learners, learners have a chance to express themselves more often than when they are part of a class of forty or more. They learn to work in a team, helping each other freely when their knowledge or skill is strong, and being helped when it is weak. Some learners might be too shy to ask a question in front of a whole class, but feel at ease asking a small group of friends.

Group work

There are many ways of organising learners into groups. Here are some ideas.

- Language groups
  If you have learners with different home languages, you can put the speakers of each language into their own language group. Same-language groups enable all the learners to develop their understanding of a new concept in their own language. At other times you can create mixed-language groups. Learners working in their second language or third language can be helped with translation and have a greater chance to contribute than they would in a large class.

- Ability groups
  There are times when it is useful to divide learners into groups according to how well they achieve in the learning area. The top achievers in the class are grouped together, the average learners form a group, and the slowest learners are grouped together. Top achievers can do enrichment activities while you attend to the slower learners.

- Remediation groups
  When you have finished assessing some aspects of the learners' work, you may often find a few learners from different groups with the same problem. There may be a new concept they haven't quite grasped, or a few learners may have been absent at the same time while you were dealing with new work. You can then group them together temporarily while you help them sort out the problem.

- Mixed-ability groups
  These groups work well on their own while you circulate between them. Vary the members of these groups so that learners have experience in working with different classmates. For instance, new groups can be formed each time a new unit of work is started.

Guidelines for using group work

- When planning group work, you should decide on the composition of each group and not always leave it to learners to cluster together with those they work with most easily.
- Divide tasks fairly among the members of each group and each member must understand his role.
- Give the learners clear and concise instructions.
- Define the work to be done clearly so that the group can go ahead without constantly referring to you.
- Learners must be settled and attentive when instructions are given.
- You must monitor progress at all times and should take into consideration not only the end result, but also focus attention on how the group has interacted and progressed through each step. This will be possible if you circulate amongst the groups and give information and guidance where and when it is required.
- Allow time for feedback so that learners have an opportunity to present evidence of their progress at the end of a session.
- Regular reminders of time limits and what progress should have been made at a particular stage are valuable when facilitating group work.
- Place groups as far apart as possible so that they enjoy a sense of privacy. Allow a certain amount of interaction as this often assists learners in solving problems or coping with complex areas.

Pair work

Pair work is easier to control than group work, particularly in large classes where it is difficult to re-arrange the seating. It is a very useful strategy for task-based teaching as it frees the teacher to be a facilitator, support guide and evaluator.

Pair work also allows for differentiation: pairs that work faster can be given extra tasks; some pairs can be given more challenging tasks; in mixed ability pairing, one partner can assist the other.

Solving problems related to pair and group work

- Noise can become a problem. Differentiate between 'good learning noise' and 'disruptive chatter'. Firmly remind learners that they might be disturbing neighbouring classes and that they should keep their voices down.
- Certain learners dominate a group, while others are idle and not actively involved. Each individual must understand his or her role or task, which should be constantly monitored. Use the report-back to assess each learner's involvement and progress.
- Learners may not like the partners they are paired or grouped with. There is no quick-fix solution to this problem. You must, however, use your knowledge of the learners and avoid grouping personalities or characters that are likely to clash.

Formal assessment

All assessment tasks that make up the formal programme of assessment for the year are regarded as formal assessment. Formal assessment tasks are marked and formally recorded by the teacher for progression and certification purposes. All formal assessment tasks are subject to moderation for the purpose of quality assurance and to ensure that appropriate standards are maintained.

Formal assessment provides teachers with a systematic way of evaluating how well learners are progressing in a grade and in a particular subject. Examples of formal assessments include tests, examinations, practical tasks, projects, oral presentations, demonstrations and performances. Formal assessment tasks form part of a year-long formal Programme of Assessment in each grade and subject.

Control tests and examinations

Control tests and examinations are written under controlled conditions within a specified period of time. Questions in tests and examinations should assess performance at different cognitive levels with an emphasis on process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts. Examination papers and control tests in the Physical Sciences in Grade 12 should adhere to the weighting of cognitive levels given in the table below. A detailed description of the cognitive levels follows on page B8.

Cognitive level	Description	Paper 1 (Physics)	Paper 2 (Chemistry)
1	Recall	15%	15%
2	Comprehension	35%	40%
3	Analysis, application	40%	35%
4	Evaluation, synthesis	10%	10%

Note: A control test and its memorandum can be found at the end of this section.

Requirements for Grade 12 practical work

In Grade 12 learners will do three prescribed experiments for formal assessment (one physics, one chemistry and a choice between a physics and a chemistry experiment). This gives a total of three formal assessments in practical work in Physical Sciences.

Learners must also do three experiments for informal assessment (two physics and one chemistry experiment or two chemistry and one physics experiment).

Practical work	Physics	Chemistry
Prescribed experiments (formal assessment)	2	1
OR Prescribed experiments (formal assessment)	1	2
Project (formal assessment)	none	
Experiments (informal assessment)	2	1
OR Experiments (informal assessment)	1	2
Total	6 practical activities = 3 physics + 3 chemistry	

Assessment tools

Checklists

Checklists consist of separate statements describing how the teacher can expect the learners to perform in a particular task. These statements are the criteria that the learners must meet to succeed. When you observe that the learner has satisfied each statement on the list by doing what it describes, tick it off on the checklist. To work well, the statements on the list need to describe in clear, concrete terms what the expected performance actions are for the task.

Rubrics

Rubrics are a combination of rating codes and descriptions of standards – that is what the learner must do, the level of competence, and so on – to be rated with a particular code. The rubric describes the range of acceptable performance in each band of the rating scale. Rubrics require teachers to know exactly what the learner must achieve – the level of competence, and so on – to meet the particular outcome being assessed.

To design a rubric, you need to decide on the following.

- What is the outcome that you are aiming at?
- What kind of evidence should be collected?
- What are the different parts of the performance that will be assessed?
- What different assessment instruments best suit each part of the task?
- What knowledge should the learners demonstrate?
- What skills should learners apply or what actions should they take?

It is crucial that you share the criteria in the rubric for the task with the learners **before** they do the required task. The rubric clarifies both what the learners should do and what they should be learning as they carry out the task. It becomes a powerful tool for self-assessment.

When the learners have completed the task and you are assessing their performance, you need to be sure that:

- each learner is assessed only once for each criterion within the rubric
- you add comprehensive comments where necessary for later moderation purposes.

Programme of Formal Assessment

The Programme of Formal Assessment consists of two components: a Programme of Assessment which makes up 25% of the total mark for Physical Sciences and an external examination which makes up the remaining 75%. The Programme of Assessment for Physical Sciences comprises six tasks that are internally assessed. Together the Programme of Assessment and external assessment make up the annual assessment plan for Grade 12. The table on the next page illustrates the assessment plan and weighting of tasks in the Programme of Assessment for Physical Sciences Grade 12.

Programme of Formal Assessment for Grade 12						External assessment
Assessment tasks (25%)						End-of-year assessment 75%
Term 1		Term 2		Term 3		Term 4
Type	%	Type	%	Type	%	Final examination (2 × 150 marks giving a total of 300 marks for papers 1 and 2)
Experiment	15	Experiment	15	Experiment	15	
Control test	10	Mid-year examination	20	Trial examination	25	
Total: 25 marks		Total: 35 marks		Total: 40 marks		Total: 300 marks
Total: 400 marks						
Final mark = 25% (assessment tasks) + 75% (final exam) = 100%						

Note: Rubrics and checklists for prescribed experiments and projects are in Section D: Teaching guidelines

Grade 12 external assessment

The external examinations are set externally, administered at schools under conditions specified in the National policy on the conduct, administration and management of the National Senior Certificate: A qualification at Level 4 on the National Qualifications Framework (NQF) and marked externally.

The core content outlined in the Physical Sciences Curriculum and Assessment Policy (CAPS) document is compulsory and will be examined through Papers 1 and 2. Note that all the topics in the Grade 12 curriculum are examinable in the end of year examination plus selected topics from Grade 10 and 11. Below is a list of selected content, outlined for Grade 10 and 11 in the CAPS document that is also examinable in the Grade 12 final examination.

Selected examinable Grade 10 and 11 topics	
Physics from Grade 11	**Chemistry from Grade 10 and 11**
• Newton's Laws (Newton I, II, III and Newton's Law of Universal Gravitation) and application of Newton's Laws • Electrostatics (Coulomb's Law and electric field) • Electric circuits (Ohm's Law, power and energy)	• Representing chemical change (Grade 10) • Intermolecular forces (Grade 11) • Stoichiometry (Grade 11) • Energy and change (Grade 11)

The table shows the weighting of questions across cognitive levels and the specification and suggested weighting of the content for the Grade 12 end-of-year examinations (across the two papers).

Paper	Content	Marks	Total marks/ paper	Duration	Weighting of questions across cognitive levels			
					Level 1	Level 2	Level 3	Level 4
Paper 1: Physics focus	Mechanics	63	150	3 hours	15%	35%	40%	10%
	Waves, sound and light	17						
	Electricity and magnetism	55						
	Matter and materials	15						
Paper 2: Chemistry focus	Matter and materials	48	150	3 hours	15%	40%	35%	10%
	Chemical change	84						
	Chemical systems	18						

Multiple-choice questions could be set in examination papers. However, such questions should have a maximum weighting of 10%. The examination paper may also consist of questions of a conceptual nature.

Recording and reporting

Recording is a process in which the teacher documents the level of a learner's performance in a specific assessment task. It indicates learner progress towards the achievement of the knowledge and skills as prescribed in the Curriculum and Assessment Policy Statements. Records of learner performance should provide evidence of the learners' conceptual progression within a grade and their readiness to progress or be promoted to the next grade. Records of learner performance should also be used to verify the progress made by teachers and learners in the teaching and learning process.

Reporting is a process of communicating learner performance to learners, parents, schools and other stakeholders. Learner performance can be reported in a number of ways. These include report cards, parents' meetings, school visitation days, parent-teacher conferences, phone calls, letters, class or school newsletters, etc. Teachers in all grades report in percentages for the subject. The various achievement levels and their corresponding percentage bands are shown in the table below.

Note: The seven point scale should have clear descriptions that give detailed information for each level. Teachers will record actual marks for the task by using a record sheet and report percentages for the subject on the learner's report card.

Rating code	Description of competence	Percentage
7	Outstanding achievement	80–100
6	Meritorious achievement	70–79
5	Substantial achievement	60–69
4	Adequate achievement	50–59
3	Moderate achievement	40–49
2	Elementary achievement	30–39
1	Not achieved	0–29

Schools are required to provide quarterly feedback to parents on the Programme of Assessment using a formal reporting tool, such as a report card. The schedule and the report card should indicate the overall level of performance of a learner.

Moderation of assessment

Moderation refers to the process that ensures that the assessment tasks are fair, valid and reliable. Moderation should be implemented at school, district, provincial and national levels. Comprehensive and appropriate moderation practices must be in place for the quality assurance of all subject assessments. All Grade 11 tasks are internally moderated. The subject head or head of department for Physical Sciences at the school will generally manage this process.

Physical Sciences assessment taxonomy

The table below provides a possible hierarchy of cognitive levels that the teacher can use to ensure tasks include opportunities for learners to achieve at various levels and tools for assessing the learners at various levels. The verbs given in the fourth column could be useful when formulating questions associated with the cognitive levels given in the first column.

Description of cognitive level	Level	Explanation	Skills demonstrated	Action verbs
Evaluation	4	At the extended abstract level, the learner makes connections not only within the given subject, but also beyond it, and generalises and transfers the principles and ideas underlying the specific instance. The learner works with relationships and abstract ideas.	• Compares and discriminates between ideas. • Assesses value of theories, presentations. • Makes choices based on reasoned arguments. • Verifies value of evidence. • Recognises subjectivity.	assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarise, critique, appraise, interpret, justify
Synthesis	4	The learner works at the extended abstract level (see level 4 above) but makes errors because they are insufficiently informed at more modest levels.	• Uses old ideas to create new ones. • Generalises from given facts. • Relates knowledge from several areas. • Predicts and draws conclusions.	combine, integrate, modify, rearrange, substitute, plan, create, design, invent, compose, formulate, prepare, generalise, rewrite, categorise, combine, compile, reconstruct, generate, organise, revise, what if?
Analysis	3	The learner appreciates the significance of the parts in relation to the whole. Various aspects of the knowledge becomes integrated, the learner acquires deeper understanding and the ability to break down a whole into its component parts. Elements embedded in the whole are identified and the relations among the elements are recognised.	• Sees patterns and the organisation of parts. • Recognises hidden meaning. • Identifies components.	analyse, separate, order, explain, connect, classify, arrange, divide, compare, select, infer, break down, contrast, distinguish, diagram, illustrate, identify, outline, point out, relate
Application	3	The learner establishes a relational construct (see level 3 above) but which has errors. The learner has the ability to use (or apply) knowledge and skills in new situations.	• Uses information, methods, concepts and theories in new situations. • Solves problems using required skills or knowledge.	apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover, construct, manipulate, prepare, produce

Description of cognitive level	Level	Explanation	Skills demonstrated	Action verbs
Comprehension	2	A number of connections may be made but the meta-connections are missed, as is their significance for the whole. The learner has first level understanding, recalls and understands information and describes meaning.	• Understands information and grasps meaning. • Translates knowledge into new contexts and interprets facts. • Compares, contrasts, orders, groups and infers causes and predicts consequences.	summarise, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend, comprehend, convert, defend, explain, generalise, give example, rewrite, infer
Recall	1	Simple and obvious connections are made. The learner recalls and remembers facts.	• Observes and recalls information.	list, define, tell, describe, identify, show, know, label, collect, select, reproduce, match, recognise, examine, tabulate, quote, name

Module 1: Mechanics: 26 marks

1 A golfer strikes a stationary golf ball of mass 100 g with his golf club. The club exerts a horizontal force of 60 N on the ball, and when the club strikes the ball it is in contact with the ball for 0,1 seconds.

a) Define impulse. (2)

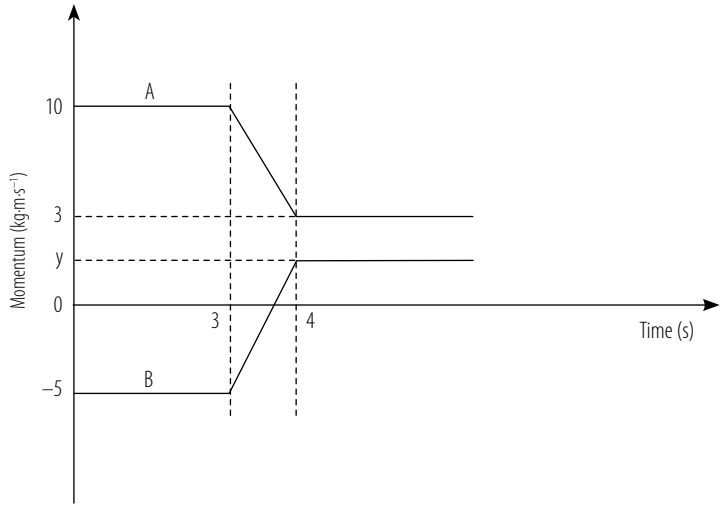
b) Calculate the velocity of the ball after it is struck. (4)

c) Explain how the golfer can give the ball a greater initial velocity, without changing the force that he exerts. (3)

[9]

2 The graph below (not drawn to scale) shows the momentum – time relationship – for two objects, A and B. They collide between the 3rd and 4th second.

Study the graph and answer the questions that follow.



a) Explain why the objects can be considered to be in a 'closed system'. (3)

b) Determine the value of *y*. (3)

c) Calculate the force that A exerts on B during the collision. (3)

[9]

3 A stone is thrown vertically downwards from the second floor of a building at 3 $m.s^{-1}$. Ignore the effects of friction.

a) The stone is said to be in free fall while it is in the air. Explain what this means. (2)

b) If the stone takes 1,2 seconds to strike the ground below, calculate the height of the building. (3)

c) Suppose that the stone was thrown *upwards* at 4 $m.s^{-1}$. State how each of the following values will be different when compared to the original throw of the stone. Write down only increases, decreases, or stays the same.

i) The acceleration of the stone. (1)

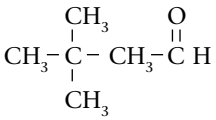
ii) The velocity of the stone when it strikes the ground. (1)

iii) The time taken for the stone to reach the ground. (1)

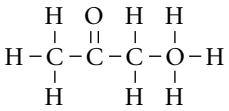
[8]

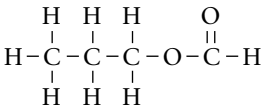
Module 2: Matter and materials: 24 marks

1 Millions of organic compounds are known to date. Four of these compounds are illustrated below.

A 

B pentan–2-ol

C 

D 

a) Write down the letter of the compound that represents a
   i) ketone (1)
   ii) ester (1)

b) Write down the IUPAC name of the following:
   i) compound A (2)
   ii) compound D (2)

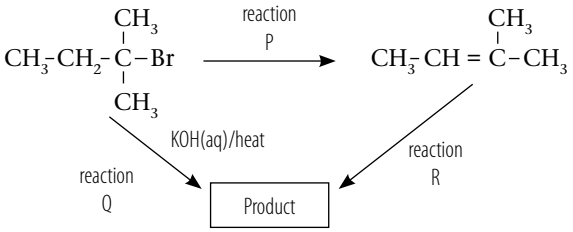
c) Write down the name and structural formula of a functional isomer for compound D. (3)

d) Write down the structural formula for compound B. (2)

e) Would you classify compound B as primary, secondary or tertiary? (1)

[12]

2 In the flow diagram below P, Q and R represent different types of organic reactions.



a) Name the type of reaction represented by P. (1)

b) State two reaction conditions needed for reaction P. (2)

c) Write down the IUPAC name and structural formula for the product. (4)

d) Apart from the organic reactant, write down the name of the other reactant needed in reaction R. (1)

e) Name the type of reactions represented by Q and R. (2)

f) The product of reaction P is 2-methylbut-2-ene. If this compound had to be polymerised, what would the polymerisation process be called? (2)

[12]

Total mark: 50

Module 1: Mechanics: 26 marks

1 a) Impulse of an object is the product of the net force and the time for which the net force acts on the object. (2)

b) $\vec{F}_{net}\Delta t = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$
$(60\text{ N})(0{,}1\text{ s}) = 0{,}1\text{ kg} \times \vec{v}_f - 0{,}1\text{ kg} \times 0\text{ m.s}^{-1}$
$\vec{v}_f = 60\text{ m.s}^{-1}$ in the direction of the club. (4)

c) The golfer can increase the contact time between the club and ball by following through after hitting the shot. This will increase $\Delta\vec{p}$, and hence $\vec{v}_f$. (3)

2 a) Before and after collision, they are travelling at constant velocity so $\vec{a} = 0\text{ m.s}^{-1}$
therefore $\vec{F}_{net} = 0$ (no external forces acting on system). (3)

b) $\vec{p}_{tot\ (before)} = \vec{p}_{tot\ (after)}$
$(10 + (-5))\text{ kg·m·s}^{-1} = (3 + y)\text{ kg·m·s}^{-1}$
$y = +2\text{ kg·m·s}^{-1} = 2\text{ kg·m·s}^{-1}$ in the original direction of A. (3)

c) $\vec{F}_{AB} = \frac{\Delta p}{\Delta t} = \frac{(2 - (-5))\text{ kg·m·s}^{-1}}{1\text{ s}} = +7\text{ N}$
$= 7$ N opposite to its original direction. (3)

3 a) The only force acting on the stone is the gravitational force. (2)

b) $\Delta y = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
$= (3\text{ m·s}^{-1})(1{,}2\text{ s}) + \frac{1}{2}(9{,}8\text{ m·s}^{-2})(1{,}2\text{ s})^2$
$= 10{,}66\text{ m}$
The height of the building is 10,66 m (3)

c) i) stays the same (1)
ii) increases (1)
iii) increases (1)

Module 2: Matter and materials: 24 marks

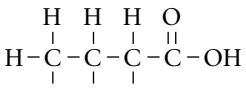
1 a) i) C (1)

ii) D (1)

b) i) 2,2-dimethylbutanal (2)

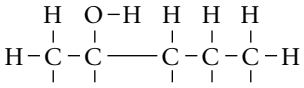
ii) propylmethanoate (2)

c) butanoic acid



butanoic acid (3)

d) pentan-2-ol



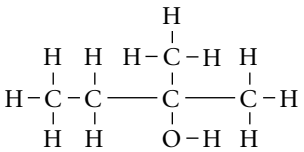
pentan-2-ol (2)

e) secondary alcohol (1)

2 a) dehydrohalogenation (elimination) (1)

b) heat under reflux; concentrated solution of NaOH/KOH in pure ethanol (2)

c) 2-methylbutan-2-ol



2-methylbutan-2-ol (4)

d) water (1)

e) reaction Q: substitution reaction
reaction R: addition reaction/ hydration (2)

f) addition polymerisation (2)

PHYSICAL SCIENCES EXEMPLAR: PAPER 1 (PHYSICS)

GRADE 12

MARKS: 150
TIME: 3 hours

This question paper consists of 8 pages

INSTRUCTIONS AND INFORMATION

1. This paper consists of TWO sections:
   SECTION A (25)
   SECTION B (125)
2. Answer ALL questions.
3. Non-programmable calculators may be used.
4. Appropriate mathematical instruments may be used.
5. Number the answers correctly according to the numbering system used in this question paper.
6. Data sheets are attached for your use.
7. Give brief motivations, discussions, et cetera where required.

SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 The SI unit for electric potential difference. (1)
1.2 The property of a sound that increases when the frequency increases. (1)
1.3 The rate at which energy is transferred. (1)
1.4 The type of electric field where a charge experiences the same force throughout the field. (1)
1.5 The type of spectrum formed when white light is incident on an element in a low energy gaseous state. (1)

[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 Car P is moving at a constant velocity of 20 $m \cdot s^{-1}$ east relative to the ground. Car X is ahead of car P and is moving at a velocity of 5 $m \cdot s^{-1}$ west relative to car P. The velocity of car X relative to the ground is:
   A 15 $m \cdot s^{-1}$ west
   B 15 $m \cdot s^{-1}$ east
   C 25 $m \cdot s^{-1}$ west
   D 25 $m \cdot s^{-1}$ east (2)

2.2 A ball of mass $\boldsymbol{m}$ falls vertically and strikes the ground with a speed of $\boldsymbol{2v}$. It rebounds vertically up with a speed of $\boldsymbol{v}$. The change in momentum of the ball is:
   A mv downwards
   B mv upwards
   C $3mv$ downwards
   D $3mv$ upwards (2)

2.3 A photon is:
   A a light wave
   B a light particle
   C an electromagnetic wave

D a continuous stream of energy (2)

2.4 An electric motor will be less efficient if:
A a larger current is used.
B slip rings are used instead of split rings.
C a bigger force is used to turn the armature.
D a weaker magnetic field is used. (2)

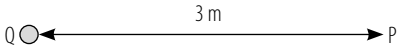
2.5 A listener is travelling towards a stationary police car whose siren makes a sound with a frequency f. If the speed of the listener is 0,1 times the speed of sound in the air, then the frequency of the siren observed by the listener is:
A 1,10 f
B 0,90 f
C 1,11 f
D 0,91 f (2)

2.6 Blue light can eject electrons from a metal surface, but yellow light cannot. Another colour that **must** cause the emission of electrons from the same metal surface is:
A red
B green
C violet
D orange (2)

2.7 A listener moves at constant velocity towards a stationary source of sound. The frequency of sound heard by the listener is higher than the frequency of the sound emitted by the source, because:
A the wavelength observed by the listener becomes shorter.
B more wave fronts reach the listener per second.
C less wave fronts reach the listener per second.
D the wavelength observed by the listener becomes longer. (2)

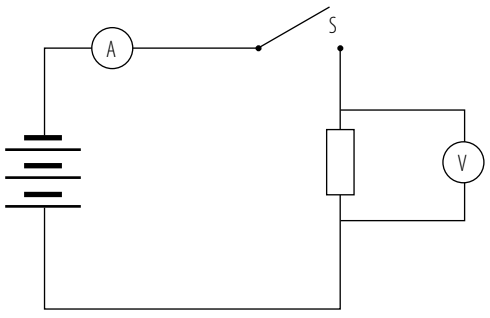
2.8 The atomic spectra of an element provides conclusive evidence that:
A electrons are negatively charged.
B electrons exist in fixed energy levels in the atoms of the element.
C electrons can absorb, but not emit energy.
D electrons can emit, but not absorb energy. (2)

2.9 A sphere Q has a charge of –4 μC. P is a point 3 m east of the sphere, as shown in the diagram below.



What is the electric field strength at point P due to the –4 μC charged sphere?
A 4 000 $N \cdot C^{-1}$ east
B 4 000 $N \cdot C^{-1}$ west
C 4×10^9 $N \cdot C^{-1}$ east
D 4×10^9 $N \cdot C^{-1}$ west (2)

2.10 The circuit below shows a battery with an emf of 12 V (with negligible internal resistance), an ammeter, a resistor (with resistance 3 Ω) with a voltmeter connected across it, and a switch. The switch in the circuit is open.



What will the ammeter and voltmeter read immediately after the switch is closed?

A The ammeter reading will be 4 A and the voltmeter reading will be 12 V.
B The ammeter reading will be 3 A and the voltmeter reading will be 9 V.
C The ammeter will not show a reading and the voltmeter reading will be 12 V.
D The ammeter reading will be 12 A and the voltmeter will not show a reading. (2)

[20]

SECTION A TOTAL: [25]

SECTION B

INSTRUCTIONS AND INFORMATION

1. Start each question on a NEW page.
2. Leave a line between two sub questions, for example between QUESTION 4.1 and QUESTION 4.2.
3. The formulae and substitutions must be shown in ALL calculations.
4. Round off your answers to a minimum of TWO decimal places where applicable.

QUESTION 3

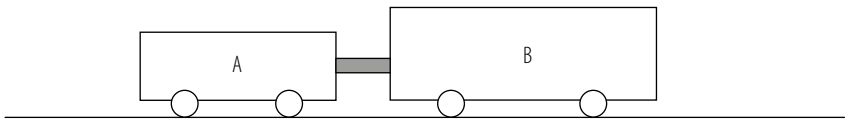
A helicopter is flying vertically up at an unknown constant velocity. An object is dropped from the helicopter when it is exactly 88 m above the ground. The object takes 1,5 s to reach its maximum height from the time it was released. Air friction is ignored.

3.1 Calculate the magnitude of the velocity of the object at the point of release. (3)
3.2 Calculate the maximum height, above the ground, reached by the object. (4)
3.3 Calculate the velocity of the object the instant it hits the ground. (4)
3.4 Using the ground as the zero position, and taking upward as the positive direction, sketch a position-time graph for the object from the time it is released to the time it hits the ground. (4)

[15]

QUESTION 4

The diagram shows two trolleys, A of mass 0,2 kg and B of mass 0,4 kg, moving to the left at 3 $m \cdot s^{-1}$. The trolleys are attached by a compressed spring. The spring is released and immediately after this trolley A moves to the left at 4 $m \cdot s^{-1}$.

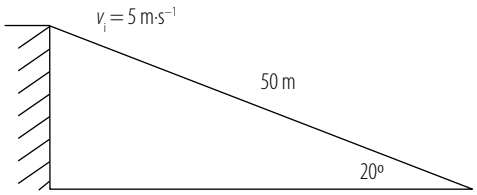


4.1 State the principle of conservation of linear momentum. (3)
4.2 Calculate the velocity of trolley B immediately after the spring is released. (5)
4.3 Is the above collision elastic or inelastic?
Perform a calculation to justify your answer. (5)

[13]

QUESTION 5

A man skis down a 50 m snow slope which makes an angle of 20° with the horizontal. The total mass of the skier and skis is 80 kg. A constant frictional force of 50 N acts on the skis as the skier moves down the slope. The speed of the skier at the top of the slope is 5 $m \cdot s^{-1}$.



5.1 Draw a free body diagram showing all the forces acting on the skier as he skis down the incline. (3)

5.2 Use the work-energy theorem to calculate the speed of the skier at the bottom of the slope. (7)

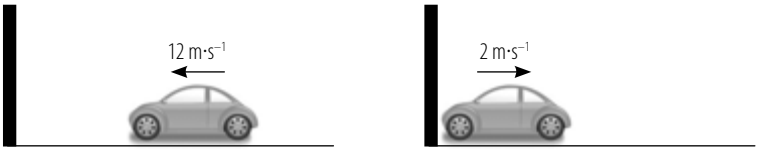
[10]

QUESTION 6

New cars have a crumple zone to help minimise injuries during accidents. In addition seat belts, air bags and padded interiors can reduce the chance of death or serious injury.

6.1 Use principles in Physics to explain how air bags can reduce the chance of death or injury. (3)

6.2 In a crash test, a car of mass $1{,}2 \times 10^3$ kg collides with a wall and rebounds as illustrated below. The initial and final velocities of the car are 12 $m{\cdot}s^{-1}$ to the left and 2 $m{\cdot}s^{-1}$ to the right respectively. The collision lasts 0,1 s.



Calculate the:

6.2.1 Impulse of the car during the accident. (4)

6.2.2 Average force exerted on the car. (3)

[10]

QUESTION 7

7.1 State Newton's Law of Universal Gravitation in words. (3)

7.2 A rocket of mass 2 000 kg is launched from the surface of Earth. When it reaches a height equal to the radius of Earth, it expels a fuel tank of mass 200 kg vertically downwards.

7.2.1 Will the speed of the rocket increase, decrease or remain the same when the tank is expelled? (2)

7.2.2 Determine the magnitude of the force exerted on the rocket tank immediately after it is expelled. (5)

[10]

QUESTION 8

8.1 Using sound waves travelling through air, explain what is meant by the Doppler effect. (3)

8.2 One use of the Doppler effect is the Doppler flow meter. This is a device that can be used to monitor the motion of the heart of a newly formed foetus in the womb of its mother.

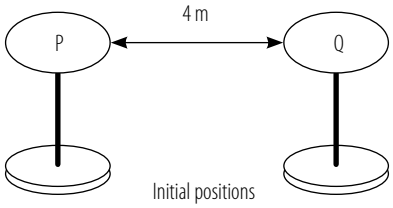
Ultrasonic waves of frequency $1{,}5 \times 10^6$ Hz and speed 2000 $m.s^{-1}$ are directed at the chest of the foetus to measure the heart rate of the foetus. Calculate the change in frequency of the waves reflected by the chest, if the chest moves up and down at a constant maximum speed of 0,02 $m.s^{-1}$. (6)

8.3 State one other use of the Doppler effect (apart from the Doppler flow meter). (2)

[11]

QUESTION 9

9.1 Two spheres, P with a charge of –4 nC and Q with a charge of +6 nC, are a distance of 4 m apart.



9.1.1 Calculate the electrostatic force between the two spheres. (4)

9.1.2 The spheres are moved together and touch and are then placed 2 m apart. Calculate the electric potential energy of sphere P in its final position. (5)

9.2 Two identical metal plates are fixed so that they are parallel to each other and 20 mm apart in a vacuum, with the negative plate placed above the positive plate. The potential difference across the plates is 24 V.

9.2.1 Draw a diagram to illustrate the electric field pattern between the plates. (3)

9.2.2 Determine the magnitude of the electric field strength between the plates. (3)

A negatively charged particle is released from the negative plate in the region between the plates.

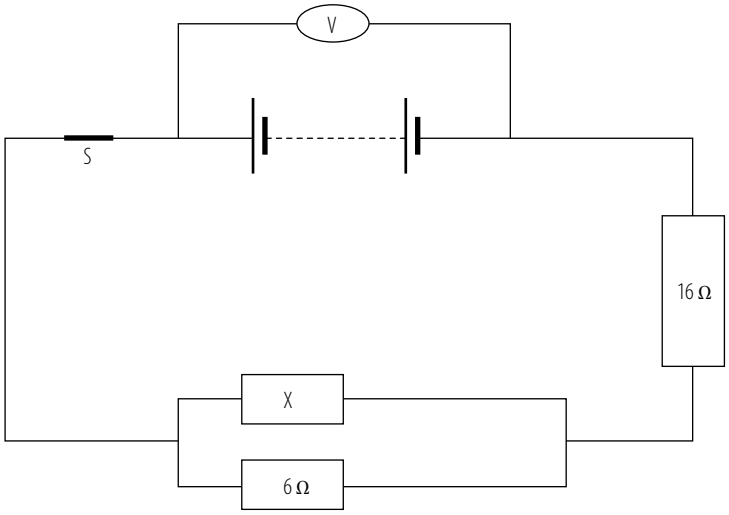
9.2.3 Draw a free body diagram to show all the forces acting on the particle. (2)

9.2.4 Sketch a graph of acceleration against time for the particle as it moves between the two plates. (3)

[20]

QUESTION 10

In the circuit below the voltmeter reading is 11 V when switch S is opened and 10 V when S is closed. The battery has an internal resistance of 2 Ω. X is a resistor of unknown resistance. Study the circuit below and then answer the questions that follow. The switch is kept closed.



10.1 Explain why the voltmeter reading drops when the switch is closed. (2)

10.2 Calculate the resistance of the unknown resistor X. (9)

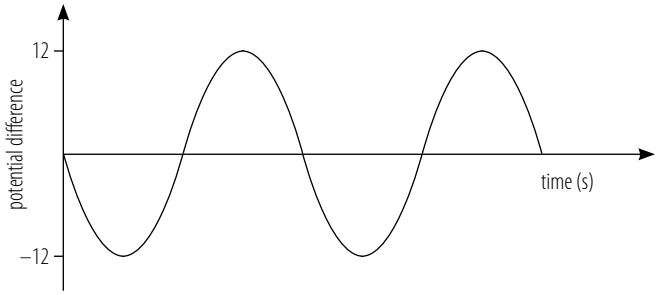
10.3 How will the reading on the voltmeter change if the branch with the unknown resistor is removed from the circuit?
Write down only **increase**, **decrease** or **stays the same**. (1)

10.4 Explain your answer to 10.3 above. (3)

[15]

QUESTION 11

The average power of a light bulb is 15 W. The lamp can be used with either an AC supply or DC supply. The graph on the next page shows the output of an AC generator.



11.1 Calculate the potential difference of a DC supply that will produce the same brightness of the light bulb. (3)

11.2 Calculate the peak current through the light bulb when connected to a 12 V AC supply. (4)

11.3 List TWO changes or additions you will make to the generator referred to in this question in order to convert it to a DC motor. (2)

[9]

QUESTION 12

A learner wants to determine the relationship between the frequency (f) of light striking a metal surface, and the kinetic energy (K) of the emitted electrons. She shines **red**, **green** and **blue** light on the metal, and is able to measure the velocity of electrons as they leave the metal surface.

12.1 Identify the independent variable in this investigation. (1)

12.2 Why does she use light of different colours? (1)

12.3 Why does she measure the velocity of the emitted electrons? (1)

The learner obtains the following average results after taking the reading several times.

COLOUR	FREQUENCY ($\times 10^{14}$ Hz)	KINETIC ENERGY OF EMITTED ELECTRON ($\times 10^{-19}$ J)
Red	4,30	0,20
Green	5,60	1,10
Blue	5,70	1,20

12.4 Use the results to plot a graph of frequency against kinetic energy on the graph paper provided. (5)

12.5 From the graph, determine the threshold frequency for the metal. (2)

12.6 State one application of the photoelectric effect. (2)

[12]

SECTION B TOTAL: [125]

Total mark: 150

DATA FOR PHYSICAL SCIENCES

PAPER 1 (PHYSICS)

TABLE 1: PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Acceleration due to gravity	g	9,8 m·s^{-2}
Speed of light in a vacuum	c	3,0 × 10^{8} m·s^{-1}
Planck's constant	h	6,63 × 10^{-34} J·s
Coulomb's constant	k	9,0 × 10^{9} N·m^{2}·C^{-2}
Charge on electron	e	–1,6 × 10^{-19} C
Electron mass	m_e	9,11 × 10^{-31} kg
Gravitational constant	G	6.67 × 10^{-11} N·m^{2}·kg^{-2}

TABLE 2: FORMULAE

MOTION

$v_f = v_i + a\Delta t$	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ or $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$v_f^2 = v_i^2 + 2a\Delta x$ or $v_f^2 = v_i^2 + 2a\Delta y$	$\Delta x = \left(\frac{v_f + v_i}{2}\right)\Delta t$ or $\Delta y = \left(\frac{v_f + v_i}{2}\right)\Delta t$

FORCE

$F_{net} = ma$	$p = mv$
$F_{net}\Delta t = \Delta p = mv_f - mv_i$	$w = mg$

WORK, ENERGY AND POWER

$W = F\Delta x\cos\theta$	$U = E_p = mgh$
$K = E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta K = \Delta E_k = E_{kf} - E_{ki}$
$P = \frac{W}{\Delta t}$	$P = Fv$

WAVES, SOUND AND LIGHT

$v = f\lambda$ or $v = v\lambda$	$T = \frac{1}{f}$ or $T = \frac{1}{v}$
$f_L = \frac{v \pm v_L}{v \pm v_s}f_s$	$E = hf$ or $E = hv$ or $E = h\frac{c}{\lambda}$
	$hf = W_0 + \frac{1}{2}mv^2 = hf_0 + \frac{1}{2}mv^2$

ELECTROSTATICS

$F = \frac{kQ_1Q_2}{r^2}$	$E = \frac{kQ}{r^2}$
$E = \frac{V}{d}$	$E = \frac{F}{q}$
	$V = \frac{W}{q}$

ELECTRIC CIRCUITS

$R = \frac{V}{I}$	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
$R_s = R_1 + R_2 + \ldots$	EMF(ε) = $I(R + r)$
$q = I\Delta t$	$W = Vq = VI\Delta t = I^2R\Delta t = \frac{v^2\Delta t}{R}$
$P = \frac{W}{\Delta t} = VI = I^2R = \frac{V^2}{R}$	

ALTERNATING CURRENT

$I_{rms} = \frac{I_{max}}{\sqrt{2}}$ $V_{rms} = \frac{V_{max}}{\sqrt{2}}$	$P_{average} = V_{rms} I_{rms} = I^2_{rms} R = \frac{V^2_{rms}}{R}$

QUESTION 12.4

ANSWERS TO EXEMPLAR PAPER: PAPER 1

SECTION A

QUESTION 1

1.1 volt ✓
1.2 pitch✓
1.3 power ✓
1.4 uniform (electric field) ✓
1.5 (line) absorption spectrum ✓

[5]

QUESTION 2

2.1 B ✓✓	2.2 D ✓✓	2.3 B ✓✓
2.4 D ✓ ✓	2.5 A ✓✓	2.6 C ✓✓
2.7 A ✓✓	2.8 B ✓✓	2.9 B ✓✓
2.10 A ✓✓		

[20]

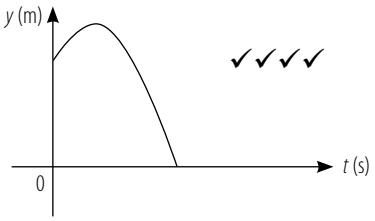
SECTION B

QUESTION 3

3.1 $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t$ ✓
$0\ m\cdot s^{-1} = v_i + (-9{,}8\ m\cdot s^{-2})(1{,}5\ s)$ ✓
$\vec{v}_i = 14{,}7\ m\cdot s^{-1}$ ✓ (3)

3.2 $\Delta\vec{y} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$ ✓
$= (14{,}7\ m\cdot s^{-1})(1{,}5\ s) + \frac{1}{2}(-9{,}8\ m\cdot s^{-2})(1{,}5\ s)^2$ ✓
$= 11{,}03\ m$ ✓
Height = 88 m + 11,03 m = 99,03 m ✓ (4)

3.3 $\vec{v}_f^2 = \vec{v}_i^2 + 2\vec{a}\Delta\vec{y}$ ✓
$= (14{,}7\ m\cdot s^{-1})^2 + 2(-9{,}8\ m\cdot s^{-2})(-88\ m)$ ✓
$\vec{v}_f = 44{,}06\ m\cdot s^{-1}$ ✓ down ✓ (4)

3.4 

✓✓✓✓ (4)

[15]

QUESTION 4

4.1 In an isolated (closed) system, the total linear momentum is conserved. (3)

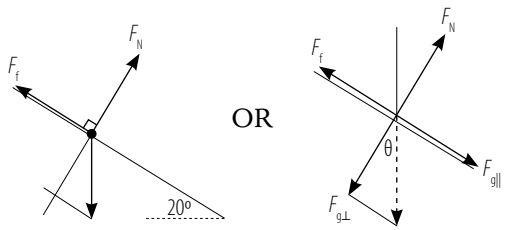
4.2 $\vec{p}_{total}$ (before) = $\vec{p}_{total}$ (after)
$(m_1 + m_2)\vec{v}_i = m_1\vec{v}_{f1} + m_2\vec{v}_{f2}$ ✓
$(0{,}2\ kg + 0{,}4\ kg)(3\ m\cdot s^{-1})$ ✓ $= (0{,}2\ kg)(4\ m\cdot s^{-1}) + (0{,}4\ kg)v_{f2}$ ✓
$\vec{v}_f = 2{,}5\ m\cdot s^{-1}$ ✓ to the left ✓ (5)

4.3 Inelastic
$E_{k(TOT)}$ before collision $= \frac{1}{2}(m_1 + m_2)v_i^2$
$= \frac{1}{2}(0{,}2\ kg + 0{,}4\ kg)(3\ m\cdot s^{-1})^2 = 2{,}7\ J$
$E_{k(TOT)}$ after collision $= \frac{1}{2}m_1v_{f1}^{\ 2} + \frac{1}{2}m_2v_{f2}^{\ 2}$
$= \frac{1}{2}(0{,}2\ kg)(4\ m\cdot s^{-1})^2 + \frac{1}{2}(0{,}4\ kg)(2{,}5\ m\cdot s^{-1})^2 = 2{,}85\ J$
Since $E_{k(TOT)}$ before collision $\neq$ $E_{k(TOT)}$ after collision, collision is inelastic. (5)

[13]

QUESTION 5

5.1



(3)

5.2
$$\begin{aligned} W_{NET} &= F_f \Delta x \cos 180^\circ + F_{g//} \Delta x \cos 0^\circ + F_N \Delta x \cos 90^\circ + F_{g\perp} \Delta x \cos 270^\circ \checkmark \\ &= 50\text{ N}(50\text{ m}) \cos 180^\circ + 80\text{ N}(9{,}8\text{ m·s}^{-2})(\sin 20^\circ)(50\text{ N}) \cos 0^\circ \checkmark + 0 + 0 \\ &= 10\,907{,}19\text{ J} \checkmark \\ W_{NET} &= \Delta K = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 \\ 10\,907{,}19\text{ J} &= \tfrac{1}{2}(80\text{ kg})\, v_f^2 - \tfrac{1}{2}(80\text{ kg})(5\text{ m·s}^{-1})^2 \\ v_f &= 17{,}25\text{ m·s}^{-1} \checkmark \end{aligned}$$

(7)

OR

$$\begin{aligned} W_{NET} &= F_f \Delta x \cos\theta_1 + F_g \Delta x \cos\theta_2 + F_N \Delta x \cos\theta_3 \checkmark \\ &= 50\text{ N}(50\text{ m}) \cos 180^\circ + 80\text{ kg}(9{,}8\text{ m·s}^{-2})(50\text{ m}) \cos 290^\circ \checkmark + 0 \\ &= 10\,907{,}19\text{ J} \checkmark \\ W_{NET} &= \Delta K = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 \\ 10\,907{,}19\text{ J} &= \tfrac{1}{2}(80\text{ kg})\, v_f^2 - \tfrac{1}{2}(80\text{ kg})(5\text{ m·s}^{-1})^2 \\ v_f &= 17{,}25\text{ m·s}^{-1} \checkmark \end{aligned}$$

(7)

[10]

QUESTION 6

6.1 When the airbag inflates during a collision, the contact time of a passenger/driver with an air bag ✓ is longer than without an airbag ✓and thus the force on the passenger/driver is reduced according to $F_{net} = \frac{\Delta p}{\Delta t}$ ✓ (3)

6.2

6.2.1 Take to the right as negative

$\vec{F}_{net}\Delta t = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$ ✓

$\therefore \vec{F}_{net}\Delta t = 1{,}2 \times 10^3\text{ kg}\ (-2\text{ m·s}^{-1} - 12\text{ m·s}^{-1})$ ✓ $= -1{,}68 \times 10^4\text{ N·s}$

$\therefore$ Impulse $= 1{,}68 \times 10^4$ N·s ✓ to the right or away from wall ✓ (4)

6.2.2 $\vec{F}_{net}\Delta t = \Delta\vec{p} = -1{,}68 \times 10^4$ N·s

$\therefore \vec{F}_{net}(0{,}1\text{ s}) = -1{,}68 \times 10^4$ N·s ✓

$\therefore \vec{F}_{net} = -1{,}68 \times 10^5$ N

$\therefore \vec{F}_{net} = 1{,}68 \times 10^5$ N ✓to the right✓ (3)

[10]

QUESTION 7

7.1 The force of attraction that two objects ✓ exert on each other is directly proportional to the product of their masses, ✓ and inversely proportional to the square of the distance between their centres. ✓ (3)

7.2 7.2.1 Increase ✓✓ (2)

7.2.2 If m is the mass of the tank, M the mass of Earth and R the radius of Earth, then on the surface of Earth:

$F = mg$✓ $= \frac{GmM}{R^2} = 200\text{ kg} \times 9{,}8\text{ m·s}^{-2} = 1\,960$ N✓ (5)

At a height above the surface equal to radius of Earth:

$F_{new} = \frac{GmM}{(2R)^2}$✓ $= \frac{1}{4} \times \frac{GmM}{R^2} = \frac{1}{4}$✓$(1\,960\text{ N}) = 490$ N✓ (5)

[10]

QUESTION 8

8.1 Whenever the source of a sound is moving relative to a listener, ✓ there is a change in the frequency (or pitch) ✓ of the sound observed by the listener✓ . This effect is called the Doppler effect. (3)

8.2 $f_L = \frac{v + v_L}{v - v_s} f_s$ ✓ heart is moving towards listener

$= \frac{2\,000\ \text{m·s}^{-1} - 0}{2\,000\ \text{m·s}^{-1} - 0{,}02\ \text{m·s}^{-1}} (1{,}5 \times 10^6\ \text{Hz})$ ✓

$= 1\,500\,015\ \text{Hz}$ ✓

$f_L = \frac{v + v_L}{v + v_s} f_s$ ✓ heart is moving away from listener

$= \frac{2\,000\ \text{m·s}^{-1} + 0}{2\,000\ \text{m·s}^{-1} + 0{,}02\ \text{m·s}^{-1}} (1{,}5 \times 10^6\ \text{Hz})$ ✓

$= 1\,499\,985\ \text{Hz}$ ✓

Change = 1 500 015 Hz – 1 499 985 Hz = 30 Hz ✓ (6)

8.3 Speed trapping devices, or applications that detect movement of light sources in space. (any one use ✓✓). (2)

[11]

QUESTION 9

9.1 9.1.1 $F = \frac{kQ_1Q_2}{r^2}$ ✓ $= \frac{9 \times 10^9\ \text{N·m}^2\text{·C}^{-2}(4 \times 10^{-9}\ \text{C})(6 \times 10^{-9}\ \text{C})}{(4\ \text{m})^2} = 1{,}35 \times 10^{-8}\ \text{N}$ attraction✓ (4)

9.1.2 $Q_f = \frac{Q_1 + Q_2}{2} = \frac{-4 \times 10^{-9}\ \text{C} + 6 \times 10^{-9}\ \text{C}}{2} = 1 \times 10^{-9}\ \text{C}$

$U = \frac{kQ_1Q_2}{r} = \frac{9 \times 10^9\ \text{N·m}^2\text{·C}^{-2} \times 1 \times 10^{-9}\ \text{C} \times 1 \times 10^{-9}\ \text{C}}{2} = 4{,}5 \times 10^{-9}\ \text{J}$ (5)

9.2 9.2.1 Field lines equidistant from, and parallel to each other, and perpendicular to plates. ✓

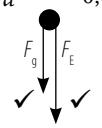
Direction of field lines: bottom to top. ✓

Field lines curved at ends. ✓

(3)

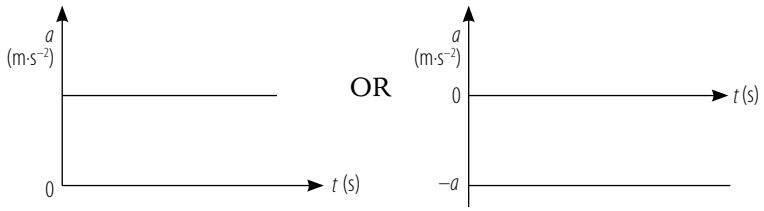
9.2.2 $E = \frac{V}{d}$ ✓ $= \frac{24\ \text{V}}{0{,}02\ \text{m}}$ ✓ $= 1\,200\ \text{V·m}^{-1}$ ✓ (3)

9.2.3



✓ ✓

9.2.4 (2)



a is constant, and $a \neq 0$✓✓

axes correctly labeled. ✓ **[20]**

QUESTION 10

10.1 The battery has internal resistance. ✓

Energy is transferred to the battery as charges flow through it. ✓ (2)

10.2 emf = $I(R + r)$ ✓

emf = $IR + Ir$

11 V = 10 V + $I(2\ \Omega)$ ✓

$I = 0{,}5$ A ✓

total $R = \frac{V}{I}$ ✓ $= \frac{10\ \text{V}}{0{,}5\ \text{A}} = 20\ \Omega$✓

$R_p = 20 - 16$ ✓ $= 4\ \Omega$ ✓

$\frac{1^p}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{4} = \frac{1}{6} + \frac{1}{R_x}$ ✓

$R_X = 12\ \Omega$ ✓ (9)

10.3 increase ✓ (1)

10.4 If resistor X is removed, total R increases. ✓ I total decreases, ✓ Ir decreases.
Because emf $= V_{ext} + Ir$ ✓the voltmeter reading (V_{ext}) increases. (3)

[15]

QUESTION 11

11.1
$$v_{rms} = \frac{v_{max}}{\sqrt{2}} \checkmark$$
$$= \frac{12\text{ V}}{\sqrt{2}} \checkmark$$
$$= 8{,}49\text{ V} \checkmark$$ (3)

11.2
$$P_{ave} = V_{rms} I_{rms} \checkmark$$
$$15\text{ W} = 8{,}49\text{ V } I_{rms}$$
$$I_{rms} = 1{,}77\text{ A} \checkmark$$
$$I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$$
$$1{,}77\text{ A} = \frac{I_{max}}{\sqrt{2}} \checkmark$$
$$\frac{I_{max}}{\sqrt{2}} = 2{,}5\text{ A} \checkmark$$ (4)

$P = \frac{V^2}{R}$ $\quad R = \frac{V}{I}$
$15\text{ W} = \frac{(8{,}49\text{ V})^2}{R}$ $\quad 4{,}81\ \Omega = \frac{12\text{ V}}{I}$
$R = 4{,}81\ \Omega$ $\quad I = 2{,}49\text{ A}$

11.3 Provide a source of potential difference ✓ (or connect a battery)
Replace slip rings with a split ring (commutator) ✓ (2)

[9]

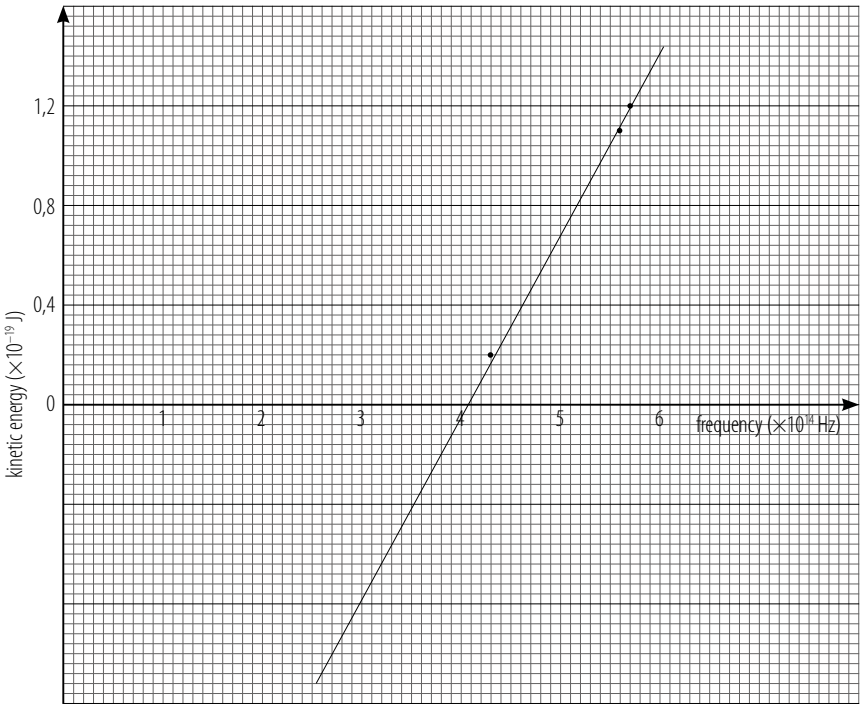
QUESTION 12

12.1 frequency of light / colour of light ✓ (1)

12.2 To vary the frequency. ✓ Different colours have different frequencies. (1)

12.3 To calculate the kinetic energy of the electrons. ✓ (1)

12.4



1 mark for correct labeling of axes. ✓
1 mark for correct scale on both axes. ✓
1 mark for plotting points correctly. ✓
1 mark for correct shape. ✓
1 mark for *x*-intercept being positive. ✓ (5)

12.5. Read off as per graph (point where graph cuts horizontal axis). ✓✓ (2)

12.6 Photocells OR Solar cells OR Photodiodes, etc. ✓✓ (2)

[12]

TOTAL: 150

PHYSICAL SCIENCES EXEMPLAR: PAPER 2 (CHEMISTRY)

GRADE 12

MARKS: 150
TIME: 3 hours

This question paper consists of 7 pages

INSTRUCTIONS AND INFORMATION

1. This paper consists of TWO sections:
   SECTION A (25)
   SECTION B (125)
2. Answer ALL questions.
3. Non-programmable calculators may be used.
4. Appropriate mathematical instruments may be used.
5. Number the answers correctly according to the numbering system used in this question paper.
6. Data sheets are attached for your use.
7. Give brief motivations, discussions, et cetera where required.

SECTION A

QUESTION 1: ONE-WORD ITEMS

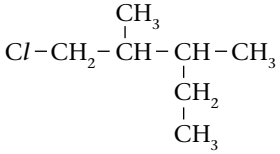
Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number on the answer sheet.

1.1 The IUPAC name for the simplest alkyne. (1)
1.2 The process of covering a less expensive metal with a more expensive metal using electricity. (1)
1.3 The half-cell which is the standard against which the potentials of other half-cells are measured. (1)
1.4 The point where equal molar amounts of an acid and a base have reacted according to the molar ratio in a chemical equation. (1)
1.5 The industrial process that produces sulfuric acid. (1)
[5]

QUESTION 2

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in your answer.

2.1 The major product formed during the hydration of propene is:
   A propane
   B propyne
   C propan-1-ol
   D propan-2-ol (2)
2.2 Which of the following is not a ketone?
   A ethanone
   B propanone
   C butanone
   D methylpentanone (2)
2.3 The correct name of the compound below is:



A 1-chloro-2,3-dimethylbutane
B 1-chloro-2,3-dimethylpentane
C 1-chloro-3-ehtyl-2-methylbutane
D 1-chloro-2-ethyl-3-methylpentane (2)

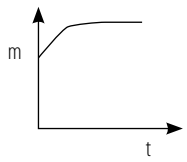
2.4 For hydrocarbons containing the same number of carbon atoms, the boiling points of branched alkanes are lower than that of straight chain alkanes. This is because branched alkanes have:
A larger molecular mass
B shorter chain length
C more electrons (2)
D smaller effective molecular surface area

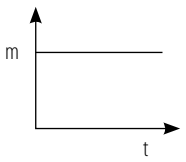
2.5 Which of the following statements about strong acids is/are TRUE?
i) Strong acids are very concentrated acids.
ii) Strong acids ionise almost completely in water.
iii) The conjugate base of a strong acid is a weak base.
A (i) and (ii)
B (i) and (iii)
C (ii) and (iii)
D (ii) only (2)

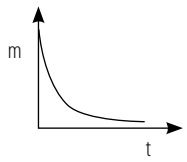
2.6 The percentage of potassium in a bag of fertiliser labelled 3:4:2(26) is:
A 5,78%
B 8,67%
C 11,56%
D 22,22% (2)

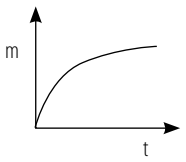
2.7 The pH of a solution increases from 8,5 to 9,5 at 298 K when a base is added to it. Which ONE of the statements below is TRUE for the original solution?
A Its $[OH^-]$ increases by 1 mol·dm^{-3}.
B Its $[H^+]$ increases by 1 mol·dm^{-3}.
C Its $[OH^-]$ increases by a factor of 10.
D Its $[H^+]$ increases by a factor of 10. (2)

2.8 Which one of the following graphs best represents the change in mass of a catalyst during a chemical reaction?

A


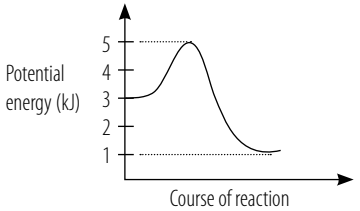
B


C


D


(2)

2.9 The graph below represents the relationship between the potential energy and course of reaction for a certain chemical reaction.



The activation energy for the forward reaction is:
A 1 kJ
B 2 kJ

C 3 kJ
D 4 kJ (2)

2.10 In the reversible reaction:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H<0$

which one of the following will increase the equilibrium constant?

A adding catalyst vanadium pentoxide
B cooling the mixture
C increasing the pressure
D heating the mixture (2)

[20]

SECTION A TOTAL: [25]

SECTION B

INSTRUCTIONS

1. Start each question on a NEW page.
2. Leave one line between two sub-questions (*e.g.* between 3.1 and 3.2)
3. Show the formulae and substitutions in ALL calculations.
4. Round off all numerical answers to a minimum of TWO decimal places.

QUESTION 3

The table below shows the results obtained during a practical investigation. The experiment was performed to determine the boiling points of compounds from three different homologous series under the same conditions. Each letter A–C represents the organic compounds written in the block next to it.

Experiment	Organic compound	Boiling point (°C)
A	$CH_3(CH_2)_2COOH$	163
B	$CH_3(CH_2)_2CH_2OH$	137
C	$CH_3(CH_2)_2CHO$	103

3.1 Name the homologous series to which each of the following compounds belong:

3.1.1 A
3.1.2 B
3.1.3 C (3)

3.2 Write down the IUPAC name for:

3.2.1 B
3.2.2 C (2)

3.3 Explain briefly why compound A has a higher boiling point than compounds B and C. (3)

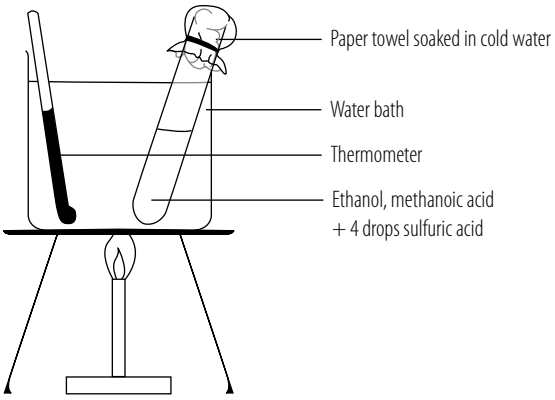
[8]

QUESTION 4

Many of the flavours and odours of fruit are esters. Ethyl methanoate is used to give foodstuffs a strawberry flavour.

A learner wants to prepare ethyl methanoate in the school laboratory. She follows the instructions below:

- Mix 1 cm^3 methanoic acid and 1 cm^3 ethanol in a test tube.
- Slowly add 4 drops of sulfuric acid while swirling the test tube.
- Soak a paper towel in cold water and fasten it around the test tube close to its mouth with an elastic band.
- Place the test tube in a water bath and heat the water with a flame to a temperature of about 60 °C.
- Leave the test tube in the hot water bath for about 15 minutes.
- Cool the test tube by placing it in a beaker of cold water.
- Smell the vapour in the test tube after 10 minutes.



4.1 Use structural formulae to write a balanced equation for the reaction taking place in the test tube. (5)

4.2 What is the function of the sulfuric acid in the above reaction? (1)

4.3 Why does the method use a water bath instead of direct heating over an open flame? (1)

4.4 State one function of the wet paper towel at the top of the test tube. (1)

4.5 The learner finds it difficult to detect the smell of the ester due to the presence of sulfuric acid and unreacted methanoic acid. A friend suggests that she add 10 drops of diluted sodium carbonate solution to the contents of the test tube. Briefly explain why this suggestion might be a solution to the problem. (2)

4.6 Write down the molecular formula of ethyl methanoate. (1)

There are other organic compounds with the same molecular formula but different structural formulae to ethyl methanoate.

4.7 What is the phenomenon described above called? (1)

4.8 Name two other organic compounds that have the same molecular formula as ethyl methanoate, but are structurally different. (2)

[14]

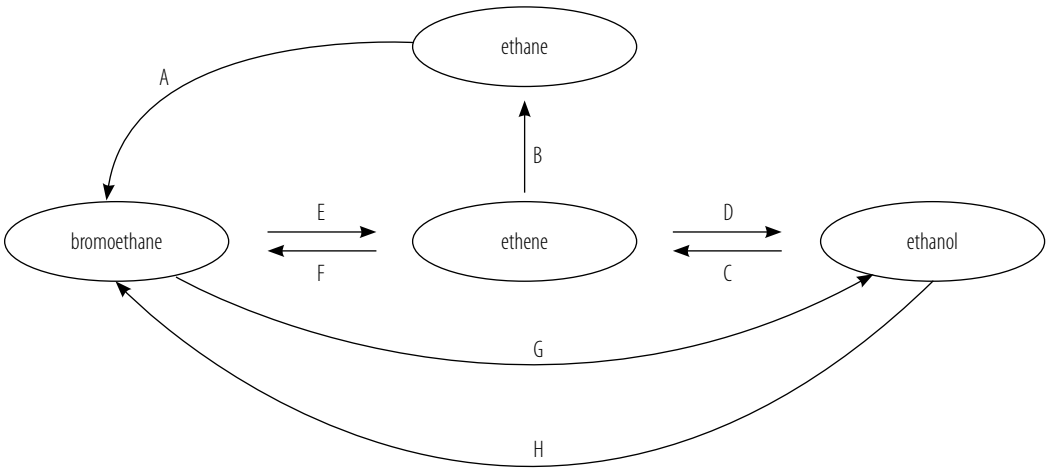
QUESTION 5

Ethene is a gaseous hormone associated with ripening fruit. It also contributes to the ageing and distortion of plants. In industry, the artificial fruit ripening takes place when ethene is passed over the fruit in large rooms. After a while the ripening fruit releases its own ethene.

5.1 Write down the structural formula of ethene. (2)

5.2 Why is it not advisable to place a banana that has been artificially ripened next to a cabbage or lettuce? (2)

In industry ethene is also used to synthesise a variety of organic compounds. The flow diagram below illustrates some of the many reactions ethene undergoes.



5.3 Write down the general formula for the homologous series to which ethene belongs. (1)
5.4 Name the type of reaction represented by each of the letters A, B, D and H. Write down the letters A, B, D and H and next to each the type of reaction. (4)
5.5 Use structural formulae to write down a balanced equation for reaction B (3)
5.6 Apart from ethene, which other reactant is needed for reaction F? Write down the formula only. (2)
5.7 Both reactions E and G occur in the presence of a base. Reaction E is an elimination reaction and reaction G is a substitution reaction.
5.7.1 How is the base in reaction E different from the base in reaction G? (2)
5.7.2 Name the type of elimination reaction represented by E. (1)
5.8 Ethene is used as a monomer to manufacture polythene. Name the type of polymerisation process that ethene undergoes. (1)
[18]

QUESTION 6

Sharon conducts an experiment to investigate the various factors that influence the rate of chemical reactions. She places a sample of calcium carbonate in a beaker. The beaker is placed on a sensitive balance and an excess of hydrochloric acid (HCl) is added.

The following reaction occurs:

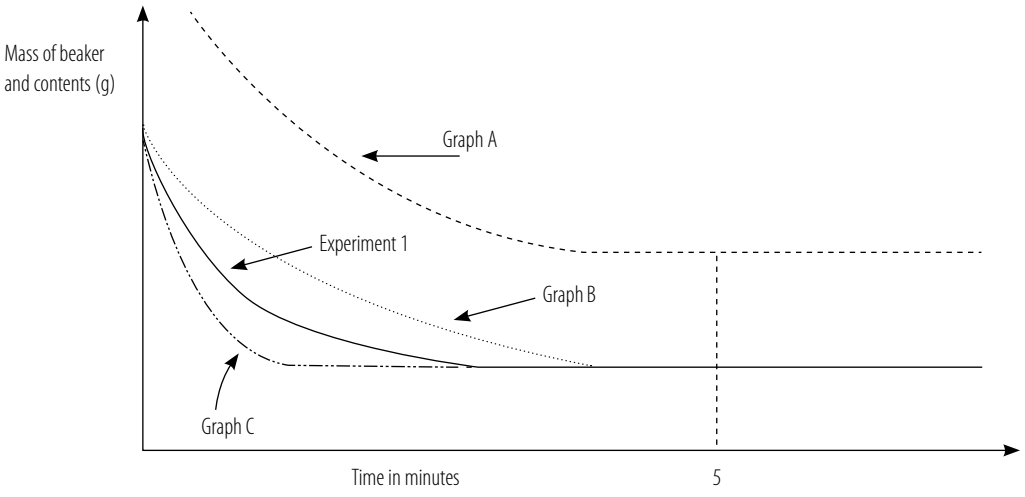
$CaCO_3 + HCl \rightarrow CaCl_2 + H_2O + CO_2$

Sharon repeats the experiment a number of times under different conditions always with the same volume of HCl in excess.

The following table summarises the different experimental conditions of four of her experiments.

Experiment	Mass of $CaCO_3$ (g)	Concentration of HCl ($mol \cdot dm^{-3}$)	Temperature of HCl (°C)	State of $CaCO_3$
1	10	2	25	granules
2	10	2	15	granules
3	20	2	25	granules
4	10	2	25	powder

During each experiment the mass of the beaker and its contents is recorded every minute. The graphs below indicate the changes in mass of the beaker and its contents during the reaction, as a function of time, for the four experiments.



6.1 What is meant by the rate of a chemical reaction? (2)
6.2 Name the quantity that was kept constant during all four experiments. (1)
6.3 Give a reason for the decrease in mass as each reaction progresses. (2)

6.4 Why are all the graphs horizontal lines after five minutes? (2)
6.5 Which one of the graphs A, B, or C, represents the results of:
6.5.1 Experiment 2 (1)
6.5.2 Experiment 3 (1)
6.5.3 Experiment 4 (1)
6.6 If a suitable catalyst is used in experiment 1, which of the graphs (A,B or C) will be obtained? Explain your answer. (4)
[14]

QUESTION 7

The following is a balanced equation for the preparation of ammonia:

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

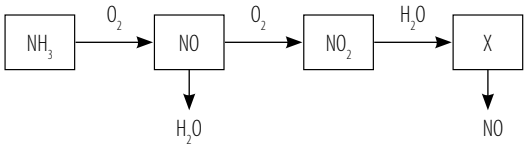
2 moles of nitrogen and 3 moles of hydrogen are initially placed in a 500 cm^3 container. The container is sealed and the gases are allowed to react. When equilibrium is reached at 350 °C, there are 1,6 moles of ammonia in the container.

7.1 Calculate the equilibrium constant at 350 °C. (6)
7.2 If the mixture is heated, the number of moles of ammonia in the container will decrease. Use Le Chatelier's principle to determine if the forward reaction is endothermic or exothermic. (4)
7.3 In each of the following cases answer either INCREASE, DECREASE or STAYS THE SAME. (Assume the temperature remains constant.)

DISTURBANCE	MOLES OF NITROGEN
Iron catalyst is added	7.3.1
Volume of container is decreased	7.3.2
Water is added to the container	7.3.3

(3)
7.4 Name the above industrial process. (1)
7.5 In the industrial preparation of NH_3, this reaction is usually carried out at temperatures higher than 350 °C. Explain why. (3)
7.6 How is the reactant nitrogen obtained? (1)

Ammonia is then used to make another industrial product, as shown in the flow diagram:



7.7 Name the industrial product. (1)
7.8 Name the process. (1)
7.9 Name the catalyst used in the oxidation of ammonia. (1)
7.10 Name the fertiliser obtained from the industrial product. (1)
7.11 Would this fertiliser have the most impact on the roots, stems or leaves of the crops? (1)
7.12 Explain a negative impact of the over-use of the fertiliser. (2)
7.13 Name a suitable organic alternative to the inorganic fertiliser chosen in 7.10. (1)
[26]

QUESTION 8

A learner finds some sulfuric acid solution in a bottle labelled 'dilute sulfuric acid'. He wishes to determine the concentration of the sulfuric acid solution. To do this he decides to titrate the sulfuric acid against a standard potassium hydroxide solution.

8.1 What is a standard solution? (1)
8.2 Calculate the mass of KOH which he must use to make 300 cm^3 of a 0,2 $mol \cdot dm^{-3}$ KOH solution. (4)

8.3 Calculate the pH of the 0,2 mol·dm^{-3} KOH solution. (4)
8.4 Write a balanced equation for the reaction between H_2SO_4 and KOH. (2)
8.5 Which one of the indicators listed in the table should he use in this titration? Briefly explain your answer. (3)

Indicator	pH range
Methyl orange	2,9–4,0
Methyl red	4,4–6,0
Bromothymol blue	6,0–7,6
Phenolphthalein	8,3–10,0

8.6 During the titration he finds that 15 cm^3 of the KOH solution neutralises 20 cm^3 of the H_2SO_4 solution. Calculate the concentration of the H_2SO_4 solution. (5)

[19]

QUESTION 9

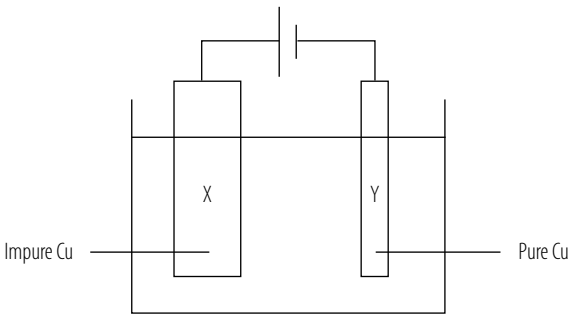
A standard electrochemical cell is set up with zinc as the anode and metal X as the cathode. The initial emf of the cell is 1,56 V.

9.1 State two standard conditions for this cell. (2)
9.2 Determine the E^o value of:
9.2.1 the cathode, when the cell is connected. (4)
9.2.2 the cell, when equilibrium is reached. (2)
9.3 Identify:
9.3.1 the cathode metal. (1)
9.3.2 the oxidising agent. (1)
9.4 Write down the cell notation. (3)
9.5 After equilibrium has been established, H_2S is bubbled through the zinc half-cell. How will the emf of the cell change? Explain briefly. (5)

[18]

QUESTION 10

The diagram below represents a cell that can be used to purify copper.



10.1 Is X or Y the anode in this cell? (1)
10.2 Write down the formula of the oxidising agent. (1)
10.3 Name a suitable electrolyte. (2)
10.4 What will happen to each of the following over time? Write only INCREASE, DECREASE or STAYS THE SAME.
10.4.1 the concentration of the electrolyte
10.4.2 the mass of Y (2)
10.5 Give the most likely use for Y. (1)
10.6 Give a probable use for the sludge formed below X. (1)

[8]

SECTION B TOTAL: 125
Total mark: 150

ANSWERS TO EXEMPLAR: PAPER 2

SECTION A

QUESTION 1

1.1 ethyne✓
1.2 electroplating✓
1.3 hydrogen ✓ (half-cell)
1.4 equivalence point ✓
1.5 Contact ✓ process **[5]**

QUESTION 2

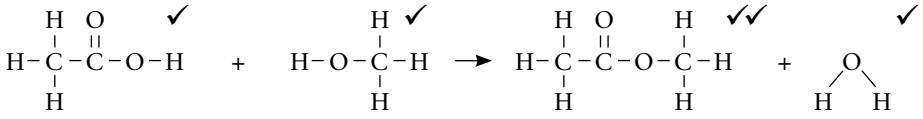
2.1 D✓✓
2.2 A✓✓
2.3 B✓✓
2.4 D✓✓
2.5 C✓✓
2.6 A✓✓
2.7 C✓✓
2.8 B✓✓
2.9 B✓✓
2.10 B✓✓ **[20]**

SECTION B

QUESTION 3

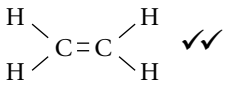
3.1.1 carboxylic acid✓
3.1.2 alcohol✓
3.1.3 aldehyde✓ (3)
3.2.1 butan-1-ol✓
3.2.2 butanal✓ (2)
3.3 Compound A has the strongest intermolecular forces✓ – hydrogen bonding and also dipole-dipole attraction. ✓
Compound B has hydrogen bonding. Compound C has dipole-dipole attraction. ✓ (3)
[8]

QUESTION 4

4.1  (5)

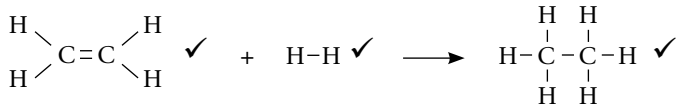
4.2 Catalyst ✓OR dehydrating agent/ remove water (1)
4.3 Ethanol is flammable✓ (1)
4.4 Vapours are cooled down and condense/return to test tube✓
OR Prevents vapours from leaving the test tube
OR Functions as a condenser
OR Causes the mixture to reflux (1)
4.5 Na_2CO_3 is a base✓ and will neutralise those acids. ✓ (2)
4.6 $C_3H_6O_2$✓ (1)
4.7 isomerism✓ (1)
4.8 methyl ethanoate✓ propanoic acid✓(OR any cyclobutanediol) (2)
[14]

QUESTION 5

5.1  ✓✓ (2)

5.2 The ethene liberated by the banana ages the cabbage and lettuce. ✓✓ (2)
5.3 C_nH_{2n}✓ (1)
5.4 A: substitution (halogenation/bromination)✓

B: addition (hydrogenation) ✓
D: addition (hydration) ✓
H: substitution✓ (4)

5.5  (3)

5.6 HBr✓✓ (2)

5.7.1 E: concentrated ✓
G: dilute✓ (2)

5.7.2 dehydrohalogenation✓ (1)

5.8 addition✓ (1)

[18]

QUESTION 6

6.1 The amount of product formed/reactant used up✓ per unit time✓ (per second). (2)

6.2 concentration of HCl✓ (1)

6.3 Product CO_2 is a gas✓ and escapes from the beaker. ✓ (2)

6.4 Calcium carbonate is used up✓ and the reaction stops, no more CO_2 formed to escape. ✓ (2)

6.5.1 graph B✓ (slower reaction, same mass loss) (1)

6.5.2 graph A ✓ (same rate, greater initial mass) (1)

6.5.3 graph C✓ (faster reaction, same mass loss) (1)

6.6 graph C✓ Catalyst speeds up the rate of reaction✓, therefore gradient ✓of graph will be steepest for same initial mass. ✓ (4)

[14]

QUESTION 7

7.1

	N_2 +	H_2 ⇌	NH
Molar ratio	**1**	**3**	**2**
Moles start	2	3	0
Moles change	0,8✓	2,4✓	1,6
Moles equilibrium	1,2	0,6	1,6
Conc equilibrium	2,4	1,2	3,2

(all 3 equilibrium conc correct) ✓

$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$ ✓

$= \frac{(3,2)^2}{(2,4)(1,2)^3}$ ✓

$= 2,47$ ✓ (6)

7.2 If the mixture is heated, then the reaction which uses up excess heat *i.e.* the endothermic will be favoured. ✓ If the moles of ammonia decrease, then the reverse reaction has been favoured. ✓ Therefore the reverse is endothermic✓ so the forward is exothermic. ✓ (4)

7.3.1 STAYS THE SAME✓

7.3.2 DECREASE ✓

7.3.3 DECREASE✓ (NH_3 will dissolve in water, equilibrium shift right) (3)

7.4 Haber✓ process (1)

7.5 Although yield of NH_3 is lower at higher temperature, ✓ rate is faster. ✓ Higher temperature compromises temperature. ✓ (3)

7.6 Fractional distillation of liquid air. ✓ (1)

7.7 nitric acid✓ (1)

7.8 Ostwald✓ process (1)

7.9 platinum✓ (1)

7.10 ammonium nitrate✓ (1)

7.11 leaves✓ (1)

7.12 Eutrophication✓ – too many nutrients in water, algal bloom, fish die✓
OR blue baby syndrome – excess nitrates in drinking water (2)

7.13 guano, manure, dried blood (any 1) ✓ (1)

[26]

QUESTION 8

8.1 The concentration of a standard solution is exactly known. ✓ (1)

8.2 $M(KOH) = 56\ g{\cdot}mol^{-1}$✓
$M = cMV$ ✓$= 0{,}2\ mol{\cdot}dm^{-3} \times 56\ g{\cdot}mol^{-1} \times 0{,}3\ dm^3$ ✓ $= 3{,}36\ g$ ✓ (4)

8.3 0,2 mol KOH yield 0,2 mol OH^-✓
$K_w = [H^+][OH^-] = [H^+][0{,}2] = 10^{-14}$✓
$[H^+] = [\frac{10^{-14}}{0{,}2}] = 5 \times 10^{-14}$ ✓
$pH = -\log[H^+] = -\log 5 \times 10^{-14} = -(-13{,}3) = 13{,}3$✓ (4)

8.4 $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$ ✓✓ (2)

8.5 Bromothymol blue; ✓ H_2SO_4 is a strong acid ✓and KOH is a strong base. ✓ The equivalence point will be at approximately pH = 7 (3)

8.6 $[\frac{n_a}{n_b}] = [\frac{c_a V_a}{c_b V_b}] = [\frac{1}{2}]$✓

$$\frac{c_a \times 20\ \cancel{cm^3}}{0{,}2\ mol{\cdot}dm^{-3} \times 15\ \cancel{cm^3}} = \frac{1}{2}$$ ✓✓

$$c_a = \frac{0{,}2 \times 15}{2 \times 20} = 0{,}075\ mol{\cdot}dm^{-3}$$✓✓ (5)

[19]

QUESTION 9

9.1 Temperature = 298 K✓
Concentration of electrolytes = 1 $mol{\cdot}dm^{-3}$ ✓ (2)

9.2.1 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$✓
$1{,}56 = X - (-0{,}76)$ ✓
$1{,}56 - 0{,}76 = X$✓
$X = +0{,}80\ V$✓ (4)

9.2.2 zero✓✓ (or 0 V) (2)

9.3.1 silver✓ (1)

9.3.2 silver ions✓ (1)

9.4 $Zn\,|\,Zn^{2+}(1mol{\cdot}dm^{-3})$ ✓$\,||\,Ag^+(1mol{\cdot}dm^{-3})\,|\,Ag$✓✓ (3)

9.5 Zinc ions✓ will react with H_2S to form ZnS✓. Concentration of Zn^{2+} will decrease. ✓
More Zn will be oxidised and the anode potential increases.✓ Voltage increases. ✓ (5)

[18]

QUESTION 10

10.1 X✓ (1)

10.2 Cu^{2+} (accept: X^{2+})✓ (1)

10.3 copper nitrate (any soluble copper(II) salt) ✓✓ (2)

10.4.1 STAYS THE SAME✓

10.4.2 INCREASE✓ (2)

10.5 Electrical conductors/plumbing pipes ✓ (1)

10.6 Valuable metals extracted and sold. ✓ (1)

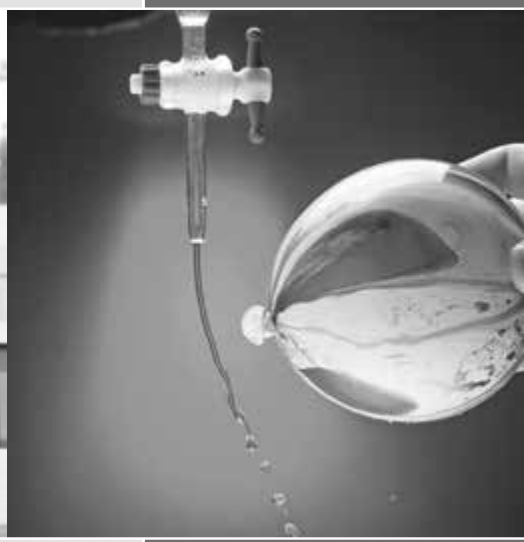
[8]

TOTAL: 150

SECTION C

PLANNING





Teachers are involved in different levels of planning for each subject. These different levels of planning make up the learning programme for that subject. A learning programme consists of a subject framework, work schedules and lesson preparations.

Phase programme and work schedule

The phase programme or subject framework specifies the scope of learning and assessment for the three grades in a phase of the FET band. An overview of the knowledge areas and topics for the Physical Sciences FET phase appears in the work schedule on page C3 of this .

The Curriculum and Assessment Policy Statement (CAPS) specifies the core knowledge and concepts to be covered during the FET phase, as well as the amount of time in hours to be devoted to each topic.

Lesson preparation

A lesson preparation is a more detailed plan for a particular section of work, a period of time during the year or a particular lesson. It describes what learning is going to take place, and how it will take place. In addition to the information in the work schedule, it explains how the activities and assessment will take place as well as the use of resources. The lesson preparation also refers to prior and future learning.

You will need to carry out your own lesson preparation for your class. Your lesson preparation will indicate when and how you will introduce each activity, each section of new knowledge, each assessment activity, and so on, using and expanding the information from the work schedule. We have included a blank lesson preparation grid in Section E: Photocopiable resources, and an example of a completed lesson preparation in this section, to help you with your planning.

Phase programme

Core knowledge area	Grades	Percentage of time (per grade)	Knowledge concepts
Mechanics	10	18,75%	1. Vectors and scalars 2. Motion in one dimension 3. Description of motion 4. Energy
	11	16,87%	1. Vectors in two dimensions 2. Newton's Laws and their application
	12	17,50%	1. Momentum and impulse 2. Vertical projectile motion in 1D 3. Work, energy and power
Waves, sound and light	10	10,00%	1. Transverse pulses on a string or spring 2. Transverse waves 3. Longitudinal waves 4. Sound 5. Electromagnetic radiation
	11	8,13%	1. Geometrical optics 2. 2D and 3D wavefronts
	12	3,75%	1. The Doppler Effect

Core knowledge area	Grades	Percentage of time (per grade)	Knowledge concepts
Electricity and magnetism	10	8,75%	1. Magnetism 2. Electrostatics 3. Electric circuits
	11	12,50%	1. Electrostatics 2. Electric circuits 3. Electromagnetism
	12	7,50%	1. Electric circuits 2. Electrodynamics
Matter and materials	10	17,50%	1. Classification of matter 2. States of matter and the Kinetic Molecular Theory 3. The atom 4. The Periodic Table 5. Chemical bonding 6. Particles making up substances
	11	15,00%	1. Atomic combinations: molecular structure 2. Intermolecular forces 3. Ideal gases and thermal properties
	12	3,75% 11,50%	Physics 1. Optical phenomena and properties of materials Chemistry 2. Organic molecules 3. Organic macromolecules
Chemical change	10	15,00%	1. Physical and chemical change 2. Representing chemical change 3. Reactions in aqueous solution 4. Quantitative aspects of chemical change
	11	17,50%	1. Quantitative aspects of chemical change 2. Energy and chemical change 3. Types of reactions
	12	17,50%	1. Reaction rate 2. Chemical equilibrium 3. Acids and bases 4. Electrochemical reactions
Chemical systems	10	5,00%	The hydrosphere
	11	5,00%	The lithosphere
	12	3,50%	The chemical industry

Sample work schedule to use with this textbook

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
Term 1						
Module 1: Mechanics						
2	Unit 1: Momentum and impulse	Momentum	31	• Define momentum. Calculate the momentum of a moving object using p = mv. • Describe the vector nature of momentum and illustrate with some simple examples. • Draw vector diagrams to illustrate the relationship between the initial momentum, the final momentum and the change in momentum in each of the above cases.		
2		Newton's Second Law expressed in terms of momentum	35	• State Newton's Second Law In terms of momentum. • Express Newton's Second Law in symbols. • Explain the relationship between the net force and change in momentum for a variety of motions. • Calculate the change in momentum when a resultant force acts on an object and its velocity increases in the direction of motion, decreases and reverses its direction of motion.		
5		Conservation of momentum, and Elastic and inelastic collisions	40, 44	• Explain what is meant by a system (in physics). Explain (when working with systems) what is meant by internal and external forces. Explain that an isolated system is one that has no net force (external) acting on it. • State the law of conservation of momentum. • Distinguish between elastic and inelastic collisions. Know that kinetic energy is only conserved in an elastic collision. • Apply the conservation of momentum to collisions of two objects moving in one dimension (along a straight line) with the aid of an appropriate sign convention. • Verify the conservation of linear momentum experimentally. • Investigate the conservation of momentum and energy using Newton's cradle.		
4		Impulse	47	• Define Impulse as the product of net force and the contact time. Know that impulse is a vector quantity. • Know that $F_{net}\Delta t$ is a change in momentum *i.e.* $F_{net}\Delta t = \Delta p$. This relationship is referred to as the impulse-momentum theorem. • Use the impulse-momentum theorem to calculate the force exerted, time for which the force is applied and change in momentum for a variety of situations involving the motion of an object In one dimension. • Apply the concept of impulse to safety considerations in everyday life.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
5	Unit 2: Vertical projectile motion in one dimension	Vertical projectile motion represented in words, diagrams, equations and graphs. (Near the surface of Earth and in the absence of friction)	52	• Explain that projectiles fall freely with gravitational acceleration '*g*', which always acts downwards and is constant irrespective of whether the projectile is moving upward or downward or is at maximum height. • Know that projectiles take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. This is known as time symmetry. • Know that projectiles can have their motion described by a single set of equations for the upward and downward motion. • Use equations of motion to determine the position, velocity and displacement of a projectile at any given time. • Draw position *vs.* time (*x vs. t*), velocity *vs.* time (*v vs. t*) and acceleration *vs.* time (*a vs. t*) graphs for 1D projectile motion. • Give equations for position versus time and velocity versus time for the graphs of 1D projectile motion. • Given *x vs. t*, *v vs. t* or *a vs. t* graphs determine position, displacement, velocity or acceleration at any time t. • Given *x vs. t*, *v vs. t* or *a vs. t* graphs describe the motion of the object *e.g.* graphs showing a ball bouncing, thrown vertically upwards, thrown vertically downward, and so on. • Investigate the motion of a falling body. • Draw a graph of position *vs.* time and velocity *vs.* time for a free falling object. Use the data to determine the acceleration due to gravity.		
Term 1						
Module 2: Matter and materials						
12	Unit 1: Organic molecules		75	• Define organic molecules as molecules containing carbon atoms. • Describe carbon as the basic building block of organic compounds that recycles through Earth's air, water, soil, and living organisms including human beings.		
3		Organic molecular structures	77	• Discuss the special properties of carbon that makes it possible to form a variety of bonds. • Give condensed structural, structural and molecular formulae for alkanes and compounds containing the following functional groups: double carbon-carbon bonds, triple carbon-carbon bonds, alkyl halides, alcohols, carboxylic acids, esters, aldehydes, and ketones (up to 8 carbon atoms). • Explain the terms functional group, hydrocarbon and homologous series.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Explain the terms saturated, unsaturated and isomer. • Identify compounds that are saturated, unsaturated and are isomers (up to 8 carbon atoms). Isomers are restricted to structural isomers: 1. chain isomers (different chain) 2. positional isomers (different position of the same functional group) 3. functional isomers (different functional group).		
3		IUPAC naming and formulae	98	• Give the IUPAC name when given the formula. • Give the formula when given the IUPAC name. • Naming is restricted to compounds with the functional groups alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids and esters, up to a maximum of 8 carbon atoms in the parent chain (*i.e.* the longest chain). • Organic compounds are restricted to one type of functional group per compound and to a maximum of two functional groups of the same type per compound. • The only substituent chains that are allowed in naming and reactions are: methyl- and ethyl-groups. • A maximum of THREE substituent chains (alkyl substituents) are allowed on the parent chain.		
1		Structure – physical property relationships	102	• Recognise and apply to given examples the relationship between: – physical properties and intermolecular forces (ethanol, dimethyl ether, ethanoic acid, ethane, chloro-ethane) – physical properties and number and type of functional groups (ethanol, dimethyl ether, ethanoic acid, ethane, chloro-ethane) – physical properties and chain length (methane, ethane, propane, butane, hexane, octane) – physical properties and branched chains (pentane, 2-methylbutane; 2,2-dimethylpropane).		
1		Applications of organic chemistry	107	• Alkanes are our most important (fossil) fuels. The combustion of alkanes (oxidation) is highly exothermic and carbon dioxide and water are produced: alkane + O_2 H_2O + CO_2 with $\Delta H<0$ • An ester is a product of an acid catalysed condensation between an alcohol and a carboxylic acid. • Identify the alcohol and carboxylic acid used to prepare a given ester and vice versa, and write an equation to present this preparation.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
3		Addition, elimination and substitution	110	• Describe criteria to use to classify elimination, substitution or addition reactions according to structural change. • Addition reactions: Unsaturated compounds (alkenes, cycloalkenes) undergo addition reactions: – Hydrohalogenation: Addition of HX to an alkene *e.g.* $CH_2 = CH_2 + HC\ell \rightarrow CH_3 - CH_2C\ell$ Reaction conditions: HX (X = Cℓ, Br, I) added to alkene; no water must be present (During addition of HX to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The X atom attaches to the more substituted C atom). – Halogenation: Addition of X_2 (X = Cℓ, Br) to alkenes *e.g.* $CH_2 = CH_2 + C\ell_2 \rightarrow CH_2C\ell\text{-}CH_2C\ell$ Reaction conditions: X_2 (X = Cℓ, Br) added to alkene – Hydration: Addition of H_2O to alkenes *e.g.* $CH_2 = CH_2 + H_2O \rightarrow CH_3 - CH_2OH$ – Reaction conditions: H_2O in excess and a small amount of HX or other strong acid (H_3PO_4) as catalyst (During addition of H_2O to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The OH group attaches to the more substituted C-atom). – Hydrogenation: Addition of H_2 to alkenes *e.g.* $CH_2 = CH_2 + H_2 \rightarrow CH_3 - CH_3$ – Reaction conditions: alkene dissolved in a non polar solvent with the catalyst (Pt, Pd or Ni) in a H_2 atmosphere. • Elimination reactions: Saturated compounds (haloalkanes, alcohols, alkanes) undergo elimination reactions. – Dehydrohalogenation: Elimination of HX from a haloalkane *e.g.* $CH_2C\ell\text{-}CH_2C\ell \rightarrow CH_2 = CHC\ell + HC\ell$ Reaction conditions: heat under reflux (vapours condense and return to reaction vessel during heating) in a concentrated solution of NaOH or KOH in pure ethanol as the solvent *i.e.* hot ethanolic NaOH/KOH (If more than one elimination product is possible, the major product is the one where the H atom is removed from the C atom with the least number of H atoms).		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				– Dehydration of alcohols: Elimination of H_2O from an alcohol *e.g.* $CH_3 – CH_2OH \rightarrow CH_2 = CH_2 + H_2O$ Reaction conditions: Acid catalysed dehydration – heating of alcohol with an excess of concentrated H_2SO_4 (or H_3PO_4) (If more than one elimination product is possible, the major product is the one where the H atom is removed from the C atom with the least number of H atoms). • Cracking of hydrocarbons: Breaking up large hydrocarbon molecules into smaller and more useful bits. • Reaction conditions: high pressures and temperatures without a catalyst (thermal cracking), or lower temperatures and pressures in the presence of a catalyst (catalytic cracking). • Substitution reactions: – Interconversion between alcohols and haloalkanes: Reactions of HX (X = Cℓ , Br) with alcohols to produce haloalkanes. Reaction conditions: Tertiary alcohols are converted into haloalkanes using HBr or HCℓ at room temperature *e.g.* $C(CH_3)_3OH + HBr \rightarrow C(CH_3)_3Br + H_2O$ – The reaction works best with tertiary alcohols. Primary and secondary alchohols react slowly and at high temperatures. – Reactions of bases with haloalkanes (Hydrolysis) to produce alcohols *e.g.* $C(CH_3)_3X + KOH \rightarrow C(CH_3)_3OH + KBr$ – Reaction conditions: Haloalkane dissolved in ethanol before treatment with aqueous sodium hydroxide and warming the mixture; the same hydrolysis reaction occurs more slowly without alkali, *i.e.* H_2O added to the haloalkane dissolved in ethanol. (Strong based will cause elimination.) – Reactions of bases with haloalkanes (hydrolysis) to produce alcohols *e.g.* $C(CH_3)_3X + KOH \rightarrow C(CH_3)_3OH + KBr$ Reaction conditions: Haloalkane dissolved in ethanol before treatment with aqueous sodium hydroxide and warming of the mixture; the same hydrolysis reaction occurs more slowly without alkali, *i.e.* H_2O added to the haloalkane dissolved in ethanol. – Haloalkanes from alkanes. Reaction conditions: X_2 (X = Br, Cℓ) added to alkane in the presence of light or heat. • Describe addition reactions that are important in industry *e.g.* addition polymerisation reactions to produce polyethylene, polypropylene, and PVC.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
4		Plastics and polymers	119	• Describe the term polymer; macromolecule, chain, monomer, functional groups. • Illustrate the reaction to produce a polymer by an addition reaction using the polymerisation of only ethene to produce polythene. [$n CH_2=CH_2 \rightarrow (-CH_2-CH_2-)n$] • What is the industrial use of polythene? (Make squeeze bottles, plastic bags, films, toys and moulded objects, electric insulation. Polythene has the recycling number 4.) • Illustrate the reaction to produce a polymer by condensation reaction with the reaction to produce a polyester. Use only the reaction to make the polymer polyethylene. • Illustrate the reaction to produce a polymer by condensation reaction with the reaction to produce a polyester. Polylactic acid (PLA) is an interesting polymer because the monomer used for this polymer comes from the biological fermentation of plant materials (as opposed to monomers coming from petroleum) and the polymer is biodegradable. This polymer (PLA) is mostly used for packaging material and because it is biodegradable it has the potential to alleviate land-fill disposal problems. • Identify the monomer used to produce a polymer from the structural formula of a section of a chain. Use only the following polymers to identify monomers: Polyvinyl chloride (PVC); polystyrene; polythene; polyvinyl acetate (PVA). (Limited to identification of monomers.) • Identify a polymer as the product of an addition or condensation polymerisation reaction, from its structural formula (use only polythene and Polylactic acid). • Identify a polymer as the product of an addition or condensation polymerisation reaction, from its structural formula.		
Term 2						
Module 1: Mechanics						
2	Unit 3: Work, energy and power	Definition of work	147	• Define the work done on an object by a force as : $W=F\Delta x\text{Cos}\theta$. • Know that work is a scalar quantity and is measured in joules (J). • Calculate the net work done on an object by applying the definition of work to each force acting on the object while it is being displaced, and then adding up (scalar) each contribution. • Positive net work done on a system will increase the energy of the system and negative net work done on the system will decrease the energy of the system.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				ALTERNATE METHOD FOR DETERMINING THE NET WORK. 1. Draw a force diagram showing only forces that act along the plane. Ignore perpendicular forces. 2. Calculate the resultant force (along the plane). 3. Calculate the net work done on an object by taking the product of the resultant force (along the plane) acting on the object and its displacement along the plane.		
2		The Work-Energy Theorem	151	• Know that the net work done on an object causes a change in the object's kinetic energy – the *work-energy theorem:* $W_{net} = E_{kf} - E_{ki}$ • Apply the work-energy theorem to objects on horizontal and inclined planes (frictionless and rough).		
3		Conservative and non-conservative forces	154	• Define conservative forces and give an example. • Define non-conservative forces and give examples. • Know that when only conservative forces are present, mechanical energy is conserved. • Know that when non-conservative forces are present mechanical energy (sum of kinetic and potential) is not conserved, but total energy (of the system) is still conserved. • Solve conservation of energy problems (with dissipative forces present) using the equation: $W_{nc} = \Delta E_k + \Delta E_p$ • Use the above relationship to show that in the absence of non-conservative forces, mechanical energy is conserved.		
3		Power	161	• Define power as the rate at which work is done. • Calculate the power involved when work is done. • Understand the average power required to keep an object moving at a constant speed along a rough horizontal surface or a rough inclined plane and do calculations using the equation $P_{av} = Fv_{av}$. • Calculate the minimum power required of an electric motor to pump water from a borehole of a particular depth at a particular rate using $W_{nc} = \Delta Ek + \Delta E_p$ • Calculate and understand minimum power. • Perform simple experiments to determine the work done in walking up (or running up a flight of stairs). By timing the run and walk (same flight of stairs) one can enrich the concept of power.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
Term 2						
Module 3: Waves, sound and light						
4	Unit 1: The Doppler Effect	With sound and ultrasound	171	• State the Doppler Effect for sound and give everyday examples. • Explain (using appropriate illustrations) why a sound increases in pitch when the source of the sound travels towards a listener and decreases in pitch when it travels away. • Use the equation $f_L = \frac{v \pm v_L}{v \pm v_S} f_S$ to calculate the frequency of sound detected by a listener (L) when either the source or the listener is moving. • Describe applications of the Doppler Effect with ultrasound waves in medicine, *e.g.* to measure the rate of blood flow or the heartbeat of a foetus in the womb.		
2		With light – red shifts in the universe (evidence for the expanding universe)	177	• State that light emitted from many stars is shifted toward the red, or longer wavelength/lower frequency, end of the spectrum due to movement of the source of light. • Apply the Doppler Effect to these 'red shifts' to conclude that most stars are moving away from the Earth and therefore the universe is expanding.		
Term 2						
Module 4: Chemical change						
2	Unit 1: Rate and extent of reaction	The rate of a reaction and factors affecting rate	185	• Explain what is meant by reaction rate. • List the factors which affect the rate of chemical reactions. (Surface area (solid), concentration (solution), pressure (gas), temperature, and catalyst.) • Explain in terms of collision theory how the various factors affect the rate of chemical reactions.		
1		Measuring rates of reaction	192	• Suggest suitable experimental techniques for measuring the rate of a given reaction including the measuring of gas volumes, turbidity (*e.g.* precipitate formation), change of colour and the change of the mass of the reaction vessel.		
1		Mechanism of reaction and of catalysis	201	• Define activation energy – the minimum energy required for a reaction to take place. Colliding molecules must have, apart from the correct orientation, a kinetic energy equal to or bigger than the activation energy of a reaction before the reaction can take place.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Use a graph showing the distribution of molecular energies (number of particles against their kinetic energy) to explain why only some molecules have enough energy to react and hence how adding a catalyst and heating the reactants affects the rate. • Explain (in simple terms) how some catalysts function by reacting with the reactants in such a way that the reaction follows an alternative path of lower activation energy.		
2	Unit 2: Chemical equilibrium	Chemical equilibrium and factors affecting equilibrium	205	• Explain what is meant by: – open and closed systems – a reversible reaction – dynamic equilibrium. • List the factors which influence the position of an equilibrium.		
4		Equilibrium constant, K_c	210	• List the factors which influence the value of the equilibrium constant K_c. • Write down an expression for the equilibrium constant having been given the equation for the reaction. • Perform calculations based on K_c values. • Explain the significance of high and low values of the equilibrium constant.		
2		Application of equilibrium principles	213	• State Le Chatelier's Principle. Use Le Chatelier's Principle to identify and explain the effects of changes of pressure, temperature, and concentration (common ion effect) on the concentrations and amounts of each substance in an equilibrium mixture. Explain the use of a catalyst and its influence on an equilibrium mixture. • Interpret only simple graphs of equilibrium. • Apply the rate and equilibrium principles to important industrial applications *e.g.* Haber process.		
8	Unit 3: Acids and bases	Acid-base reactions	223	• Explain what is meant by acids and bases. • State acid and base models (Arrhenius, Lowry- Brønsted). • Write the reaction equations of aqueous solutions of acids and bases. • Give conjugate acid-base pairs for given compounds. • Determine the approximate pH of salts in salt hydrolysis. • Give the neutralisation reactions of common laboratory acids and bases. • How do indicators work? What is the range of methyl orange, bromo thymol blue and phenolphthalein indicators? • Do simple acid-base titrations. • Do calculations based on titration reactions.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Name some common strong and weak acids and bases. • Explain the pH scale. • Calculate pH values of strong acids and strong bases. • Define the concept of K_w. • Distinguish between strong and concentrated acids. • Distinguish between concentrated and dilute acids. • Explain the auto-ionisation of water. • Compare the K_a and K_b values of strong and weak acids and bases. • Compare strong and weak acids by looking at pH, conductivity and reaction rate. • Look at the application of acids and bases in the Chlor-alkali industry (chemical reactions only). • Look at the application of acids and bases in the chemistry of hair. (What is the pH of hair? What is permanent waving lotion and how does it work? What are hair relaxers and how do they work? Discuss different ways of colouring hair.)		
Term 3						
Module 5: Electricity and Magnetism						
4	Unit 1: Electric circuits	Internal resistance, and series and parallel networks	262, 265	• Solve problems involving current, voltage and resistance for circuits containing arrangements of resistors in series and in parallel. • State that a real battery has internal resistance. • The sum of the voltages across the external circuit plus the voltage across the internal resistance is equal to the emf: $\varepsilon = V_{circuit} + V_{internal\ resistance}$ or $\varepsilon = IR_{ext} + Ir$ • Solve circuit problems in which the internal resistance of the battery must be considered. • Solve circuit problems, with internal resistance, involving series-parallel networks of resistors.		
4	Unit 2: Electro-dynamics	Electrical machines (generators, motors)	276	• State that generators convert mechanical energy to electrical energy and motors convert electrical energy to mechanical energy. • Use Faraday's Law to explain why a current is induced in a coil that is rotated in a magnetic field. • Use words and pictures to explain the basic principle of an AC generator (alternator) in which a coil is mechanically rotated in a magnetic field. • Use words and pictures to explain how a DC generator works and how it differs from an AC generator.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Explain why a current-carrying coil placed in a magnetic field (but not parallel to the field) will turn by referring to the force exerted on moving charges by a magnetic field and the torque on the coil. • Use words and pictures to explain the basic principle of an electric motor. • Give examples of the use of AC and DC generators. • Give examples of the use of motors.		
		Alternating current	293	• Explain the advantages of alternating current. • Write expressions for the current and voltage in an AC circuit. • Define the rms (root mean square) values for current and voltage as $I_{rms} = \frac{I_{max}}{\sqrt{2}}$ en $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ respectively, and explain why these values are useful. • Know that the average power is given by: $P_{av} = I_{rms}V_{rms} = \frac{1}{2}I_{max}V_{max}$ (for a purely resistive circuit). • Draw a graph of voltage *vs.* time and current *vs.* time for an AC circuit. • Solve problems using the concepts of I_{rms}, V_{rms}, P_{av}		
Term 3						
Module 2: Matter and materials						
6	Unit 2: Optical phenomena and properties of materials	The photoelectric effect	305	• Describe the photoelectric effect as the process that occurs when light shines on a metal and it ejects electrons. • Give the significance of the photoelectric effect: it establishes the quantum theory and it illustrates the particle nature of light. • Define cut-off frequency, f_o. • Define work function and know that the work function is material specific. • Know that the cut-off frequency corresponds to a maximum wavelength. • Apply the photoelectric equation: $E = W_o + KE_{max}$, waar $E = hf$ en $W_o = hf_o$; $KE_{max} = \frac{1}{2}m(v_{max})^2$ • Know that the number of electrons ejected per second increases with the intensity of the incident radiation.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Know that if the frequency of the incident radiation is below the cut-off frequency, then increasing the intensity of the radiation has no effect *i.e.* it does not cause electrons to be ejected. • Understand that the photoelectric effect demonstrates the particle nature of light.		
2		Emission and absorption spectra	314	• Explain the source of atomic emission spectra (of discharge tubes) and their unique relationship to each element. • Relate the lines on the atomic spectrum to electron transitions between energy levels. • Explain the difference between of atomic absorption and emission spectra.		
Term 3						
Module 4: Chemical change						
2	Unit 4: Electro-chemical reactions	Electrolytic cells and galvanic cells	323	• Define the galvanic cell in terms of: self-sustaining electrode reactions; conversion of chemical energy to electrical energy. • Define the electrolytic cell in terms of: electrode reactions that are sustained by a supply of electrical energy; conversion of electrical energy into chemical energy. • Define oxidation and reduction in terms of electron transfer. • Define oxidising agent and reducing agent in terms of oxidation and reduction. • Define anode and cathode in terms of oxidation and reduction.		
1		Relationship of current and potential to rate and equilibrium	328	• Give and explain the relationship between current in an electrochemical cell and the rate of the reaction. • State that the potential difference of the cell (V_{cell}) is related to the extent to which the spontaneous cell reaction has reached equilibrium. • State and use the qualitative relationship between V_{cell} and the concentration of product ions and reactant ions for the spontaneous reaction viz. V_{cell} decreases as the concentration of product ions increase and the concentration of reactant ions decrease until equilibrium is reached at which the $V_{cell} = 0$ (the cell is 'flat').		
2		Redox reaction in cells	329	• Describe the movement ions through the solutions the electron flow in the external circuit of the cell; the half reactions at the electrodes; the function of the salt bridge in galvanic cells. • Use cell notation or diagrams to represent a galvanic cell.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
		Standard electrode potentials	332	• Give the standard conditions under which standard electrode potentials are determined. • Describe the standard hydrogen electrode and explain its role as the reference electrode. • Explain how standard electrode potentials can be determined using the reference electrode and state the convention regarding positive and negative values. • Use the Table of Standard Reduction Potentials to calculate the emf of a standard galvanic cell. • Use a positive value of the standard emf as an indication that the reaction is spontaneous under standard conditions.		
2		Equations representing redox reactions	339	• Predict the half-cell in which oxidation will take place when connected to another half-cell. • Predict the half-cell in which reduction will take place when connected to another half-cell. • Write equations for reactions taking place at the anode and cathode. • Deduce the overall cell reaction by combining two half-reactions. • Describe, using half equations and the equation for the overall cell reaction, the following electrolytic processes: the decomposition of copper chloride; a simple example of electroplating (*e.g.* the refining of copper).		
1		Oxidation numbers	343	• Revise from Grade 11 and extend in Grade 12. • Describe, using half equations and the equation for the overall cell reaction, the layout of the particular cell using a schematic diagram and potential risks to the environment of the following electrolytic processes used industrially: – The production of chlorine (the chemical reactions of the chloroalkali-industry) – The recovery of aluminium metal from bauxite. (South Africa uses bauxite from Australia.)		
Term 3						
Module 6: Chemical systems						
6	Unit 1: Chemical industry	The fertiliser industry	359	• List, for plants, three non-mineral nutrients, *i.e.* nutrients that are not obtained from the soil: C, H and O and their sources *i.e.* the atmosphere (CO_2) and rain (H_2O); three primary nutrients N, P and K and their source *i.e.* the soil. These nutrients are mineral nutrients that dissolve in water in the soil and are absorbed by the roots of plants. • Fertilisers are needed because there are not always enough of these nutrients in the soil for healthy growth of plants. • Explain the function of N, P and K in plants. • Give the source of N (guano), P (bone meal) and K (German mines) before and after the first world war.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Interpret the N:P:K fertiliser ratio. • Describe and explain (rates, yields, neutralisation, …), using chemical equations wherever appropriate, these aspects of the industrial manufacture of fertilisers, given diagrams, flow charts and so on. – N_2 – fractional distillation of air – H_2 – at Sasol from coal and steam – NH_3 – Haber process – HNO_3 – Ostwald process – H_2SO_4 – including the contact process – H_3PO_4 and Ca $(H_2PO_4)_2$ (super phosphates) – NH_4NO_3 and $(NH_4)_2SO_4$ – H_2NCONH_2 (urea) • Give sources of potash (mined imported potassium salts like KNO_3, $K_2SO_{4\ and}$ KNO_3). • Evaluate the use of inorganic fertilisers on humans and the environment. • Link Sasol to the production of fertilisers, *i.e.* ammonium nitrate (fertiliser and explosive). • Define eutrophication. • Discuss alternatives to inorganic fertilisers as used by some communities.		

Example of lesson preparation grid

Lesson preparation			
Teacher:	**Grade:** 12	**School:** A Nother Secondary School	
Time	2 hours		
Knowledge area	Mechanics: Work, energy and power		
Prior knowledge	Identify forces acting on an object. Draw force diagrams / free body diagrams. Resolve forces into components along the direction of motion, and perpendicular to the direction of motion. Determine the net force acting on an object along the direction of motion.		
Core knowledge and concepts	Definition of work. Calculation of work done by a force. Calculation of net work done on an object.		
Teacher activities	**Learner activities**	**Resources**	**Assessment methods**
• Revise force diagrams and free body diagrams. • Revise the resolution of forces into components (horizontal and vertical components, and parallel and perpendicular components). • Revise the calculation of net force acting on an object (vector sum). • Define work done by a force. • Calculate work done by a force using the equation $W = \vec{F}\Delta x Cos\,\theta$ • Explain how the angle θ can be calculated for different directions of force and displacement. • Explain what is meant by positive work and negative work. • Calculate the net work done on an object by adding the work done by each force acting on the object (scalar sum). • Calculate the net work done on an object by using the equation $W_{net} = \vec{F}_{net}\Delta x \,\text{Cos}\,\theta$	• Answer questions for baseline assessment. • Discussion: work done by a force, how to determine angle between force and displacement, and what is meant by positive and negative work. • Completion of class work activity. • Completion of homework activity.	• Study & Master, Grade 12 page 147 to page 169. • Scientific calculators to compute trigonometric ratios.	• Baseline assessment to establish learner understanding of prior knowledge. Teacher assessment. • Class work exercise: to identify forces acting on an object, and calculate work done by each force. Teacher and self-assessment. • Homework exercise: completion of class work exercise, and additional questions. Self-assessment and peer assessment.

Updating your knowledge

As a professional educator, you should constantly update your knowledge on your subject. Here is a list of addresses, websites and other resources that you may find useful for this purpose.

Careers

http://www.pacecareers.com
http://www.saip.org.za/careers/CareersWithPhysics.html

Education

http://education.pwv.gov.za

Organisations

Academy of Science of South Africa (ASSAf)
PO Box 72135, Lynwood Ridge, 0400; Tel: 012 349-5461
Cambridge University Press: *http://uk.cambridge.org/africa/*
Cape Town Science Centre: *http://www.mtnsciencecentre.org.za/visit.html*
Chevron/Caltex Oil: *http://www.caltex.com*
PO Box 4907, Johannesburg, 2000; Tel: 011 280-2000
Chamber of Mines: *http://www.bullion.org.za*
PO Box 61809, Marshalltown, 2107; Tel: 011 498-7421
Council for Scientific and Industrial Research (CSIR): *http://www.csir.co.za*
PO Box 395, Brummeria, Pretoria (Tshwane), 0184; Tel: 012 841-2911
Department of Mineral and Energy Affairs: *http://www.energy.gov.za*
Private Bag X59, Pretoria (Tshwane), 0001
Department of National Education Film Library
Private Bag X239, Pretoria (Tshwane), 0001; Tel: 012 322-6625
Department of Environmental Affairs and Tourism:
http://www.environment.gov.za
Private Bag X447, Pretoria (Tshwane), 0001; Tel: 012 310-3911
Department of National Health and Planning: *http://www.doh.gov.za*
Private Bag X828, Pretoria (Tshwane), 0001; Tel: 012 312-0000
Department of Water Affairs and Forestry: *http://www.dwaf.gov.za*
Private Bag X313, Pretoria (Tshwane), 0001; Tel: 012 229-0111
Earthlife Africa: *http://www.earthlife.org.za*
PO Box 32131, Braamfontein, 2107; Tel: 011 339-3662
Environmental Education Centres:

- **Abe Bailey Nature Reserve**, Box 13, Carletonville, 2500; Gauteng; Tel: 018 788-3290
- **Ben Lavin Nature Reserve**, Box 782, Makhado, 0920; Limpopo; Tel: 015 516-4534, 078 477-3118
- **South African Education and Environment Project**: *http://www.saep.org*
  B14 Waverley Court, Kotzee Road, Mowbray, 7700; Tel: 021 447-3610
- **Delta Park Environmental Centre**: *http://www.deltaenviro.org.za*
  Road No. 3, Victory Park, Johannesburg, 2001; Tel: 011 888-4831
- **Umgeni Valley Project**: PO Box 394, Howick, 3290; KwaZulu-Natal; Tel: 033 330-3931

Environmental Education and Resources Unit: *http://www.uwc.ac.za*
Encyclopaedia Britannica online: *http://www.britannica.com/*
Environmental Education Association of Southern Africa (EEASA): *http://www.eeasa.org.za*
PO Box 394, Howick, 3290
Eskom: *http://www.eskom.co.za*
PO Box 1091, Johannesburg, 2000; Tel: 011 800-5401
Exploratorium: Dock Road, V & A Waterfront, Cape Town
Institute for Natural Resources: *http://www.inr.org.za*
PO Box 100396, Scottsville, 3209; Tel: 033 346-0796
Keep South Africa Beautiful: PO Box 1514, Randburg, 2125; Tel: 011 787-1080
Libraries
Use local municipal libraries, community health libraries, university and college libraries.

Museums

Museums provide a range of useful education resources, *e.g.* collections, books, outreach programmes, courses. Find a suitable museum by searching on: *http://www.museumsonline.co.za*

MTN Science Centres: *http://www.ctsc.org.za*

Gateway, Durban

National Advisory Council on Innovation (**NACI**): *http://www.naci.org.za*

The Secretary (NACI), Box 1758, Pretoria (Tshwane), 0001; Tel: 012 392-9352

Quest: Science for South Africa (**science magazine and website**):

http://www.questinteractive.co.za

Published by the Academy of Science of South Africa (ASSAf – see p. C18)

Research and Development in Mathematics, Science and Technology (**RADMASTE**): *http://www.radmaste.org.za*

SASOL: *http://www.sasol.com*

Science in Africa online science magazine: *http://www.scienceinafrica.co.za*

Science Education Centre: *http://www.sec.org.za*

Funda Centre, Diepkloof, Soweto; Tel: 011 938-1760

Society of South African Geographers: *http://www.ssag.co.za*

PO Box 128, PO Wits, 2050; Tel: 011 339-1951

Shell Education Service

PO Box 747, Saxonwold, Johannesburg, 2123; Tel: 011 441-7000

Shell South Africa: *http://www.shell.com*

Education Program Organiser, Box 2231, Cape Town, 8000; Tel: 021 213-1111

South African Agency for Science and Technology Advancement (**SAASTA**): *http://www.saasta.ac.za*

PO Box 1758, Pretoria (Tshwane), 0001; Tel: 012 392-9300

South African Institute of Physics (**SAIP**): *http://www.saip.org.za*

The Secretary, Postnet Suite 228, Private Bag X10, Musgrave 4062

South African Traditional Healers Association: *http://www.traditionalhealth.org.za*

PO Box 3722, Johannesburg, 2001

Southern African Association of Science and Technology Centres:

http://www.saastec.co.za

Statistics on Africa and social issues: *www.afdb.gov; www.fao.int*; *www.sadc.int; www.statssa.gov.za; www.worldbank.org*

Teachers' centres

Most areas in the country are supported by teachers' centres. They have a range of resources for you to borrow, as well as facilities for making your own teaching aids.

Universities and colleges

Approach various departments at your nearest university and college regarding a wide range of resources, such as visits, teaching aids, specimens, courses and speakers.

University of the Western Cape

Private Bag X17, Bellville, 7530; Tel: 021 959-2498

University of the Witwatersrand, PO Wits, 2050; Tel: 011 716-1111

Wilderness Leadership School: *http://www.wildernesstrails.org.za*

Box 87230, Houghton, 2041; Tel: 031 462-8642

Wildlife Environmental Society of South Africa (**WESSA**): *http://www.wessa.org.za*

Box 394, Howick, 3290; Tel: 033 330-3931

Worldwide Fund for Nature (**WWF**): *http://www.wwf.org.za*

PO Box 456, Stellenbosch, 7599; Tel: 021 887-2801

SECTION D

TEACHING GUIDELINES



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TERM ONE

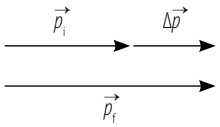
MODULE 1: MECHANICS

In this module learners will build on concepts in mechanics taught in Grade 11.

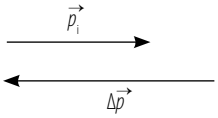
There is one prescribed experiment for formal assessment in this unit: Verify the conservation of linear momentum. You will find it on page 43 of the Learner's Book and page D7 of the Teacher's Guide. There is also one recommended experiment for informal assessment: Investigate the motion of a falling body. You will find it on page 64 of the Learner's Book and page D10 of the Teacher's Guide.

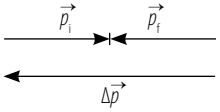
Test yourself 1 (LB p. 35)

1 a) $\Delta\vec{p} = \vec{p}_f - \vec{p}_i$
$\Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$
$= 50\text{ kg } (+3\text{ m·s}^{-1}) - 50\text{ kg } (+2\text{ m·s}^{-1})$
$= 50\text{ kg·m·s}^{-1}$ in the original direction of motion.

b)


2 a) $\vec{p}_i = mv_i = 0{,}1\text{ kg} \times 34\text{ m·s}^{-1} = 3{,}4\text{ kg·m·s}^{-1}$.



b)


$\vec{p}_f$ is opposite to the direction of the initial momentum. It should be the difference in size between Δp and p_i. Prediction: p_f appears to be smaller in size than p_i (*i.e.* less than 3,4 kg·m·s^{-1}), but opposite in direction to p_i.

c) Take direction towards the bat as negative.
$\Delta\vec{p} = \vec{p}_f - \vec{p}_i$
$\Delta\vec{p} = \vec{p}_f - m\vec{v}_i$
$5{,}4\text{ kg·m·s}^{-1} = p_f - 0{,}1\text{ kg } (-34\text{ m·s}^{-1})$
$p_f = +2\text{ kg·m·s}^{-1}$
$\vec{p}_f = 2\text{ kg·m·s}^{-1}$ opposite to the original direction of the ball.

Test yourself 2 (LB p. 40)

1 a) This is to control the amount of fuel and oxygen burnt to produce the required amount of gas for upward propulsion. If they were in the same compartment, then there is a danger of uncontrolled burning, or even explosions.

b) The gases escaping downwards provide the downward force that the rocket exerts on the gases. The gases in turn exert an upward force on the rocket, which propels the rocket upwards.

c) Boosters are additional smaller rockets attached to the outside of certains stages of the rocket. When they are fired downwards, they exert a force upward on the main rocket, causing it to accelerate in the upwards direction.

2 a) $\Delta\vec{p} = \vec{p}_f - \vec{p}_i$
$\Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$
$= 20\text{ kg } (+13\text{ m·s}^{-1}) - 20\text{ kg } (+10\text{ m·s}^{-1})$
$= 60\text{ kg·m·s}^{-1}$ in the original direction of motion.

b) $\Delta\vec{p} = \vec{p}_f - \vec{p}_i$
$\Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$
$= 4\text{ kg } (-5\text{ kg·m·s}^{-1}) - 4\text{ kg } (+10\text{ m·s}^{-1})$
$= -60\text{ kg·m·s}^{-1}$ in the original direction of motion.

3 The rocket exerts a force on the fuel tank downward. By Newton's Third Law, the fuel tank exerts a force on the rocket upward. The net force increases in the upward direction, thus changing the momentum in the upward direction. Therefore the velocity in the upward direction increases.

4 Learners are expected to research the impact of the explorations into space. Some guidelines that can be provided include:
- The launching of satelites above Earth's atmosphere – provides technological benefits such as global positioning systems (GPS), electronic communication, weather satelites and warning systems. Humans have benefitted from this technology.
- The landing on the moon, and the first-hand knowledge of the conditions on the moon.
- The landing of unmanned space crafts – for example, Curiosity's exploration of Mars, and the information sent to Earth.
- Any other space travel.

Knowledge gained from these space missions has advanced human understanding of space and its vastness.

LB p. 43

Activity 1 Recommended experiment for formal assessment

G

Verify the conservation of linear momentum

Answers to questions

1 $\vec{p}_{\text{before}} = m_1\vec{v}_{i1} + m_2\vec{v}_{i2} = 0$ (since both trolleys are initially stationary).

2 $p = mv = m\frac{\Delta x}{\Delta t}$ and since Δt for both are the same, $p \propto m\Delta x$.

3 Learner's own findings and answer.

4 Learner should arrive at the conclusion that $\vec{p}_{\text{before}} = \vec{p}_{\text{after}}$ which means that momentum is conserved.

5 The most likely reason is that the trolleys do not travel the measured distance in constant velocity as we cannot exclude friction. The presence of the frictional force results in lower velocities for both trolley. This leads to inaccurate readings.

Guidelines for assessment

Verify the conservation of linear momentum.

In this activity, learners are expected to conduct the experiment to verify momentum conservation. The aim, apparatus, procedure and the table to capture the relevant data are provided. Therefore, these aspects should not be assessed. The aspects that should be assessed can be classified into two categories; those for which learners can demonstrate understanding of the procedure and their theoretical links, and those where learners need to demonstrate the skills of conducting the experiment in terms of the procedure outlined. Learner feedback for the former is obtained by means of written responses to a set of questions asked, and by means of observation and verification for the latter. The tools for assessment are a memorandum for the questions, and a checklist for the skills that were observed.

The memorandum for the questions asked in the Learner's Book is provided. A checklist to assess how learners follow instructions to conduct the experiment, is included on the next page.

The learner ensures the following:		Yes	No
1	Bumpers and trolleys set up to affect motion of trolleys in a straight line.		
2	Trolleys are released simultaneously.		
3	Several trials conducted to establish position of trolleys.		
4	Initial positions of trolleys are correct.		
5	Displacement of each trolley is correctly measured.		
6	Mass of each trolley is correctly measured.		
7	Positive and negative displacements recorded correctly, in metres.		
8	Mass of each trolley is recorded correctly, in kg.		
9	Product of mass and displacement for each trolley is correctly computed and recorded.		
10	The products are compared to ascertain accuracy of the results.		

LB p. 46

Activity 2 Recommended demonstration for informal assessment

Newton's Cradle

Answers to questions

1 We assume that there is no energy transferred to heat or sound when the balls collide and that the collisions are elastic. This means that the balls at the ends will continue to reach the same height, and they will continue to swing. In reality some energy is transferred to heat and sound and the ball will eventually come to rest.

2 a) $m_1\vec{v}_{i1} + m_2\vec{v}_{i2} = m_1\vec{v}_{f2} + m_2\vec{v}_{f2}$ (since momentum is conserved)
$m_1\vec{v}_{i1} + 0 = 0 + m_2\vec{v}_{f2}$ (since ball 2 starts from rest, and ball 1 comes to rest)
The mass of each ball is the same, so $\vec{v}_{f2} = \vec{v}_{i1} = \vec{v}_i$.
The velocity of ball 2 just after the collision is the same as the velocity of ball 1 just before the collision, namely $\vec{v}_i$.

b) Before collision, $E_{k(total)} = \frac{1}{2}m_1\vec{v}_{i1}^{\,2} + \frac{1}{2}m_2\vec{v}_{i2}^{\,2}$
$= \frac{1}{2}m\vec{v}_{i1}^{\,2} + 0$
$= \frac{1}{2}m\vec{v}_i^{\,2}$
After collision, $E_{k(total)} = \frac{1}{2}m_1\vec{v}_{f1}^{\,2} + \frac{1}{2}m_2\vec{v}_{f2}^{\,2}$
$= 0 + \frac{1}{2}m\vec{v}_{f2}^{\,2}$
$= \frac{1}{2}m\vec{v}_i^{\,2}$ (because $v_{f2} = v_i$)
Since total E_k before collision = total E_k after collision, we conclude that the collision is elastic.

3 Origins of the Newton cradle – learners are expected to research this, and engage in the contested nature of its origin.

Its utility is associated with the unusual continuity in the swing of the balls, and the symmetrical nature of this movement. It is an aesthetically pleasing sight, and is therefore referred to as an 'executive toy'. However, it is also used in many laboratories and science centres to demonstrate elastic collisions.

Test yourself 3 (LB p. 47)

1 Take the original direciton of the motion of the boy to be positive.

$$\text{Total } \vec{p}_{\text{before}} = \text{Total } \vec{p}_{\text{after}}$$
$$m_1\vec{v}_{i1} + m_2\vec{v}_{i2} = (m_1 + m_2)\vec{v}_f$$
$$40 \text{ kg } (+3 \text{ m·s}^{-1}) + 5 \text{ kg } (-6 \text{ m·s}^{-1}) = 45 \text{ kg} \times v_f$$
$$\vec{v}_f = +2 \text{ m·s}^{-1}$$
$$= 2 \text{ m·s}^{-1} \text{ in the original direciton that the boy was moving in.}$$

2 a) In an isolated system, the total linear momentum is conserved in both magnitude and direction.

b) Take motion to the left as positive.

$$\text{Total } \vec{p}_{\text{before}} = \text{Total } \vec{p}_{\text{after}}$$
$$(m_A + m_B)\vec{v}_i = m_A\vec{v}_{fA} + m_B\vec{v}_{fB}$$
$$(0{,}2 \text{ kg} + 0{,}4 \text{ kg})(+3 \text{ m·s}^{-1}) = 0{,}2 \text{ kg } (+4 \text{ m·s}^{-1}) + 0{,}4\ \vec{v}_{fB}$$
$$\vec{v}_{fB} = +2{,}5 \text{ m·s}^{-1}$$
$$= 2{,}5 \text{ m·s}^{-1} \text{ to the left}$$

c) Before explosion, $E_{k(\text{total})} = \frac{1}{2}m_A\vec{v}_{iA}^{\,2} + \frac{1}{2}m_B\vec{v}_{iB}^{\,2}$
$$= \tfrac{1}{2}(0{,}2 \text{ kg})(3 \text{ m·s}^{-1})^2 + \tfrac{1}{2}(0{,}4 \text{ kg})(3 \text{ m·s}^{-1})^2$$
$$= 2{,}7 \text{ J}$$

After explosion, $E_{k(\text{total})} = \frac{1}{2}m_A\vec{v}_{fA}^{\,2} + \frac{1}{2}m_B\vec{v}_{fB}^{\,2}$
$$= \tfrac{1}{2}(0{,}2 \text{ kg})(4 \text{ m·s}^{-1})^2 + \tfrac{1}{2}(0{,}4 \text{ kg})(2{,}5 \text{ m·s}^{-1})^2$$
$$= 2{,}85 \text{ J}$$

Since total E_k before explosion ≠ total E_k after explosion, the explosion is inelastic.

Test yourself 4 (LB p. 50)

1 In this question, the velocity of the cricket ball is given in km·h^{-1}. The velocity must be changed to m·s^{-1}.
54 km·h^{-1} = 15 m·s^{-1}, and 36 km·h^{-1} = 10 m·s^{-1}.
Take the original direction of the ball to be positive.

a) $F_{\text{net}}\Delta t = \Delta p = m_{vf} - m_{vi}$
$= 0{,}15 \text{ kg } (-10 \text{ m·s}^{-1} - 15 \text{ m·s}^{-1})$
$= -3{,}75 \text{ kg·m·s}^{-1}$
$= 3{,}75 \text{ kg·m·s}^{-1}$ opposite to the original direction of the ball.

b) $F_{\text{net}}\Delta t = \Delta p = -3{,}75 \text{ kg·m·s}^{-1}$
$F_{\text{net}}(0{,}1 \text{ s}) = -3{,}75 \text{ kg·m·s}^{-1}$
$F_{\text{net}} = -37{,}5 \text{ N}$
Therefore the average force exerted by the bat is 37,5 N opposite to the direction of the ball.

2 When the knees are bent upon landing, the time (Δt) for which the legs exert a force on the ground, and hence time for which the ground exerts a force on the legs is increased. The change in momentum (whether the knees are bent or not) is constant:
$F_{\text{net}} \propto \frac{1}{\Delta t}$ when Δp is constant.
i.e. if Δt is increased, F_{net} decreases.
The smaller net force on the legs will make the landing less painfull.

3 a) total $\vec{p}_{\text{before}}$ = total $\vec{p}_{\text{after}}$
$(0{,}040 \text{ kg})(500 \text{ m.s}^{-1}) + 0 = (0{,}040 \text{ kg})(200 \text{ m.s}^{-1}) + (6 \text{ kg})\ v_{f2}$
$\therefore \vec{v}_{f2} = +2 \text{ m.s}^{-1}$ in the original direction.

b) $\vec{F}_{\text{net}}\Delta t = \Delta p = m\vec{v}_f - m\vec{v}_i$
$480 \text{ N}\Delta t = \Delta p = (0{,}04 \text{ kg})(+500 \text{ m·s}^{-1}) - (0{,}04 \text{ kg})(+200 \text{ m·s}^{-1})$
$480 \text{ N}\Delta t = \Delta p = 20 \text{ kg·m·s}^{-1} - 8 \text{ kg·m·s}^{-1}$
$\Delta t = 0{,}025 \text{ s}$

Test yourself 5 (LB p. 51)

1 a) $v = \frac{\Delta x}{\Delta t}$, since the car is traveling at a constant velocity for 0,677 s.
$\therefore \Delta x = v\Delta t = 31 \text{ m.s}^{-1}(0{,}677\ s)$
$= 20{,}99 \text{ m}$

b) $\vec{F}_{net}\Delta t = \Delta p = m\vec{v}_f - m\vec{v}_i$
$\vec{F}_{net}\ 6{,}45 \text{ s} = (600 \text{ kg})(0 \text{ m·s}^{-1}) - (600 \text{ kg})(31 \text{ m·s}^{-1})$
$\vec{F}_{net} = 2883{,}72 \text{ N}$ opposite to the direction of the car's motion.

2. a) This part is very general. Learners are expected to refer to:
   i) Safe driving speeds.
   ii) Safe following distance.
   iii) Fatigue and the lack of driver alertness.
   iv) The dangers associated with cellphone usage while driving.
   v) The importance of effective and operational braking systems.
   vi) Safe pedestrian crossing.
   vii) The dangers associated with alcohol and drug usage for drivers and pedestrians.

   b) More specific responses are expected from learners for this part. Physics principles must be listed, *e.g.*
   i) Driving speeds and following distances must be safe, so that vehicles can be brought to a stop over shorter distances when necessary, to avoid accidents.
   ii) Cars must be fitted with seatbelts to avoid injuries – application of Newton's Third Law.
   iii) Cars should be fitted with airbags and crumple zones to prevent injuries during accidents. These features in a car increase the time of collision, and hence reduce the net force acting on the occupants of the car – application of the impulse-momentum-theorem.
   iv) Drivers and pedestrians need to stay alert so that their reaction time in potential accident situations can be reduced. This will ensure that stopping times are shorter.
   v) Braking systems need to be efficient, so that the forces applied during braking are large enough to reduce speeds effectively.

Unit 2 Vertical projectile motion in one dimension

TERM 1, MODULE 1

LB p. 64

Activity 3 Recommended experiment for informal assessment

I

Investigate the motion of a falling body

Answers to questions

1 To minimise the effects of air friction.
2 The mass piece must be aerodynamically shaped (or bullet-shaped), so that it can cut through the air and minimise air friction.
3 Place padding on the floor (*e.g.* a thick rubber mat).

4 The dots are too close together, and therefore difficult to analyse. Also, when the mass piece was released, there is no guarantee that the ticker timer was switched on simultaneously.

5 a) If the experiment is repeated with different masses, then mass is the independent variable.

b) Acceleration.

6 Learners need to compare their answers to 9,8 $m.s^{-2}$.

7 Friction between tape and timer, air friction, wind, inaccurate measurements.

8 No. The acceleration due to gravity is independent of mass.

Test yourself 6 (LB p. 70)

1 B

2 D

3 a) Bongi: $\Delta\vec{x} - 16\text{ m} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$\vec{v}_1 = 0\text{ m}\cdot\text{s}^{-1}$

so

$\Delta\vec{x} = \frac{1}{2}\vec{a}\Delta t^2 + 16\text{ m}$

Alex: $\Delta\vec{x} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$\vec{v}_1 = 12\text{ m}\cdot\text{s}^{-1}$

so

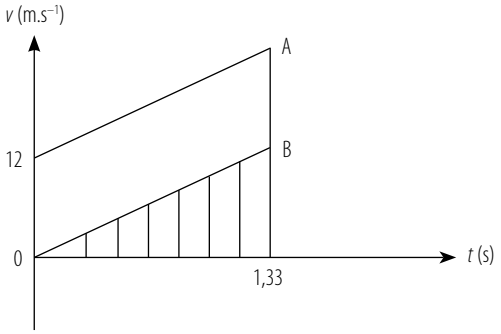
$\Delta x = 12\text{ m}\cdot\text{s}^{-1}\,\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$\frac{1}{2}\cancel{\vec{a}\Delta t^2} + 16\text{ m} = 12\text{ m}\cdot\text{s}^{-1}\,\Delta t + \cancel{\frac{1}{2}\vec{a}\Delta t^2}$

$16\text{ m} = 12\text{ m}\cdot\text{s}^{-1}\,\Delta t$

$\Delta t = 1{,}33\text{ s}$

b)



A – ball thrown by Alex

B – ball thrown by Bongi

Height of ball B when it was released = shaded area under graph B.

Gradient of graph = acceleration

$\frac{\Delta\vec{v}}{\Delta t} = 9{,}8\text{ m}\cdot\text{s}^{-2}$

$\frac{\Delta\vec{v}}{(1{,}33 - 0)\text{s}} = 9{,}8\text{ m}\cdot\text{s}^{-2}$

$\Delta\vec{v} = 13{,}034\text{ m}\cdot\text{s}^{-1}$

Therefore, shaded area $= \frac{1}{2}\,b \times h = \frac{1}{2}\,(1{,}33\text{s})(13{,}034\text{ m}\cdot\text{s}^{-1}) = 8{,}67\text{ m}$

4 a) Velocity increases from $t = 0$ s, as the ball falls from maximum height towards the ground and strikes the ground at $t = 0{,}4$ s. Acceleration is constant throughout the fall.

b) Height from which the ball is dropped = displacement of ball

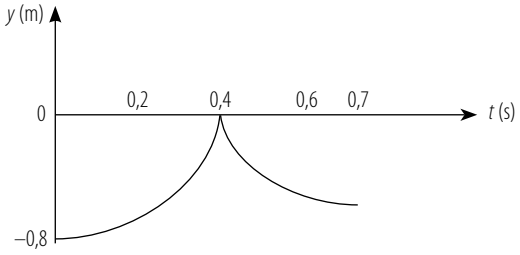
= area under the graph from $t = 0$ s to $t = 0{,}4$ s

$= \frac{1}{2}b \times h$

$= \frac{1}{2}(0{,}4\text{ s})(4\text{ m}\cdot\text{s}^{-1})$

$= 0{,}8\text{ m}$

c) Take the ground to be zero position.



Learner's Book pages 71–73

Unit 1 and 2 Summative assessment: Mechanics

TERM 1, MODULE 1

1 a) closed system
b) kinetic energy
c) impulse
d) Newton's Third Law
e) the impulse–momentum theorem
f) free fall
g) instantaneous velocity
h) displacement
i) acceleration / net force
j) velocity / final velocity

2 a) The momentum that an object has is in the direction of the velocity of the object.
b) The momentum of a body is directly proportional to the velocity of the body, and directly proportional to the mass of the body.
c) The impulse of an object is the change in momentum of the object.
d) Net force and impulse are always in the same direction.
e) Rockets can accelerate from the ground because the force of the hot gases expelled downwards causes the rocket to accelerate upwards.
f) Momentum is only conserved in collisions that occur in isolated systems.
g) An object is in free fall if the only force acting on the object is the gravitational force.
h) When an object is thrown upwards and returns to its starting point, the upward speed is equal to the downward speed at this point.
i) At the highest position reached by an object thrown upward, the velocity is zero. OR the acceleration is equal to the gravitational acceleration.
j) The object will take longer to reach the ground if it is released from rest.

3 a) B b) A
c) C d) B
e) A f) D

4 a) Whether the wine glass falls on a carpeted floor or a concrete floor from the same height, the change in momentum is the same. Now $F_{net} \alpha \frac{1}{\Delta t}$ (Δp constant). The contact time between the wine glass and the carpeted floor is greater than the contact time between the wine glass and the concrete floor because of the soft carpet fibres. Hence the net force exerted by the concrete floor is greater than that exerted

by the carpet. Hence, the wine glass is more likely to break on the concrete floor.

b) Bending your knees upon landing increases the contact time between the floor and yourself. Since F_{net} is inversely proportional to contact time (Δt) when Δp is constant, increasing the contact time decreases the net force, reducing the chances of injury to yourself.

5 Take the direction of the red ball's motion as positive.

$m_1\vec{v}_{i1} + m_2\vec{v}_{i2} = m_1\vec{v}_{f1} + m_2\vec{v}_{f2}$

$(0{,}6\text{ kg})(5\text{ m}\cdot\text{s}^{-1}) + (0{,}3\text{ kg})(0\text{ m}\cdot\text{s}^{-1}) = (0{,}6\text{ kg})(2\text{ m}\cdot\text{s}^{-1}) + (0{,}3\text{ kg})\vec{v}_{f2}$

$\vec{v}_{f2} = 6\text{ m}\cdot\text{s}^{-1}$

Therefore, the green ball moves at $6\text{ m}\cdot\text{s}^{-1}$ in the original direction of the red ball.

6 Let the mass of each trolley be m.

Take the direction of trolley A as positive.

$m_1\vec{v}_{i1} + m_2\vec{v}_{i2} = m_1\vec{v}_{f1} + m_2\vec{v}_{f2}$

$m_1(3{,}2\text{ m}\cdot\text{s}^{-1}) + m_2(0\text{ m}\cdot\text{s}^{-1}) = m_3(0\text{ m}\cdot\text{s}^{-1}) + m_2\vec{v}_{f2}$

$\vec{v}_{f2} = 3{,}2\text{ m}\cdot\text{s}^{-1}$

Therefore, trolley B moves at $3{,}2\text{ m}\cdot\text{s}^{-1}$ in the original direction of trolley A.

7 When the girl catches the ball, momentum is conserved.

$m_G\vec{v}_{iG} + m_B\vec{v}_{iB} = (m_G + m_B)\vec{v}_f$

$m_G(0) + m_B\vec{v}_{iB} = (m_G + m_B)\vec{v}_f$

$v_f = \dfrac{m_B\vec{v}_{iB}}{(m_G + m_B)} \approx \dfrac{m_B\vec{v}_{iB}}{m_G}$ (Since m_G is much bigger than m_B)

a) doubling the initial velocity of the ball ($\vec{v}_{iB}$) doubles $\vec{v}_f$; $\vec{v}_f = 4\text{ m}\cdot\text{s}^{-1}$.

b) doubling the mass of the ball (m_B) doubles $\vec{v}_f$; $\vec{v}_f = 4\text{ m}\cdot\text{s}^{-1}$.

c) doubling the mass of the girl (m_G) halves $\vec{v}_f$; $\vec{v}_f = 1\text{ m}\cdot\text{s}^{-1}$.

d) If the ball bounced of the girl and returned at the same speed, then:

$\vec{v}_{iB} = -\vec{v}_{fB}$

$m_G\vec{v}_{iG} + m_B\vec{v}_{iB} = m_G\vec{v}_{fG} + m_B\vec{v}_{fB}$

$m_G(0) + m_B\vec{v}_{iB} = m_G\vec{v}_{fG} + m_B(-\vec{v}_{iB})$

$\vec{v}_{fG} = \dfrac{2m_B\vec{v}_{iB}}{m_G} = 2(2) = 4\text{ m}\cdot\text{s}^{-1}$, since $\dfrac{m_B v_{iB}}{m_G} \approx v_f = 2\text{ m}\cdot\text{s}^{-1}$

8 Take upward motion as positive.

When the ball is moving down:

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\Delta y$

$= 0^2 + 2(-9{,}8\text{ m}\cdot\text{s}^{-2})(-3\text{m})$

$\vec{v}_f = -7{,}67\text{ m}\cdot\text{s}^{-1}$ (This is the velocity with which ball strikes the ground.)

When the ball is moving up:

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\Delta y$

$0^{(2)} = v_i^2 + 2(-9{,}8\text{ m}\cdot\text{s}^{-2})(2{,}2\text{ m})$

$\vec{v}_i = +6{,}57\text{ m}\cdot\text{s}^{-1}$ This is the velocity with which ball leaves the ground.

$\vec{F}_{net}\Delta t = \Delta p = m\vec{v}_f - m\vec{v}_i$ (where $\vec{v}_f$ is the velocity with which the ball leaves the ground, and $\vec{v}_i$ the velocity with which the ball strikes the ground)

$\vec{F}_{net}(0{,}002\text{ s}) = 0{,}2\text{ kg}(+6{,}57\text{ m}\cdot\text{s}^{-1}) - 0{,}2\text{ kg}(-7{,}67\text{ m}\cdot\text{s}^{-1})$

$\vec{F}_{net} = +1\,424\text{ N}$

The average force exerted by the floor on the ball is 1,424 N upward.

9 a) Take upward as positive.

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\Delta\vec{y}$

$0^2 = (30\text{ m}\cdot\text{s}^{-1})^2 + 2(-9{,}8\text{ m}\cdot\text{s}^{-2})\Delta\vec{y}$

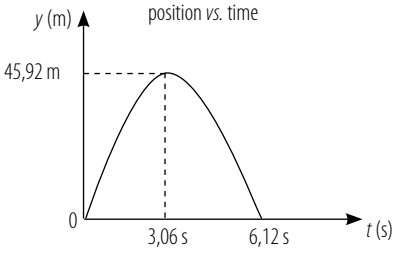
$\Delta\vec{y} = 45{,}92\text{ m}$

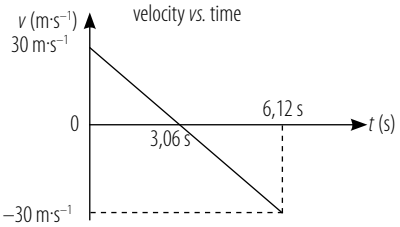
b) $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t$

$-30\ \text{m·s}^{-1} = +30\ \text{m·s}^{-1} + (-9{,}8\ \text{m·s}^{-2})\Delta t$

$\Delta t = 6{,}12\ \text{s}$

c)





10 Take downward motion as positive.

$\Delta\vec{y} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$+36\ \text{m} = \vec{v}_i(2{,}2\ \text{s}) + \frac{1}{2}(+9{,}8\ \text{m·s}^{-2})(2{,}2\ \text{s})^2$

$\vec{v}_i = +5{,}58\ \text{m·s}^{-1}$

Jannie threw the brick 5,58 m·s^{-1} downward.

11 a) Let the time taken for B to reach the ground be t seconds. Therefore time taken for A to reach the ground is $(t + 1{,}4)$ seconds. Also let the height of the building be y. Take upward as positive.

For object A:

$\Delta\vec{y} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$-y = (+10\ \text{m·s}^{-1})(t + 1{,}4)\text{s} + \frac{1}{2}(-9{,}8\ \text{m·s}^{-2})(t + 1{,}4)^2\text{s}^2$ (equation 1)

For object A:

$\Delta\vec{y} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$

$-y = 0 + \frac{1}{2}(-9{,}8\ \text{m·s}^{-2})(t\ \text{s})^2$ (equation 2)

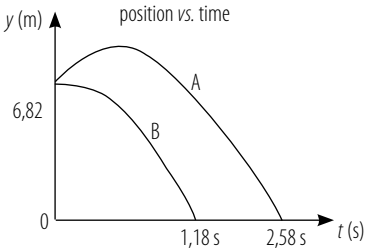
Solving equations 1 and 2 simultaneously, we get $t = 1{,}18$ s.

Therefore time taken for B to reach the ground is 1,18 s.

b) Substituting for $t = 1{,}18$ s in equation 2, we get $y = 6{,}82$ m.

Therefore height from which objects were launched = 6,82 m.

c)



12 a) Independent variable: mass

Dependent variable: acceleration

b) Height from which object is dropped, OR size of objects.

c) What is the relationship between the mass of an object, and the acceleration due to gravity when this object falls freely?

d) Use a ticker timer, and analyse the tape generated.

e) Protect the floor with padding, use mass pieces with similar shapes, ensure ticker tape runs freely through the timer, etc.

f) The acceleration due to gravity is independent of the mass of the object.

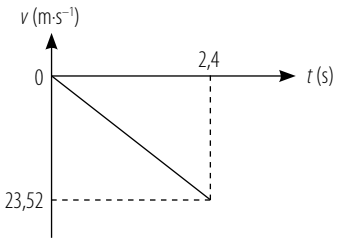
13 a) The change in velocity from t seconds to 2,4 seconds.

b) Area $= l \times b$

$= (2{,}4 - t)\text{ s} \times (-9{,}8\text{ m·s}^{-2}) = -13{,}72\text{ m·s}^{-1}$

$t = 1\text{ s}$

c)



14 Take upward motion as positive.

a) Consider the motion from the tenth floor to the large window:

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2a\Delta y$

$(2\vec{v})^2 = \vec{v}^2 + 2(-9{,}8\text{ m·s}^{-2})(-6\text{ m})$

$\vec{v} = +6{,}26\text{ m·s}^{-1}$

For the motion from the large window to the smaller window:

$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2a\Delta y$

$(24\text{ m·s}^{-1})^2 = (2 \times 6{,}26\text{ m·s}^{-1})^2 + 2(-9{,}8\text{ m·s}^{-2})\Delta y$

$\Delta y = -21{,}39\text{ m}$

Therefore, the vertical distance between the large window and the small window is 21,39 m.

b) Height of the tenth floor above ground:

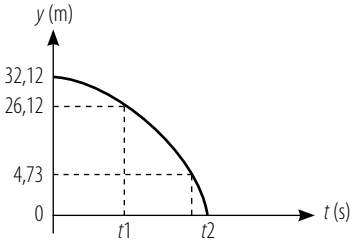
$\Delta y = \vec{v}_i \Delta t + \frac{1}{2} a \Delta t^2$

$= (-6{,}26\text{ m·s}^{-1})(2\text{ s}) + \frac{1}{2}(-9{,}8\text{ m·s}^{-2})(2\text{ s})^2$

$= -32{,}12\text{ m}$

i.e. the tenth floor is 32,12 m above the ground.

Therefore, large window is (32,12 m – 6 m) = 26,12 m above the ground, and the small window (26,12 m – 21,39 m) = 4,73 m above the ground.



MODULE 2: MATTER AND MATERIALS

This unit introduces the learner to organic chemistry. Not only do 90% of all known compounds contain carbon, but all living organisms are carbon-based. We surround ourselves with carbon compounds, such as plastics, fibres and rubber. These products enrich our lives and also provide jobs for thousands of chemists. Learners should be made aware of the importance of organic chemistry as well as the many opportunities for research and development in this field. Link everyday commodity articles with their chemical structure to bring the theory in context with everyday life.

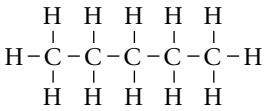
There is one prescribed experiment for formal assessment in this unit: Activity 5: Prepare different esters. You will find it on page 108 of the Learner's Book and page D23 of the Teacher's Guide. There are also two recommended experiments for informal assessment: Activity 3: Investigate saturated and unsaturated molecules, and Activity 8: Make 'slime' and 'silly putty'. Activity 3 can be found on page 93 of the Learner's Book and page D19 of the Teacher's Guide. Activity 8 can be found on page 128 of the Learner's Book and page D27 of the Teacher's Guide.

Test yourself 1 (LB p. 80)

1 carbon and hydrogen

2 Carbon can make four covalent bonds.
Carbon atoms can join each other to form long chains. Atoms of other elements can then attach to the chain.
Carbon atoms in a chain can be linked by single, double or triple covalent bonds.
Carbon atoms can also arrange themselves in rings.

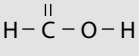
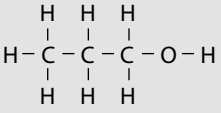
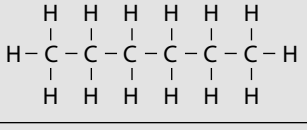
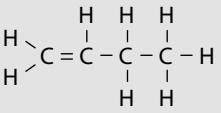
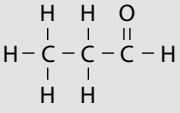
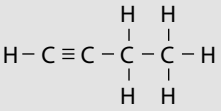
3 Pentane structural formula:



pentane

Pentane condensed structural formula: $CH_3CH_2CH_2CH_2CH_3$ or $CH_3(CH_2)_3CH_3$
Pentane molecular formula: C_5H_{12}

4

Molecule name	Structural formula	Holomogous series	Functional group
Methanoic acid		carboxylic acid	–COOH
Propanol		alcohol	–OH
Hexane		alkane	
Butene		alkene	
Propanal		aldehyde	
Butyne		alkyne	– C ≡ C –

5 a) Lactic acid: alcohol group: –OH; carboxylic acid group: –COOH
b) Glucose: aldehyde group: –CHO; alcohol groups: –OH
c) Methyl methacrylate: alkene group: $>C=C<$; ester group: $-\overset{\overset{O}{\|}}{C}-O-$

Activity 1 Research project

Investigate the principles and applications of the alcohol breathalyser

Ethanol can be oxidised by the strong oxidising agent potassium dichromate ($K_2Cr_2O_7$) in the presence of an acid.

The orange dichromate ion ($Cr_2O_7^{2-}$ ion) is converted to the green chromium ion (Cr^{3+} ion). The ethanol is first oxidised to form the aldehyde ethanal. Further oxidation will produce ethanoic acid.

The photoelectric intoximeter made use of the redox reaction between alcohol and potassium dichromate. A breath sample is bubbled through an aqueous solution of sulfuric acid, potassium dichromate and silver nitrate. The silver nitrate acts as the catalyst and allows the alcohol to be oxidised at a reasonable rate. In an acidic solution, ethanol reacts with potassium dichromate to reduce the dichromate ion to the chromium ion. This reduction results in a change in colour from orange to green. This method was used to test the levels of alcohol in a person's breath.

Nowadays a breathaliser is used. This is a device for estimating blood alcohol content from a breath sample. When the user exhales into a breath analyser, any alcohol present in their breath is oxidised to acetic acid at the anode.

$CH_3CH_2OH(g) + H_2O(\ell) \rightarrow CH_3COOH(\ell) + 4H^+(aq) + 4e^-$

At the cathode, atmospheric oxygen is reduced:

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(\ell)$

The overall reaction is the oxidation of ethanol to acetic acid and water.

$CH_3CH_2OH(\ell) + O_2(g) \rightarrow CH_3COOH(\ell) + H_2O(\ell)$

The electrical current produced by this reaction is measured by a microprocessor, and displayed as an approximation of overall blood alcohol content (BAC) by the Alcosensor.

Tests done by various groups found that breath mints, onions, toothpastes, mouthwash, pennies and batteries are all ineffective methods to lower the result from the breathaliser test. They might fool the person conducting the test, but not the analiser. Mouthwash and breath spray can push up the reading on the breathaliser, as these products contain alcohol.

Activity 2 Experiment

Compare the physical properties of organic compounds

Investigation 1: Compare the smell of organic compounds

Demonstrate the wafting technique to your learners and make sure they all do it correctly. They should not put their noses close to the beaker and inhale sharply.

Investigation 2: Compare the vapour pressure of organic compounds

Manometers are not all the same. Test the apparatus beforehand to ensure that a 2 ml sample of the organic liquid is enough to provide a noticeable vapour pressure, that is, there is a noticeable change in the mercury levels in the two arms of the manometer. Increase the sample size if necessary.

Investigation 3: Compare the solubility and density of organic compounds

To determine which layer is aqueous and which is organic, drip a drop of water into the test tube. The drop will dissolve in the aqueous layer and sink

as a droplet through the organic layer. Use the table below to check that the learners arrive at the correct conclusions.

Investigation 4: Compare boiling points of organic compounds
Use the method provided in the Learner's Book. It can be dangerous to determine the boiling points of organic solvents. Many solvents have harmful vapours and are flammable. This investigation should only be done with the correct apparatus and as a teacher demonstration. Never heat organic solvents on an open flame.

Table of physical constants for the organic compounds

Compound	Vapour pressure (kPa at 20 °C)	Density (g/mℓ)	Solubility in water (g/ℓ)	Boiling point (°C)
Diethyl ether	58,7	0,713	69	34,6
Dichloromethane	47,5	1,326	13	39,8
Acetone	24,5	0,786	completely	56,5
Hexane	17,6	0,655	0,01	68,7
Ethyl acetate	9,7	0,894	83	77,1
Ethanol	5,9	0,789	completely	78,5
Propan-1-ol	2,1	0,803	completely	97,5
Butan-1-ol	0,6	0,810	73	117,6

LB p. 93

Activity 3 Recommended experiment for informal assessment

G

Investigate saturated and unsaturated molecules

The chemicals used in this experiment are dangerous. Please read the safety instructions and discuss them with your class.

Safety:
- Cyclohexane, cyclohexene and ethanol are extremely flammable; do not use near a flame.
- Bromine vapours are poisonous and carcinogenic. Use in a fume cupboard or well-ventilated room.
- Dispose of waste in an appropriate manner.
- Potassium permanganate is a strong oxidising agent and must be disposed of separately. Do not mix with organic chemical waste.

Experiment 1: Compare reactivity of alkanes and alkenes with bromine
Follow the instructions in the Learner's Book and conduct the experiment in a fume cupboard or well-ventilated classroom. Bromine reacts rapidly with cyclohexene to produce dibromocyclohexane, which is colourless. A successful reaction is indicated when the reddish-brown bromine is used up and a colourless product is formed. Cyclohexane will not react immediately, so place the test tube with cyclohexane and bromine water in bright light for about 30 minutes. The cyclohexane will eventually discolour the bromine solution.

Experiment 2: Investigate the reactivity of organic compounds with potassium permanganate
Potassium permanganate will stain your skin brown. Use gloves when handling the chemical and making up the solution. $KMnO_4$ is an oxidising

agent that can react with alkenes to form diols, but does not react with alkanes. This is not a selective test for alkenes only, as $KMnO_4$ will also oxidise alkynes, alcohols, aldehydes and other groups. Cyclohexene should react immediately and cyclohexane will not react.

Experiment 3: Test the reactivity of ethyne

Follow the method provided in the Learner's Book.

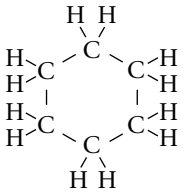
Answers to questions

1 Add a small amount of bromine solution to the unknown hydrocarbon. The alkene will discolour the bromine solution immediately from orange-brown to colourless.

2 $CaC_2(s) + 2H_2O(\ell) \rightarrow C_2H_2(g) + Ca(OH)_2(aq)$

3 There should be no difference in the reactivity of cyclohexene and ethyne. Both are unsaturated.

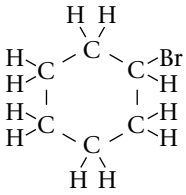
4



cyclohexane

$+ Br_2 \xrightarrow{\triangle}$

bromine solution

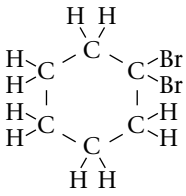


bromocyclohexane

+ HBr

hydrogen bromide

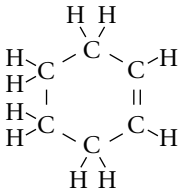
or



1,1-dibromocyclohexane or any substitution product

$+ H_2$

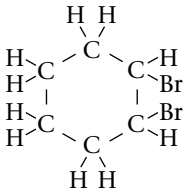
hydrogen gas



cyclohexane

$+ Br_2 \rightarrow$

bromine solution

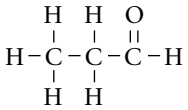


1,2-dibromocyclohexane

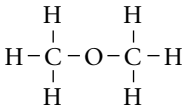
Test yourself 2 (LB p. 97)

1 Saturated compounds: methane, ethanoic acid, pentanal
Unsaturated compounds: propene, butyne

2

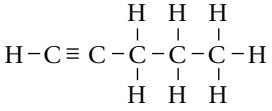


ethanal

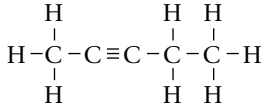


dimethyl ether

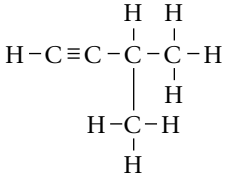
3



pent-1-yne



pent-2-yne



3-methylbut-1-yne

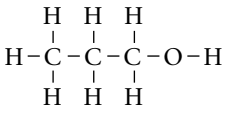
Pent-1-yne and pent-2-yne are positional isomers and 3-methylbut-1-yne is a chain isomer.

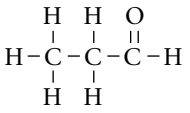
Build molecular models

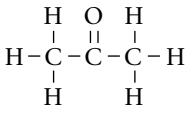
Allow learners to play around with the atoms and molecules. They should rearrange the correct number of atoms in different structures to experience how the three-dimensional structure of the molecules change. Emphasise that they are building models of the molecules and that the molecules will look different in reality, for example, atoms have no colour and are not all the same size. Remind them that the carbon atom forms four bonds that are tetrahedrally arranged around the atom.

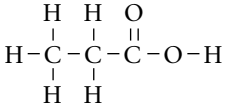
1 The number of hydrogen atoms decreases when the number of bonds increases. Propene will have two less hydrogen atoms than propane, and propyne will have two less hydrogen atoms than propene. The molecular formulae of the compounds are: propane C_3H_8; propene C_3H_6; propyne C_3H_4.

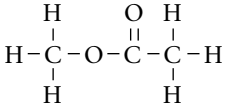
2 All the compounds have three carbon atoms but different functional groups.


propanol


propanal

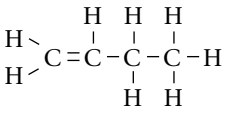

propanone

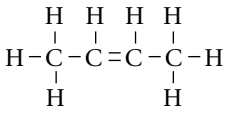

propanoic acid

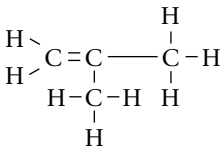

methyl ethanoate

For the next 3 exercises, provide the correct number of atoms to each learner and ask them to arrange the atoms in all the possible ways.

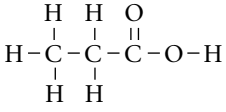
3

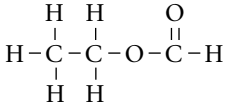

but-1-ene

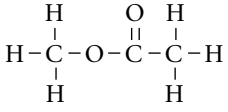

but-2-ene


methyl propene

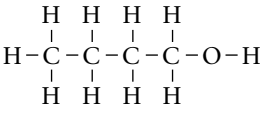
4

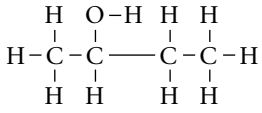

propanoic acid

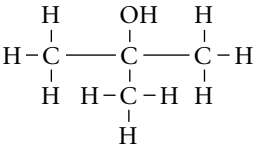

ethyl methanoate

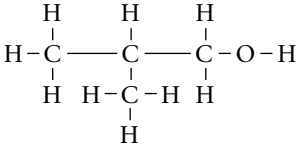

methyl ethanoate

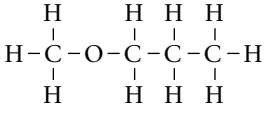
5

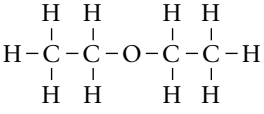

butan-1-ol


butan-2-ol


methyl propan-2-ol


methyl propan-1-ol


methyl propyl ether


diethyl ether

Test yourself 3 (LB p. 101)

1 a) i) and iii) are identical

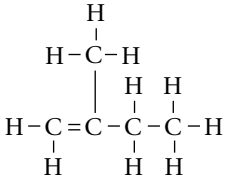
b) i) 2,4,4-trimethylhexane

ii) 2,5-dimethylheptane

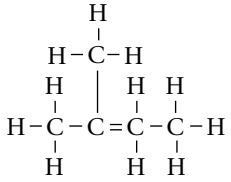
iii) 2,4,4-trimethylhexane

2 Positional isomers: $CH_2 = CHCH_2CH_2CH_3$ (pent-1-ene) $CH_3CH = CHCH_2CH_3$ (pent-2-ene)

Chain isomers:



2-methyl but-1-ene



2-methyl but-2-ene

3 a) 3-methylbut-1-ene

b) 1,2-dichloroethane

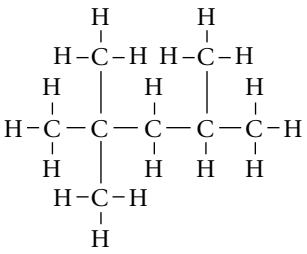
c) butan-2-ol

d) pentanoic acid

e) heptan-4-one

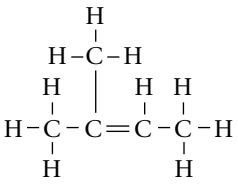
f) ethylmethanoate

4 a)



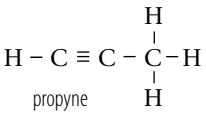
2,2,4-trimethylpentane

b)



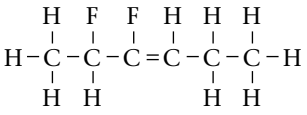
2-methylbut-2-ene

c)



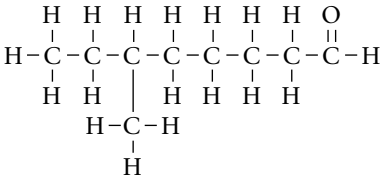
propyne

d)



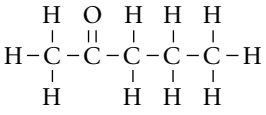
2,3-difluorohex-3-ene

e)



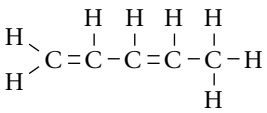
3-methyloctanal

f)



pentan-2-one

g)



1,3-pentadiene

Test yourself 4 (LB p. 106)

1 a) Melting points and boiling points increase as the length of the molecules increases. In larger molecules, the surface area in contact between adjacent molecules increases, and there are more opportunities for van der Waals forces to form weak interactions. There are therefore stronger intermolecular forces between large molecules than between small molecules.

b) The butane molecule forms a straight chain and individual molecules can get close to one another. There are more points of contact for intermolecular forces to form. Methylpropane molecules are branched and more spherical, with fewer points of contact for intermolecular forces. Melting and boiling points are lower for methylpropane than for butane.

2 a) Intermolecular forces between alkane molecules: van der Waals forces. Intermolecular forces between alcohol molecules: hydrogen bonds.

b) The boiling points of the alkanes increase with molecular mass. As the molecules become larger, greater parts of the molecules are closer to the adjacent molecules and form momentary dipoles. More energy is needed to free larger molecules from their neighbours, so the boiling point increases.

c) Like dissolves like. This means that only molecules with intermolecular forces of similar strength will dissolve in each other. Both water and alcohols have polar molecules. The forces between water molecules are hydrogen bonds, and so are the forces between alcohol molecules. The hydrogen bonds between water molecules and between alcohol molecules can be replaced easily by hydrogen bonds between water and alcohol molecules. Alkanes are non-polar molecules with weak van der Waals forces between them. Van der Waals forces and hydrogen bonds have different order strengths and cannot replace each other. Alkanes do not mix with water.

LB p. 108

Activity 5 Prescribed experiment for formal assessment

G

Prepare different esters

The chemicals used in this experiment can be dangerous. Please read the safety instructions and discuss them with your class.

Safety:
- Wear safety goggles.
- Organic solvents can have harmful vapours; use in a well-ventilated room.
- Organic solvents can be flammable; extinguish all open flames.

- Concentrated sulfuric acid and glacial (concentrated) acetic acid are very corrosive chemicals and will vigorously attack skin and tissue. They must be handled with extreme care. Wash off any contacted area immediately with large amounts of cold water.

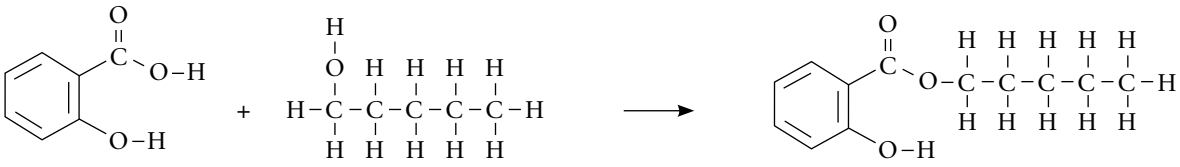
Follow the method provided in the Learner's Book.

1 See names of esters in table below.

Alcohol	Carboxylic acid	Ester	Smell
methanol	acetic acid	methyl acetate	glue
methanol	salicylic acid	methyl salicylate	wintergreen oil
ethanol	acetic acid	ethyl acetate	nail polish remover
ethanol	salicylic acid	ethyl salicylate	wintergreen oil
pentanol	acetic acid	pentyl acetate	banana
pentanol	salicylic acid	pentyl salicylate	floral

2 $CH_3OH + CH_3COOH \rightarrow CH_3OCOCH_3 + H_2O$

3



4 See smells in above table.

5 Sulfuric acid act as the catalyst in the reaction.

6 Ether is not miscible with water, but the starting materials (which also have a smell) are soluble in water. Pouring the product on water dissolves the starting materials still in the mixture, meaning that the only thing which is on the surface (and thus able to be easily smelled) is the ether product.

Assessment of experimental part of activity 5 **Total allocated marks: 15**

Assessment criteria	Rating					
	5	4	3	2	1	0
Organisation – worked through method in orderly manner	Method followed; efficiently organised; neat	Method partly followed; reasonably organised; neat	Method partly followed; not well organised	Method not well followed; disorganised; untidy	No idea how to follow method; dis-organised; messy	No attempt to do experiment
Efficient use of allocated time			Experiment completed efficiently and in time	Some parts of experiment not completed in time	Experiment not completed; inefficient	Not attempted
Teamwork and enthusiasm		Effective and enthusiastic teamwork; good spirit	Evidence of some effort made, but not very enthusiastic	Some effort made, but lacking in enthusiasm	Learner does not participate and leaves others to do the work	Refused to participate

Ability to use apparatus			All apparatus used correctly and with care	Apparatus sometimes used incorrectly	Apparatus used incorrectly	No attempt to use apparatus

Assessment of learner report **Total allocated marks: 5**

Assessment criteria	Rating					
	5	4	3	2	1	0
Presentation of results and neatness	Results neatly presented in a suitable report; handed in on time	Results presented in a report; handed in on time	Some results presented in a report; neat, but late	Some results presented, but confusing, late	Report late and untidy	No results presented

Use the answers above as a marking memo for the report.

Test yourself 5 (LB p. 109)

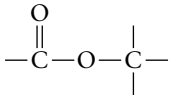
1

Alcohol	Carboxylic acid	Ester	Smell
ethanol	methanoic acid	ethyl methanoate	rum
propanol	ethanoic acid	propyl ethanoate	pear
butanol	butanoic acid	butyl butanoate	pineapple
ethanol	heptanoic acid	ethyl heptanoate	apricot
propanol	hexanoic acid	propyl hexanoate	blackberry

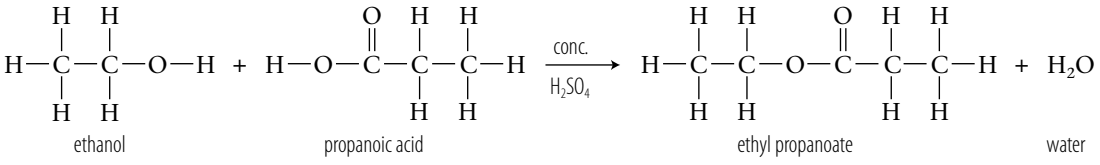
Test yourself 6 (LB p. 118)

1 a) oxygen
b) $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$
c) The reaction is very exothermic and the flame is very hot.

2 a) esters
b) pleasant smells
c)

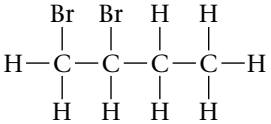


d) ethanol + propanoic acid
e)



f) H_2SO_4 acts as a catalyst.

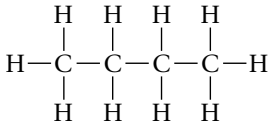
3 a) alkenes
b) i)



1,2-dibromobutane

ii) addition reaction: halogenation
iii) The orange-brown colour of the bromine solution is discoloured.

c) i)



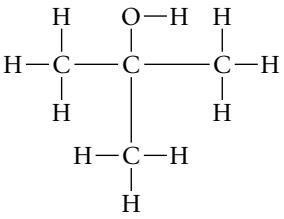
butane

ii) addition reaction: hydrogenation

iii) vegetable oil is hydrogenated to increase its saturation level and decrease the melting point to form soft solids (margarine) at room temperature.

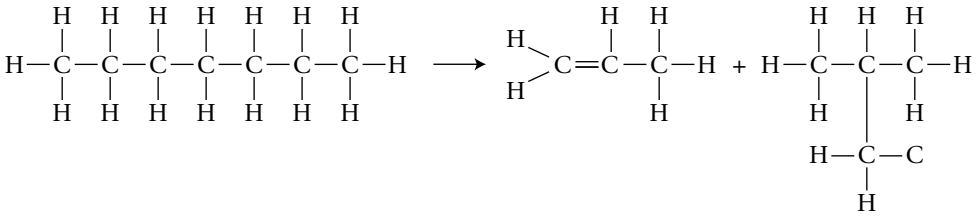
d) i) addition reaction: hydration

ii)



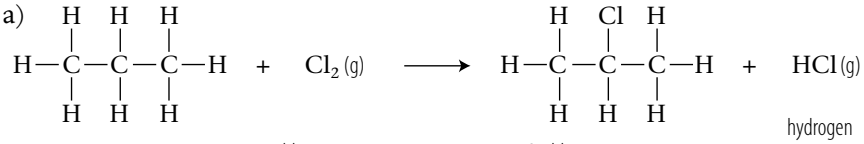
2-methyl propan-2-ol

4 a) and b)



heptane propene methyl propane

5 a)



propane chlorine gas 2-chloropropane hydrogen chloride

b) substitution

c) No reaction occurs.

6 a) $CH_3CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH_2OH + NaBr$

b) substitution reaction

c) propan-1-ol

LB p. 116

Activity 6 Experiment

Make silicone rubber

Silicone rubber is a rubber-like material composed of silicone together with carbon, hydrogen and oxygen. Silicone rubber is very flexible and widely used in industry. It is generally non-reactive, stable, and resistant to extreme environments and temperatures while still maintaining its useful properties. Normal organic rubber has a carbon backbone which can leave it susceptible to break down in heat and sunlight, but silicone rubber has a backbone that consists of Si–O–Si units which can withstand aging much better.

Some learners may find that their polymers crumble when pressed. They should gently press all of the materials together to get rid of the excess alcohol from the polymer as they roll it in their palms to form a ball. Wet it occasionally to make a smooth, glistening surface. They can add a drop of food colouring to colour the ball.

LB p. 128

Activity 7 Experiment

Make plastic sulfur

We strongly recommend that you use this experiment as a demonstration to the class. The Learner's Book contains the background information for this demonstration. Mention that sulfur has three allotropes: rhombic sulfur, monoclinic sulfur and plastic sulfur. Rhombic sulfur is the most stable form and consists of puckered S_8 rings. When heated, it slowly converts to monoclinic sulfur (melting point 119 °C) which also consists of S_8 rings. When the liquid sulfur is heated above 150 °C, the rings begin to break up and the short chains form a viscous entangled mass. Further heating produce plastic sulfur, as explained in the Learner's Book.

LB p. 129

Activity 8 Recommended experiment for informal assessment

Make 'slime' and 'Silly Putty'

Experiment 1: Make 'slime'

Experiment 2: Make 'Silly Putty'

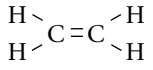
Slime is a gel that will flow and stretch if you pull it slowly, although it will break if pulled suddenly. You can rework chunks of the gel into a single mass. When placed in a container, the gel takes on the shape of the container. When placed on a flat surface, it flows to form a film. Silly Putty has similar properties, but has a more rubbery and solid consistency.

Answers to questions

1 The function of the borax is to cross-link the polymer chains. More borax will result in a more stiff slime or putty.
2 You can use less borax, but there must be enough borax to allow cross-linking of the polymer.
3 No; the water separates from the polymer product.
4 The polymer loses its elasticity.
5 Learner's own work.

Test yourself 7 (LB p. 130)

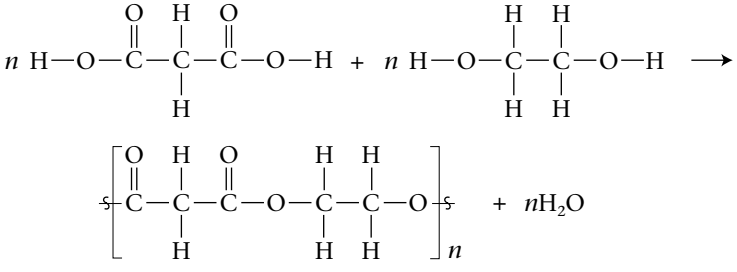
1 a) The IUPAC name is poly(ethene).
b) The IUPAC name of the monomer is ethene with structure:



ethene

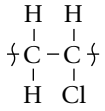
c) $\left[CH_2CH_2–CH_2CH_2–CH_2CH_2\right]_n$
d) Ethene is a gas, and polyethylene is a solid at room temperature.
e) No other products form during addition polymerisation.

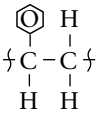
2

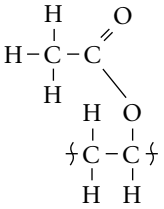


a) condensation polymerisation

b) Water also forms during this reaction.

3 a) A 
PVC

B 
polystyrene

C 
polyvinyl acetate

b) A: $CH_2 = CHCl$
B: $C_6H_5CH = CH_2$
C: $CH_3COOCH = CH_2$

LB p. 136

Activity 9 Investigation

Investigating plastics

Investigation 1: Plastics physical properties

Plastics have the following physical properties in common:

- practically unbreakable and durable
- electrical and thermal insulators
- easily moulded into different shapes and sizes
- corrosion resistant
- low density makes them light
- cost-effective
- hygienic, inert and safe; does not contaminate food or other products
- produced in different colours.

Learners should draw up their own tables.

Investigation 2: History of polymers

Polythene

Polythene, known in industry as polyethylene, was first produced accidentally in 1933 by Eric Fawcett and Reginald Gibson at the Imperial Chemical Industries Laboratory (ICI) in England. They reacted ethylene with benzaldehyde under high pressure and found a small amount of a white, waxy solid in the reaction vessel. Fawcett identified it as the polymer polyethylene. This polymer had interesting moulding and electrical properties and was patented in 1936.

PVC

Poly(chloroethene) is known as PVC in the industry and was discovered by a French physicist Henri Victor Regnault, and German physicist Eugen Baumann. It was first produced in the laboratory in 1912 and commercial production started in 1931. Today the production of PVC is the second largest of all plastics in the world.

Polystyrene

The styrene (phenylethene) monomer was first distilled from a balsam tree in 1831 by the French chemist Bonastre. Later, the German pharmacist Eduard Simon gave the name styrol to this liquid. He found that when the liquid was left to stand for several months it formed a jelly-like substance. Various other chemists worked with the substance and found that by heating the liquid, a reaction took place that changed it into a solid. In the 20th century the name of the substance was changed to styrene. Commercial production of styrene

commenced in the 1930s, and played an important role during World War II in the production of synthetic rubber.

Polypropylene
Propylene was first polymerised to a crystalline isotactic polymer by Giulio Natta as well as by the German chemist Karl Rehn in March 1954. In isotactic polypropylene the methyl groups are on the same side of the polymer chain. It has a regular structure, making the polymer rigid and tough. This pioneering discovery led to large-scale commercial production of isotactic polypropylene by the Italian firm Montecatini from 1957 onwards. Syndiotactic polypropylene was also first synthesized by Natta and his coworkers. In syndiotactic polypropylene the methyl groups alternate between one side of the polymer chain and the other.

PVA
Polyvinyl acetate was discovered by Fritz Klatte, a German chemist in 1912. He found that the catalysed reaction of acetylene with acetic acid gave a low boiling liquid (vinyl acetate) that can easily be polymerised to form a range of dense solid materials.

Polylactic acid
Polylactic acid was first discovered in the 1930s when a DuPont scientist, Wallace Caruthers, produced a low molecular weight PLA product. In 1954, DuPont patented Carothers' process. Initially the focus was on the manufacture of medical grade applications due to the high cost of the polymer, but advances in fermentation of glucose, which forms lactic acid, has dramatically lowered the cost of producing lactic acid and significantly increased interest in the polymer.

Investigation 3: Build a model
Learners' own work

Investigation 4: Environmental issues regarding plastics
'Research has shown that in industrial countries where plastic packaging is used extensively the quality of food wasted before it reaches the consumer is only 2%. The level of food wastage reaches 50% in developing countries where packaging, refrigeration and distribution are not as sophisticated.'

Organise a class discussion or debate to discuss this statement and debate the pros and cons of plastic packaging and the use of plastic products in general. Ask learners to then write down their own thoughts about the advantages and disadvantages of plastics and prompt them to take a stance against littering and to actively promote recycling.

a) Plastics:
   - are corrosion-resistant, inert and non-biodegradable, so they last for a long time
   - are also often colourful and can be seen from a distance
   - have received a lot of negative publicity, *e.g.* fishing line entangles seabirds and fish; grazing animals and birds eat plastic.

b) Plastics do not damage plant-life, but are a hazard to animals and birds as they confuse it with food. Sea-animals and birds get entangled in fishing line and plastic debris.

c) In previous eras disposable containers did not exist. There were no tissues, plastic and paper bags, packaging material, and so on. People reused containers and other items after washing them. Degradable plant

material was used to make compost. The volume of waste was much less and could be buried or burnt.

Today we throw away many items than can be reused. By being more aware and careful of what we dump, we can decrease the amount of rubbish that we generate. Vegetable matter can still be used for compost-making and many containers can be washed and reused. If everyone decreases the amount of litter they create, it would make a huge impact on the economy.

Investigation 5: Survey

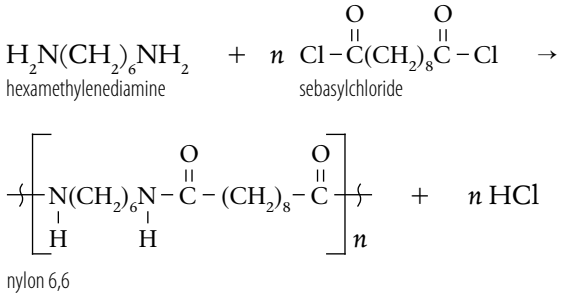
Learners' own opinions, initiative and work.

» Optional activity Preparation of nylon

When polymer chains are pulled while they are being formed, they become more ordered and closely packed. The intermolecular forces between the closely spaced chains increase. The fibre becomes stronger with greater tensile strength. You can demonstrate this physical property of polymers by making nylon in class. Some school laboratories might carry the ingredients for this experiment.

You will need: 250 ml beaker, 100 ml beaker, hexamethylenediamine, sebasylchloride, crucible tongs, glass rod

This is also an elimination reaction, but HCl is eliminated instead of H_2O.



1 Dissolve 1 ml sebasylchloride in 50 ml of tetrachloroethene and pour into a 250 ml beaker.
2 Dissolve 2,2 g hexamethylenediamine in 50 ml of distilled water.
3 Carefully add the hexamethylenediamine solution to the sebasylchloride solution. Two layers form, and a thin layer of polymer can be seen at the boundary between the two liquid layers.
4 Slowly lift the layer out of the beaker with the crucible tongs. A long thread forms. Wrap the thread onto a glass rod and roll it up as new polymer forms at the boundary between the two liquid layers.
5 While pulling and wrapping the polymer onto the glass rod, the molecules of the polymer are aligned and become more closely packed. Explain how this action changes the physical properties of the polymer.

1 a) hydrocarbons
b) functional group
c) homologous series
d) unsaturated
e) alkynes
f) C_nH_{2n+2}
g) (structural) isomers
h) IUPAC system
i) alkanes
j) esterification
k) hydrohalogenation
l) hydration
m) cracking
n) substitution
o) polymerisation
p) condensation polymerisation

2 a) Hydrocarbons can contain the elements hydrogen and carbon.
b) C_5H_{12} is a member of the alkane homologous series. C_7H_{14} is an alkene.
c) Alkynes have the general formula C_nH_{2n-2} and are **unsaturated** hydrocarbons.
d) Ethanol is an example of a **primary** alcohol and is **completely** soluble in water.
e) The boiling points of the alkenes **increase** with increasing molecular mass.
f) Alcohols and carboxylic acids have hydrogen bonds between their molecules. Alkyl halides have van der Waals forces between their molecules.
g) Chlorination of methane is a **substitution** reaction.
h) Unsaturated compounds undergo **addition** reactions to form saturated compounds.
i) Two types of saturated structures can be interconverted by **substitution.**
j) Polythene is an **addition** polymer made from ethyne monomers.

3 a) A b) B c) D d) D e) B
f) C g) B h) C i) A j) D

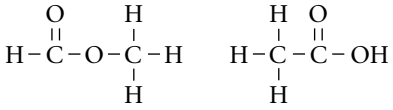
4 a) D b) G c) F d) E e) K
f) A g) B h) L i) H j) C

5 a) General formula: All members of a homologous series have the same general formula. The general formula for the alkanes is C_nH_{2n+2} where n is the number of carbon atoms in the molecule.
b) Homologous series: A family of organic molecules forms a homologous series. All the molecules in a homologous series have the same functional group, but different lengths of carbon chains. Alkanes, alkenes and alcohols are examples of organic homologous series.
c) Functional group: The distinctive group of atoms attached to a carbon chain that all the members of the homologous series have in common is called the functional group. Functional groups are responsible for the characteristic chemical reactions of a homologous series. The functional group of the alkenes is a double bond C=C and the functional group of the alcohols is the hydroxyl group OH.

6 a) C b) G c) I d) H e) J
f) E g) D h) F i) B j) A

7 a) Compounds that have the same molecular formula but different structural formulae.

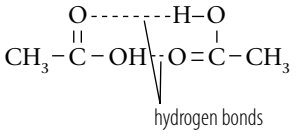
b)



methyl methanoate ethanoic acid

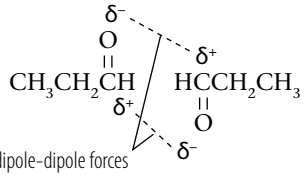
c) Ethanoic acid: The hydrogen bonds between ethanoic acid molecules are stronger than the van der Waals forces between ester molecules; more energy is needed to break bonds between ethanoic acid molecules.

8 Ethanoic acid has the highest boiling point, so the intermolecular forces must be the strongest. Each molecule can form two hydrogen bonds as shown in the diagram. Propanol molecules also form hydrogen bonds, but only one for each molecule and the boiling point is lower than that of ethanoic acid. Propanal has a carbonyl group and the difference in electronegativity between the O and C atoms result in a polar bond. Dipole forces form between adjacent propanal molecules. Dipole-dipole forces are weaker than hydrogen bonds, but stronger than the van der Waals forces between non-polar butane molecules.



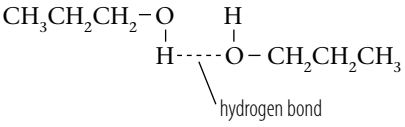
hydrogen bonds

ethanoic acid



dipole-dipole forces

propanal



hydrogen bond

propanol

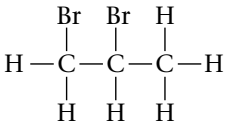
9

Reaction type	Homologous series involved	Products formed
Combustion	alkanes (alkenes, alkynes, alcohols)	$CO_2 + H_2O$
Substitution	alkanes, haloalkanes, alcohols (saturated compounds)	alkanes, haloalkanes, alcohols (saturated compounds)
Addition	alkenes, cycloalkenes and alkynes (unsaturated compounds)	alkanes, haloalkanes, alcohols (saturated compounds)
Elimination	alkanes, alcohols, haloalkanes (satuated compounds)	alkenes, haloalkenes (unsaturated compounds)
Esterification	alcohols + carboxylic acids	esters + H_2O

10 a) C_nH_{2n-2}

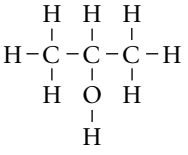
b) i) addition reaction: halogenation

ii) 1,2- dibromopropane



1,2-dibromopropane

c) i)



propan-2-ol

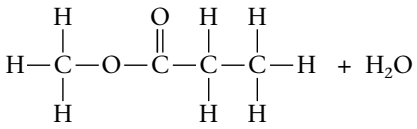
ii) Strong acid such as HCl, H_2SO_4 or H_3PO_4

d) carboxylic acids

e) i) esterification

ii) concentrated sulfuric acid

iii)



methyl proponoate water

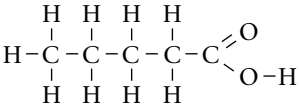
11 a) ethyl propanoate

b) esters

c) ethanol

d) concentrated sulfuric acid

e)

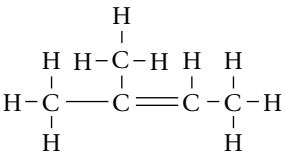


Pentanoic acid

12 a) alkenes

b) C_nH_{2n}

c)



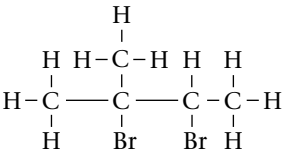
2-methylbut-2-ene

d) The compound contains a double bond and during an addition reaction, more atoms can be added onto the molecule.

e) i) The brown bromine solution discolours.

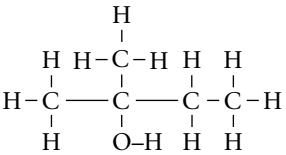
ii) halogenation (addition reaction)

iii) 2,3-dibromo-2-methylbutane



f) i) Water must be in excess; a small amount of strong acid (HCl, H_2SO_4 or H_3PO_4) to act as catalyst

ii) 2-methyl-butan-2-ol



13 a) reaction III: elimination – dehydration

b) but-2-ene $CH_3CH = CHCH_3$

c) reaction I: hydration; reaction II: hydrohalogenation

d) butan-2-ol $CH_3CH_2\overset{\overset{OH}{|}}{C}HCH_3$

e) 2-bromo-2–methylpentane $CH_3\overset{\overset{CH_3}{|}}{\underset{\underset{Br}{|}}{C}}CH_2CH_2CH_3$

f) alkenes

14 a) Large hydrocarbons are cracked to form smaller alkanes and alkenes that are more useful.

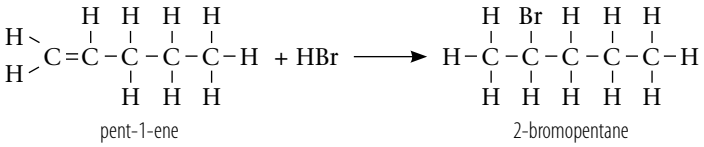
b) C_8H_{18}

c) $CH_3(CH_2)_6CH_3 \rightarrow CH_3CH_2CH_2CH_3 + CH_3CH = CHCH_3$

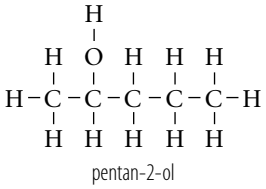
d) butane and but-2-ene (or but-1-ene)

e) Thermal cracking happens at high temperature without a catalyst; catalytic cracking happens at lower temperature with a suitable catalyst.

15 a) Pent-1-ene contains a double bond and during reactions the double bond can break and more atoms can be added on to the molecule.

b) 

c) hydrohalogenation (addition)

d) 
pentan-2-ol

e) hydrolysis

f) i) water

ii) HCl, H_2SO_4 or H_3PO_4

iii) hydration

g) i) pent-1-ene

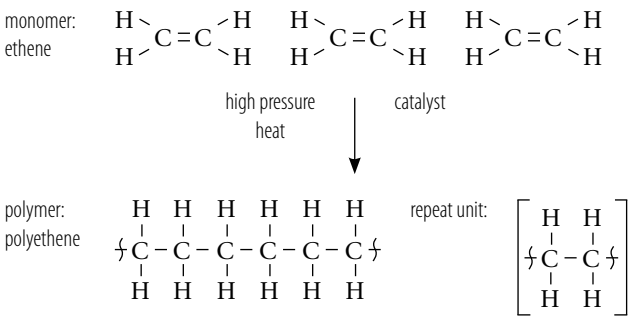
ii) dehydrohalogenation (elimination)

16 a) Monomer: the smallest unit in a polymer which is repeated many hundreds to thousands of times, *e.g.* ethene is the monomer in poly(ethene).
Copolymer: made up of two or more types of monomer, *e.g.* polyester is made from the monomers terephthalic acid and ethylene glycol.
Homopolymer: contains only one type of monomer, *e.g.* poly(ethene).

b) Polymers are macromolecules with large molecular masses. Intermolecular forces are stronger in large molecules and keep these molecules in a solid state.

17 a) ethene

b) addition polymerisation

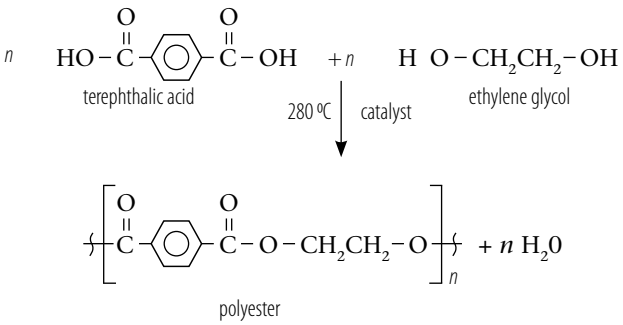
c) 

d) plastic bags, squeeze bottles, films, toys, molded objects, electric insulation, etc.

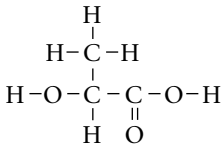
18 a) condensation polymerisation

b) ester bond

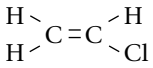
c)



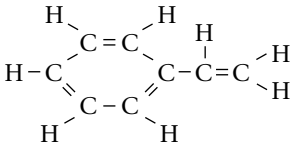
19 a) lactic acid (polylactic acid)



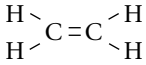
b) chloro ethene (vinyl chloride) (PVC)



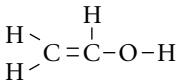
c) styrene (polystyrene)



d) ethene (ethylene) (polythene)



e) ethenol (vinyl alcohol) (PVA)



20 Plastics are used in packaging for the following reasons:

- good strength and elasticity
- durability
- photodegradability
- easily moulded into shapes
- low density gives light mass
- insulation properties
- hygienic, inert and safe; does not contaminate food
- corrosion and chemical resistant
- transparent and allows us to see the packaged product
- cost-effective.

Plastics are used for a wide variety of other products because they are:

- practically unbreakable and durable
- electrical and thermal insulators
- produced in different colours
- easily moulded in different shapes and sizes
- corrosion resistant.

Test yourself 7 (LB p. 154)

1 a) Work done by a force is the energy transferred to or from an object, given by the product of the magnitudes of the displacement and the component of the force in the direction of the displacement.

b) The net work done on an object is the change in the kinetic energy of the object.

2 a) $W_F = F\Delta x \cos\theta = 800\text{ N}(80\text{ m})\cos 180^\circ$

$= -64\,000\text{ J}$

b) $W_{Ff} = \vec{F}_f\,\Delta x\cos\theta = 240\text{ N}(80\text{ m})\cos 180^\circ$

$= -19\,200\text{ J}$

c) $W_{net} = W_F + W_{Ff}$

$= -64\,000\text{ J} + -19\,200\text{ J} = -83\,200\text{ J}$

d) $W_{net} = \Delta E_k = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$-83\,200\text{ J} = \frac{1}{2}(960\text{ kg})v_f^2 - \frac{1}{2}(960\text{ kg})(27{,}78\text{ m·s}^{-1})^2$

$v_f = 24{,}46\text{ m·s}^{-1}$.

3 $W_F = F\Delta x\cos\theta = (6\text{ N})(20\text{ m})\cos 180^\circ = -120\text{ J}$

$W_{FN} = F_N\,\Delta x\cos\theta = F_N(20\text{ m})\cos 90^\circ = 0\text{ J}$

$W_{Ff} = F_f\,\Delta x\cos\theta = (2\text{ N})(20\text{ m})\cos 180^\circ = -40\text{ J}$

$W_{Fg} = F_g\,\Delta x\cos\theta = (2\text{ kg})(9{,}8\text{ m·s}^{-2})(20\text{ m})\cos 60^\circ = +196\text{ J}$

Therefore, $W_{net} = -120\text{ J} + 0\text{ J} + (-40\text{ J}) + 196\text{ J} = +36\text{ J}$

$W_{net} = \Delta E_k = E_{kf} - E_{ki}$

$= \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$+36\text{ J} = \frac{1}{2}(2\text{ kg})v_f^2 - \frac{1}{2}(2\text{ kg})(0\text{ m·s}^{-1})^2$

$v_f = 6\text{ m·s}^{-1}$.

Test yourself 8 (LB p. 160)

1 A conservative force is a force where the work done by this force is independent of the path taken by the object experiencing the force.

2 a) The only force acting on the stone is the gravitational force; hence the mechanical energy is conserved.

$(E_p + E_k)_{TOP} = (E_p + E_K)_{BOTTOM}$

$(mgh + \frac{1}{2}mv_f^2)_{TOP} = (mgh + \frac{1}{2}mv_i^2)_{BOTTOM}$

$m(9{,}8\text{ m·s}^{-2})(20\text{ m}) + 0 = 0 + \frac{1}{2}mv_i^2$

$v_i = 19{,}80\text{ m·s}^{-1}$

b) The work is done by the gravitational force which acts opposite to the direction of motion.

$W_{Fg} = F_g\Delta y\cos\theta = (0{,}05\text{ kg})(9{,}8\text{ m·s}^{-2})(20\text{ m})\cos 180^\circ$

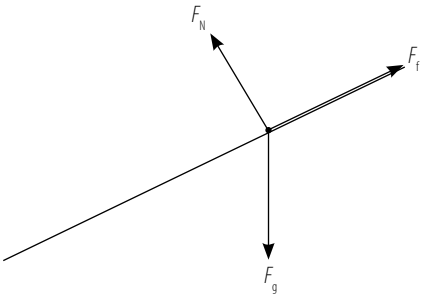
$= -9{,}8\text{ J}$

c) $\Delta E_k = E_{kf} - E_{ki} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$= 0 - \frac{1}{2}(0{,}05\text{ kg})(19{,}80\text{ m·s}^{-1})^2$
$= -9{,}8\text{ J}$

d) $\Delta E_p = E_{pf} - E_{pi} = mgh_{TOP} - mgh_{BOTTOM}$
$= (0{,}05\text{ kg})(9{,}8\text{ m·s}^{-2})(20\text{ m}) - 0$
$= 9{,}8\text{ J}$

3 $W_{Fg} = \Delta E_k = -\Delta E_p$
Since $\vec{F}_g$ is the only force acting, $W_{Fg} = W_{net}$
Hence, $W_{net} = \Delta E_k$ (The work-energy theorem)
Also, $W_{Fg} = -\Delta E_p$ (Because of the conservative nature of the gravitational force. This relationship was established earlier.)
Finally, $\Delta E_k = -\Delta E_p$ (Which confirms the conservation of mechanical energy.)

4 a)



b) $W_{nc} = \Delta E_p + \Delta E_k$
$= -mgh + (\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2)$
$= -20\text{ kg} \times 9{,}8\text{ m·s}^{-2} \times 10\text{ m} + [\frac{1}{2}\,20\text{ kg} \times (12\text{ m·s}^{-1})^2 - 0]$
$= -520\text{ J}$

c) The only non-conservative force acting on the trolley is the frictional force.
Therefore, $W_{nc} = W_{Ff} = F_f\,\Delta x \cos 180°$
$-520\text{ J} = 25\text{ N}\,(\Delta x)(-1)$
$\Delta x = 20{,}8\text{ m}$
The displacement of the trolley along the incline is 20,8 m.

LB p. 161

Activity 4 Recommended practical investigation for informal assessment

Determine the work done in climbing up a flight of stairs

Answers to questions

1 To maintain a constant force to move you up the stairs, and hence a constant net force. This will ensure that $\Delta E_k = 0$.

2 Work done by yourself (W) = work done by the non-conservative forces (W_{nc}).
$W_{nc} = \Delta E_p + \Delta E_k$
$W = \Delta E_p + 0 = mgh$
Therefore work done by you = mgh.

3 a) Work done when walking or running is the same.

b) $P = \frac{W}{\Delta t}$, which implies that $P \propto \frac{1}{\Delta t}$ (W is constant)
$\Delta t_{running} < \Delta t_{walking}$
Therefore, $P_{running} > P_{walking}$

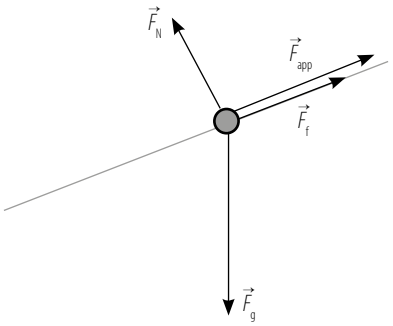
4. Work done by a force is independent of the time for which the force acts, while power developed by the force depends on the time ($P \propto \frac{1}{\Delta t}$ when W is constant).

Test yourself 9 (LB p. 163)

1 The only force acting on the car is the force of the engine, *i.e.* $\vec{F}_{eng} = \vec{F}_{net}$.
Therefore, $W_{eng} = W_{net} = \Delta E_k = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$= \frac{1}{2}(800\text{ kg})(25\text{ m·s}^{-1})^2 - 0$
$= 250\,000\text{ J}$
Power dissipated by the engine:
$P = \frac{W_{eng}}{\Delta t}$
$= \frac{250\,000\text{ J}}{10\text{ s}}$
$= 25\,000\text{ W}$

2 The force applied by the girl (F) is the only non-conservative force acting on the girl.
Therefore, $W_F = W_{nc} = \Delta E_p + \Delta E_k$
$= mgh_{TOP} - mgh_{BOTTOM} + \Delta E_k$
$= (50\text{ kg})(9{,}8\text{ m·s}^{-1})(250\text{ m}) - 0 + 0$
$= 122\,500\text{ J}$
$P_{ave} = \frac{W_F}{\Delta t} = \frac{122\,500\text{ J}}{600\text{ s}}$
$= 204{,}17\text{ W}$

3 a)



b) $W_{net} = \Delta K = 0\text{ J}$ (since the pram moves down at constant velocity)
$W_{net} = W_{FN} + W_{Fg} + W_{Ff} + W_{Fapp}$
$0\text{ J} = 0\text{ J} + mg\Delta x\cos\theta + \vec{F}_f\,\Delta x\cos\theta + W_{Fapp}$
$0\text{ J} = 0\text{ J} + (25\text{ kg})(9{,}8\text{ m·s}^{-2})(20\text{ m})\cos 75° + (35\text{ N})(20\text{ m})\cos 180° + W_{Fapp}$
$W_{Fapp} = -568{,}21\text{ J}$

c) $W_{Fapp} = \vec{F}_{app}\,\Delta x\cos\theta$
$-568{,}21\text{ J} = \vec{F}_{app}\,(20\text{ m})\cos 180°$
$\vec{F}_{app} = 28{,}41\text{ N up the incline.}$

d) $P_{av} = \vec{F}_{app}\,v$
$= 28{,}41\text{ N} \times 1\text{ m·s}^{-1}$
$= 28{,}41\text{ W}$

Test yourself 10 (LB p. 166)

1 a) $P = 5000\ \text{W} = 5000\ \text{J}\cdot\text{s}^{-1}$
$P = \frac{W}{\Delta t}$
$5\ 000\ \text{J}\cdot\text{s}^{-1} = \frac{W}{1\text{s}}$
$W = 5\ 000\ \text{J}$
Therefore, 5 000 J of energy is used to pump water every second.

b) Electrical energy is converted to mechanical energy, *i.e.* gravitational potential energy to raise the water to the surface, and kinetic energy to discharge the water.

c) Assuming no friction between the water and the pipes or the pump, the only non-conservative forces acting on the water are the forces exerted by the pump to raise and discharge the water. In one second:
$W_{nc} = \Delta E_k + \Delta E_p = -(mgh - 0) + (\frac{1}{2}mv^2 - 0)$
$5\ 000\ \text{J} = m(9{,}8\ \text{m}\cdot\text{s}^{-2})(20\ \text{m}) - 0 + \frac{1}{2}m(10\ \text{m}\cdot\text{s}^{-1})^2 - 0$
$m = 20{,}33\ \text{kg}$
Therefore, the maximum mass of water that can be raised and discharged every second is 20,33 kg.

Learner's Book page 167–169

Unit 3 Summative assessment: Mechanics

TERM 2, MODULE 1 (CONTINUED)

1 a) work done
b) kinetic energy
c) conservative force
d) net work
e) power

2 a) Work is done by the applied force when a mass is lifted upward.
b) A conservative force does no work on a body if the body is moved around a closed path by this force.
c) When a force does work on an object that moves at a constant velocity, the power due to the applied force is given by Fv.
d) Mechanical energy is conserved in a swinging pendulum, because the tension in the string does no work on the pendulum bob.
e) Two people will only have the same power output when they run down a flight of stairs in equal time if their masses are the same.

3 a) C b) C c) B d) C e) B

4 a i) Since the only force acting on the brick while it is in motion is the gravitational force, mechanical energy is conserved.
$(E_p + E_k)_{bottom} = (E_p + E_k)_{top}$
$(mgh + \frac{1}{2}mv^2)_{bottom} = (mgh + \frac{1}{2}mv^2)_{top}$
$m(9{,}8\ \text{m}\cdot\text{s}^{-2})(1{,}5\ \text{m}) + \frac{1}{2}mv^2_{bottom} = m(9{,}8\ \text{m}\cdot\text{s}^{-2})(4\ \text{m}) + \frac{1}{2}m(2\ \text{m}\cdot\text{s}^{-1})^2$
$v_{bottom} = 7{,}28\ \text{m}\cdot\text{s}^{-1}$
Therefore, Sifiso threw the brick at 7,28 m·s^{-1}.

ii) $(E_p + E_k)_{bottom} = (E_p + E_k)_{top}$
$(mgh + \frac{1}{2}mv^2)_{bottom} = (mgh + \frac{1}{2}mv^2)_{max\ height}$
$m(9{,}8\ \text{m}\cdot\text{s}^{-2})(1{,}5\ \text{m}) + \frac{1}{2}m(7{,}28\ \text{m}\cdot\text{s}^{-1})^2 = m(9{,}8\ \text{m}\cdot\text{s}^{-2})h_{max} + \frac{1}{2}m(0)^2$
$h_{max} = 4{,}20\ \text{m}$
Therefore, height above the roof = 4,20 m – 4 m = 0,20 m.

b) It is advisable for Khaya to catch the brick on its return downwards because the time taken for the brick to reach him will be greater, allowing him more time to react, while the speed of the brick will be the same at the point where it is caught.

5 a) Since the surface from A to B is frictionless, by the conservation of mechanical energy we have:

$$(E_p + E_k)_A = (E_p + E_k)_B$$
$$mgh + 0 = 0 + \frac{1}{2}mv^2$$
$$(0{,}04\text{ kg})(9{,}8\text{ m·s}^{-2})(0{,}8\text{ m}) = \frac{1}{2}(0{,}04\text{ kg})v^2$$
$$v = 3{,}96\text{ m·s}^{-1}$$

b) For the motion from B to C, the only non-conservative force acting on the bead is the frictional force. Therefore,

$W_{Ff} = W_{nc} = \Delta E_p + \Delta E_k$

$= E_p(\text{at C}) - E_p(\text{at B}) + E_k(\text{at C}) - E_k(\text{at B})$

$= mgh_C - mgh_B + \frac{1}{2}mv_C^2 - \frac{1}{2}mv_B^2$

$= (0{,}04\text{ kg})(9{,}8\text{ m·s}^{-2})(0{,}6\text{ m}) - 0 + \frac{1}{2}(0{,}04\text{ kg})(1\text{ m·s}^{-1})^2 - \frac{1}{2}(0{,}04\text{ kg})(3{,}96\text{ m·s}^{-1})^2$

$= -0{,}0584\text{ J}$

6 a) Assuming that each learner moves upward at a constant speed, and ignoring friction, work is done on the crates by an applied force (non-conservative force) in each case.

$W_{nc} = \Delta E_p + \Delta E_k = mg\Delta h + 0 = mg\Delta h.$

Since the crates have the same mass, and gain the same height, the work done in each case is the same.

b) $P = \frac{W}{\Delta t}$

i.e. $P \propto \frac{1}{\Delta t}$ (W is the same for both learners),

$\Delta t_{Bongi} < \Delta t_{Sam}$, therefore $P_{Bongi} > P_{Sam}$

7 F is the force applied by the engine to overcome friction.

$$v = 100\text{ km·h}^{-1} = \frac{100\,000\text{ m}}{60 \times 60\text{ s}} = 27{,}78\text{ m·s}^{-1}$$
$$P = Fv$$
$$20\,000\text{ W} = F(27{,}28\text{ m·s}^{-1})$$
$$F = 720\text{ N}$$

Therefore the magnitude of the frictional force is 720 N.

8 The force applied by the motor on the elevator (F_{app}) must balance the weight and frictional force downwards, since the net acceleration of the lift is zero (velocity is constant).

$F_{app} = mg + F_{fr} = (1\,000\text{ kg} + 50\text{ kg})(9{,}8\text{ m·s}^{-2}) + 2\,000\text{ N}$

$= 12\,290\text{ N}$

$P = F_{app}v = (12\,290\text{ N})(3\text{ m·s}^{-1})$

$= 36\,870\text{ J·s}^{-1} = 36\,870\text{ W} = 36{,}87\text{ kW}$

9 $m = 2\,000\text{ kg}$ $\quad u = 10\text{ m·s}^{-1}$

$v = 0$ $\quad \Delta x = 12{,}5\text{ m}$

$a = ?$

a) $v^2 = u^2 + 2\Delta x$

$0^2 = (10\text{ m·s}^{-1})^2 + 2a(12{,}5\text{ m})$

$a = -4\text{ m·s}^{-2}$

$a = 4\text{ m·s}^{-2}$ opposite to the direction of motion.

$F = ma = 2\,000\text{ kg} \times (-4\text{ m·s}^{-2})$

$= -8\,000\text{ N}$

$= 8\,000\text{ N}$ opposite to the direction of motion.

b) The component of the gravitational force acting down the incline (F_1) is given by:
$F_1 = mg \sin 5{,}74 = 1\,960{,}28$ N down the incline.
Frictional (F_{fr}) force also acts down the incline; $F_{fr} = 200$ N
To keep the van at constant velocity, the force exerted by the engine (F_E) is given by:
$F_E = F_1 + F_{fr}$
$= 1\,960{,}28 \text{ N} + 200 \text{ N}$
$= 2\,160{,}28$ N up the incline.
Therefore: $P = Fv$
$= 2\,160{,}28 \text{ N} \times 10 \text{ m·s}^{-1}$
$= 21\,602{,}8$ W

10 Consider a mass of 1 200 kg of water. The work done to raise the water from the well and to project it is given by the equation:
$W = \Delta E_p + \Delta E_k$
$= mgh + \frac{1}{2}mv^2$
$= (1\,200 \text{ kg})(9{,}8 \text{ m·s}^{-2})(10 \text{ m}) + \frac{1}{2}(1\,200 \text{ kg})(15 \text{ m·s}^{-1})^2$
$= 252\,600$ J
Therefore, power of motor $= \frac{W}{t}$
$= \frac{252\,600 \text{J}}{60 \text{ s}}$
$= 4210$ W (1 minute)

11 a) From B to C, the only horizontal force acting on the ball is the frictional force.
$W_{net} = W_{Ff} = F_f \Delta x \cos 180°$
$= 1{,}8 \text{ N } (2{,}5 \text{ m})(-1) = -4{,}5$ J
$W_{net} = \Delta E_k = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$-4{,}5 \text{ J} = 0 - \frac{1}{2}(0{,}05 \text{ kg})v_f^2$
$v_f = 13{,}42 \text{ m·s}^{-1}$.
Therefore the ball must have a speed of 13,42 m·s^{-1} at B.

b) $W_{Ff} = F_f \Delta x \cos 180°$
$= 1{,}2 \text{ N } (2 \text{ m}) (-1) = -2{,}4$ J

c) For the ball to land in the hole, it must be struck at A so that the speed at B is 13,42 m·s-1. Frictional force is the only non-conservative force as it moves from A to B.
$W_{Ff} = W_{nc} = \Delta E_p + \Delta E_k = \quad (mgh - 0) + (\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2)$
$-2{,}4 \text{ J} = 0{,}05 \text{ kg } (9{,}8 \text{ m·s}^{-2})(0{,}6 \text{ m}) - 0 + \frac{1}{2}(0{,}05 \text{ kg})(13{,}42 \text{ m·s}^{-1})^2$
$-\frac{1}{2}(0{,}05 \text{ kg})v_i^2$
$v_i = 16{,}96 \text{ m·s}^{-1}$
Therefore, the speed at which the ball must be struck at A is 16,96 m·s^{-1}.

TERM TWO

MODULE 3: WAVES, SOUND AND LIGHT

This module focuses on the Doppler Effect. Start off by revising the concepts of frequency, wavelength and period associated with waves.

There is one practical demonstration in this unit: Investigating the Doppler Effect. You will find it on page 172 of the Learner's Book and page D44 of the Teacher's Guide.

Practical demonstration 1 (LB p. 172)

Investigating the Doppler Effect [Teacher demonstration]
Tie a tuning fork firmly to a piece of string. Set the fork into vibration by hitting it with a wooden or rubber hammer. Now whirl the string and fork in a horizontal circle. An electronic buzzer can be used instead of the tuning fork.

Test yourself 1 (LB p. 174)

1 The Doppler Effect is the apparent change in the frequency of sound from a source due to the relative motion of the source and listener.

2 C

3 a) If both the source and listener are stationary, then $v_s = v_l = 0$. If we substitute these values into the Doppler Effect equation we have:
$f_L = (\frac{v \pm v_L}{v \pm v_S}) f_S = (\frac{v \pm 0}{v \pm 0}) f_S = f_S$

b) If both the source and listener are moving in the same direction at the same speeds, then $v_S = v_L = x$. If we substitute these values into the Doppler Effect equation, we have:
$f_L = (\frac{v \pm v_L}{v \pm v_S}) f_S = (\frac{v \pm x}{v \pm x}) f_S = f_S$

Test yourself 2 (LB p. 176)

1 We are required to find f_L , given that $v_S = 20$ m.s^{-1}, $f_S = 512$ Hz and $v = 340$ m.s^{-1}, $v_L = 0$.
$f_L = (\frac{v \pm v_L}{v \pm v_S}) f_S = (\frac{340 \text{ m·s}^{-1}}{340 \text{ m·s}^{-1} - 20 \text{ m·s}^{-1}})512 \text{ Hz} = 544 \text{ Hz}$

2 Since the observed frequency is lower than the emitted (source) frequency, the bat is moving away from the observer.

This situation corresponds to a moving source and stationary listener, with:
$v_L = 0$ m.s^{-1}, $v_S = x$ m.s^{-1} = speed of bat, $f_S = 80$ MHz, $f_L = 78$ MHz and $v = 340$ m.s^{-1}

$f_L = (\frac{v \pm v_L}{v \pm v_S}) f_S$

$f_L = (\frac{v}{v + x}) f_S$

$v + x = (\frac{f_S}{f_L})(v)$

$x = (\frac{f_S}{f_L})(v) - v$

$x = v(\frac{f_S}{f_L} - 1)$

$= 340 \text{ m·s}^{-1} (\frac{80 \text{ MHz}}{78 \text{ MHz}} - 1)$

$= 8{,}7 \text{ m·s}^{-1}$

The speed of the bat is 8,7 m·s^{-1}

Test yourself 3 (LB p. 180)

1 a) Stars A and C are blue-shifted (increased frequencies) and are therefore moving towards the reference star.
b) Stars B and D are red-shifted (decreased frequencies) and therefore moving away from the reference star, but Star B is more red-shifted and therefore moving fastest away from the reference star.

Learner's Book pages 181–183

Unit 1 Summative assessment: Waves, sound and light

TERM 2, MODULE 3

1 a) A
b) D
c) C
d) C
e) A

2 a) False: the Doppler Effect is the change in frequency of the sound waves.
b) True
c) False: when the spectral lines are shifted towards increasing frequencies, the galaxy is moving towards the reference galaxy.

3 The object is moving to the top because the wavelength in this region has become smaller, due to the Doppler Effect.

4 The source is moving and the listener is stationary. We use the equation:
$f_L = \left(\frac{v \pm v_L}{v \pm v_S}\right) f_S$ to obtain $f_L = \left(\frac{340\ \text{m.s}^{-1}}{340\ \text{m.s}^{-1} - 20\ \text{m.s}^{-1}}\right) 450\ \text{Hz}$
$f_L = 478\ \text{Hz}$
The observed frequency is higher than the emitted frequency.

5 The listener moves away from the siren, and we use the equation
$f_L = \left(\frac{v \pm v_L}{v \pm v_S}\right) f_S$ to obtain
$f_L = \left(\frac{340\ \text{m.s}^{-1} - 27{,}78\ \text{m.s}^{-1}}{340\ \text{m.s}^{-1}}\right) 900\ \text{Hz}$
$f_L = 826$ Hz. The observed frequency is lower than the emitted frequency.

6 The source is stationary and the listener is moving. We use the equation:
$f_L = \left(\frac{v \pm v_L}{v \pm v_S}\right) f_S$ to obtain $392\ \text{Hz} = \left(\frac{340\ \text{m.s}^{-1} + x}{340\ \text{m.s}^{-1}}\right) 380\ \text{Hz}$
$v_L = 10{,}7\ \text{m.s}^{-1}$.

7 The source is stationary and the listener is moving. We are required to find v_L given that $v_S = 0$; $f_S = 740$ Hz; $v = 340\ \text{m.s}^{-1}$
We are also given $\Delta f = 80$ Hz, which is the difference in the two observed frequencies. When the professor approaches the parked car his observed frequency is $f_L = \frac{v + v_L}{v} = \left(\frac{340\ \text{m.s}^{-1} + v_L}{340\ \text{m.s}^{-1}}\right)(740\text{Hz})$
$= (340\ \text{m.s}^{-1} + v_L)\ 2{,}18$ Hz. When the professor drives away from the parked car his observed frequency is
$f_{L2} = \frac{v - v_L}{v} = \left(\frac{340\ \text{m.s}^{-1} - v_L}{340\ \text{m.s}^{-1}}\right)(740\text{Hz}) = (340\ \text{m.s}^{-1} - v_L)\ 2{,}18$ Hz.
The difference in the two frequencies is: $\Delta f = f_{L1} - f_{L2}$
$= (340\ \text{m.s}^{-1} + v_L)\ 2{,}18\ \text{Hz} - (340\ \text{m.s}^{-1} - v_L)\ 2{,}18\ \text{Hz}$
We also know that $\Delta f = 80$ Hz. Therefore:
$(340\ \text{m.s}^{-1} + v_L)\ 2{,}18\ \text{Hz} - (340\ \text{m.s}^{-1} - v_L)\ 2{,}18\ \text{Hz} = 80\ \text{Hz}$
$2v_L = \frac{80}{2{,}18}\ \text{m.s}^{-1}$
$v_L = 18{,}4\ \text{m.s}^{-1}$
The speed of the professor was $18{,}4\ \text{m.s}^{-1}$.

8 a) The wavelength = length of one complete wave = 2 cm = 0,02 m.

b) from $v = f\lambda$ we have $f = \frac{v}{\lambda} = \frac{340\ \text{m.s}^{-1}}{0{,}02\ \text{m}} = 17\ \text{kHz}$

c) The source is moving and the listener is stationary. We use the equation: $f_L = \left(\frac{v \pm v_L}{v \pm v_S}\right) f_S$

$v_S = \left(\frac{340\ \text{m.s}^{-1}}{17\ \text{kHz}}\right) 30\ \text{kHz} - 340\ \text{m.s}^{-1} = 260\ \text{m.s}^{-1}$

9 a) The frequency is 474 Hz, since this is larger than the frequency emitted by the source.

b) The source is moving and the listener is stationary. We have $v_S = 10\ \text{m.s}^{-1}$; $v_L = 0\ \text{m.s}^{-1}$; $f_S = 460\ \text{Hz}$; $f_L = 474\ \text{Hz}$

We use the equation: $f_L = \left(\frac{v \pm v_L}{v \pm v_S}\right) f_S$ to obtain $f_L = \left(\frac{v}{v - v_S}\right) f_S$

Rearrange the equation: $(v - v_S) = \left(\frac{v}{f_L}\right) f_S \rightarrow v = \frac{v_S}{\left(1 - \frac{f_S}{f_L}\right)} = \frac{v_S f_L}{(f_L - f_S)}$

$v = \frac{10\ \text{m.s}^{-1} \times 474\ \text{Hz}}{474\ \text{Hz} - 460\ \text{Hz}}$

$= 339\ \text{m.s}^{-1}$

If we use the source moving away from the listener then:

$v = \frac{-v_S f_L}{(f_L - f_S)} = \frac{-10(447\ \text{Hz})}{447\ \text{Hz} - 460\ \text{Hz}}$

$= 343{,}8\ \text{m.s}^{-1}$

10 There will be two Doppler shifted frequencies, one occurring when the chest moves towards the source and the other when the chest moves away. The moving chest is regarded as the source of the sound, and the receiver of the Doppler flow meter is the stationary listener.

For the first Doppler shifted frequency, when the chest moves towards the Doppler flow meter, we have $v_S = 0{,}01\ \text{m.s}^{-1}$; $v_L = 0\ \text{m.s}^{-1}$; $f_S = 1 \times 10^6$ Hz; $v = 1{,}5 \times 10^3\ \text{m.s}^{-1}$

$f_{L1} = \left(\frac{v}{v - v_S}\right) f_S = \left(\frac{1{,}5 \times 10^3\ \text{m.s}^{-1}}{1{,}5 \times 10^3\ \text{m.s}^{-1} - 0{,}01\ \text{m.s}^{-1}}\right)(1 \times 10^6\ \text{Hz})$

$= 1{,}000006667 \times 10^6$ Hz

For the second Doppler shifted frequency, when the chest moves away from the Doppler flow meter, we have $v_S = 0{,}01\ \text{m.s}^{-1}$; $v_L = 0\ \text{m.s}^{-1}$; $f_S = 1 \times 10^6$ Hz; $v = 1{,}5 \times 10^3\ \text{m.s}^{-1}$

$f_{L2} = \left(\frac{v}{v - v_S}\right) f_S = \left(\frac{1{,}5 \times 10^3\ \text{m.s}^{-1}}{1{,}5 \times 10^3\ \text{m.s}^{-1} + 0{,}01\ \text{m.s}^{-1}}\right)(1 \times 10^6\ \text{Hz}) = 0{,}9999933 \times 10^6$ Hz

The change in frequency will be

$1{,}000006667 \times 10^6\ \text{Hz} - 0{,}9999933 \times 10^6\ \text{Hz}$

$= 13{,}3$ Hz

11 The observed wavelength (656,315 nm) from the nearby star is larger than the wavelength (656,285 nm) in the reference star (sun). The wavelength is red-shifted and hence the nearby star is moving away from the sun.

12 a) If galaxy A is chosen as the reference galaxy, we notice that the lines in the emission spectrum of galaxy B are shifted towards the blue end, *i.e.* they are blue-shifted towards increasing frequencies, and hence this galaxy is moving towards galaxy A.

b) If galaxy D is chosen as the reference galaxy, we notice that the lines in the emission spectrum of galaxy C are shifted towards the red end, *i.e.* they are red-shifted towards decreasing frequencies, and hence this galaxy is moving away from galaxy D.

13 a) Star B, since its frequency has decreased. It is moving away from the earth.

b) Star A, since it is moving towards the earth at a faster rate than star C.

MODULE 4: CHEMICAL CHANGE

In this module learners will be introduced to the importance of the chemical knowledge of the chemist and chemical engineer in the chemical industry. Emphasise the economic factors that make a chemical business profitable – that is, high quality product manufactured in the shortest possible time. Use the Haber and Contact processes to explain the importance of reaction kinetics and shifting the equilibrium.

Acid-base reactions were done in Grade 11 and learners should be familiar with most of these concepts. pH and volumetric analysis are new concepts.

There is plenty of opportunity for practical work in this module. Some learners might find the theory in this module difficult, and therefore it is very important that the theoretical concepts are applied and demonstrated in the practical work. There are two experiments recommended for informal assessment:

Activity 3: Determine the quantitative reaction rate in the thiosulfate reaction

Activity 5: Investigate reactions in equilibrium.

The prescribed experiment for formal assessment for Term 2 is:

Activity 10: Use acid-base titration in neutralisation reactions.

You will find Activity 3 on page 198 of the Learner's Book and page D49 of the Teacher's Guide.

Activity 5 can be found on page 208 of the Learner's Book and page D52 of the Teacher's Guide.

Activity 10 can be found on page 239 of the Learner's Book and page D62 of the Teacher's Guide.

LB p. 192

Activity 1 Experiments

Investigate the factors that affect rate of reaction

Experiment 1: The vinegar and baking soda reaction

a) A higher temperature and an increase in vinegar concentration speeds up the reaction.
b) The volume of the acid does not affect the rate of reaction. The volume affects the total amount of gas produced, depending on which was the limiting reactant. If the acid was the limiting reactant, double the volume of acid produces double the volume of gas.
c) When the reactants are more concentrated, more collisions per unit time will occur, because there are more particles that can collide in a given volume. More collisions will speed up the reaction. At higher temperatures, the particles have more energy and move faster, so the frequency of collisions also increases. There is a higher chance of effective collisions resulting in a chemical reaction.

Experiment 2: The zinc and hydrochloric acid reaction

a) The factors that increased the rate of reaction were a larger surface area, a higher temperature, a more concentrated HCl solution and addition of a catalyst.
b) The factor that did not affect the rate of reaction was the total volume of liquid.
c) Zinc pieces of similar size must have similar surface areas. Surface area is one of the factors that affect rate of reaction and must be kept constant when the effect of other factors are examined.
d) Copper powder acts as a catalyst to speed up the reaction.
e) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

Experiment 3: The thiosulfate reaction

a) We are timing the appearance of a product.
b) Thiosulfate solution 1 has the highest concentration because no water is added to dilute the original solution.
c) Sulfur is responsible for the cloudiness that develops in the solutions.
d) The concentration of the $Na_2S_2O_3$ solution decreases from experiment 1 to 3. The time taken for the cross to disappear should be the shortest in experiment 1 and the longest in experiment 3. A higher concentration increases the rate of reaction.
e) The concentration of the HCl solution decreases from experiment 1 to 5. The time taken for the cross to disappear should be the shortest in experiment 1 in which the HCl is most concentrated and the longest in experiment 5 in which the HCl is most dilute.
f) The temperature increases from experiment 1 to 7. The cross should disappear much quicker in experiment 7 which is the warmest. A higher temperature speeds up the reaction rate.

Experiment 4: The hydrogen peroxide reaction

a) We can speed up the decomposition of hydrogen peroxide by adding a catalyst or by heating the solution.

b) The decomposition of hydrogen peroxide can be slowed down by removing the catalyst, by cooling the solution or by adding water to it, thus diluting the solution.
c) You could weigh the amount of manganese(IV) oxide before you add it to the flask. When the reaction is complete, filter off the manganese(IV) oxide, dry and weigh it again.
d) Powdered manganese(IV) oxide would be a better catalyst because the surface area is larger and the reaction rate will increase.

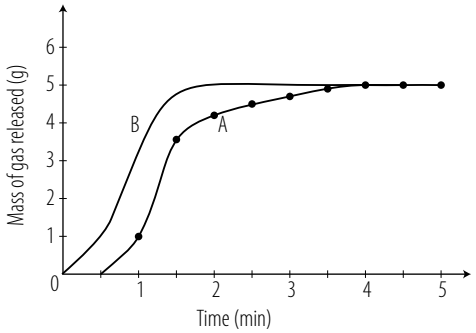
LB p. 197

Activity 2 Experiment

Design an experiment to test the effect of surface area on reaction rate

1 Learner's own choice. Use apparatus and methods in activity 1 as a guideline.
2 $MgCO_3$ and $CaCO_3$ release CO_2 when reacted with HCl.
3 When you chew the tablet, you are breaking it up into smaller pieces and increasing its surface area. A larger surface area will result in a faster reaction and quicker relief from heartburn.
4 a) The mass decreases because CO_2 gas is liberated and escapes into the air.
b) & c)

Mass of gas released (g)	0	0	1,0	3,7	4,2	4,5	4,7	4,9	5,0	5,0	5,0
Time (min)	0	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0



d) The rate of reaction could also be changed by changing the surface area (by breaking up the antacid tablet or grounding it into a powder) and by changing the temperature of the acid.

LB p. 198

Activity 3 Recommended experiment for informal assessment

Determine the quantitative reaction rate in the thiosulfate reaction

Sodium thiosulfate solution is reacted with hydrochloric acid to form a precipitate of sulfur. The time taken for a certain amount of sulfur to form is used to indicate the rate of the reaction. The effect of temperature on the reaction rate is investigated.

Learners will understand the method better if you first demonstrate the reaction.

The equation for the reaction is:

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow SO_2(g) + S(s) + H_2O(\ell)$$

Note that sulfur dioxide forms as a by-product. SO_2 is toxic and attacks the mucus membranes. It might trigger an asthma attack. Perform the experiment in a well-ventilated room or a fume cupboard. Wash away all reaction mixtures with plenty of water as soon as the experiments are completed.

Results:
A curve showing that an increase in temperature increases the reaction rate, as measured by $\frac{1}{\text{time}}$ should be obtained. This is not a direct proportionality and learners must draw a best-fit curve. As a guide, for every 10°C rise in temperature the reaction rate doubles.

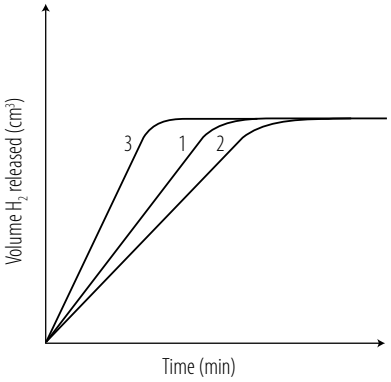
An increase in temperature will increase the rate of reaction, as more particles have enough activation energy to react and there is an increase in frequency of collisions.

LB p. 199

Activity 4 Experiment

The magnesium reaction

a) Here the factor of concentration is examined. An excess of magnesium is used to ensure that there is enough magnesium to sustain the reaction until all the HCl is used up.
b) The reactions slow down after a few minutes because the reactants are being used up and products form. The concentration of the reactants decreases.
c) The reaction will eventually stop when the acid is used up.
d) The curve in 1 is steeper than in 2 because the acid concentration in 1 is higher than in 2.



e) The third line on the graph should be much steeper because the reaction rate for powdered magnesium will be much faster than magnesium ribbon. An increase in surface area will increase the rate of reaction.
f) $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

Test yourself 1 (LB p. 200)

1 Order of increasing rate:
   a) rotting wood
   b) milk turning sour
   c) an egg cooking in boiling water
   d) sodium hydroxide neutralising hydrochloric acid

2 a) $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$
   b) Reactants: zinc (Zn) and sulfuric acid (H_2SO_4)
   c) Products: zinc sulfate ($ZnSO_4$) and hydrogen (H_2)
   d) The zinc may have a layer of impurities (dirt and oxides) on its surface that must be removed first. This is an exothermic reaction and as the reaction progresses, the temperature increases and so will the rate of reaction.
   e) The acid concentration decreases as more products form and the zinc surface area decreases as it is used up.
   f) The reaction rate of B is higher than that of A.
   g) More concentrated acid was used; the reaction was carried out at a higher temperature; the zinc was powdered.

3 a)

Experiment	1	2	3	4	5
Graph	B	D	C	E	A

Experiments 1 and 5: Here the effect of surface area was tested. All other factors were the same. The powdered marble will react faster than the whole marble.

Experiments 2 and 3: Here the effect of temperature was tested. Experiment 2 was done at a lower temperature and will react slower.

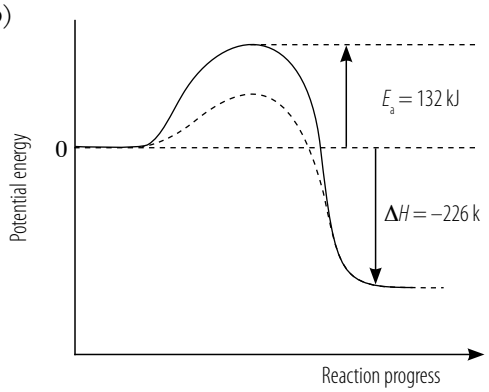
Experiments 1 & 5, 2 & 3 and 4 contain decreasing amounts of acid. 1 & 5 have the largest amount of acid and will release the most gas; 4 contains the smallest amount of acid and will release the smallest amount of gas.

   b) The acid concentration is the same in all the experiments.
   c) The reaction in experiment 4 finished first.

Test yourself 2 (LB p. 204)

1 At higher temperatures, the number of molecules with the minimum kinetic energy needed for a reaction increases. The number of molecules that can overcome the activation energy increases. The molecules move faster, frequency of collisions increases; hence the rate of reaction increases.

2 a and b)



LB p. 208

Activity 5 Recommended experiment for informal assessment

Investigate reactions in equilibrium

The two different coloured Co(II) complex ions, $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, exist together in equilibrium in solution in the presence of chloride ions:

$$[Co(H_2O)_6]^{2+}(aq)(\textbf{pink}) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq)(\textbf{blue}) + 6H_2O(\ell)$$

Or simplified:
pink cobalt species + chloride ions ⇌ blue cobalt species + water molecules.
This equilibrium can be disturbed by changing the chloride ion concentration or by changing the temperature.

A white background will help to show the colour changes to best effect.

The change in colour from blue to pink of the cobalt complexes is used in cobalt chloride indicator papers for the detection of the presence of water.

Experiment 1: $CoCl_4^{2-}/Co(H_2O)_6^{2+}$ equilibrium

a) The pink solution turns blue.
b) HCl ionises in water to form H^+ ions and Cl^- ions. There are already Cl^- ions in solution, so adding more Cl^- ions will increase the $[Cl^-]$. It seems as if the reverse reaction happens faster to make more blue $CoCl_4^{2-}$.
c) The solution will be pink.
d) The pink solution will turn blue.
e) The forward reaction is exothermic. Heat is given off during the forward reaction. When heat is applied, more blue $CoCl_4^{2-}$ ions form to colour the solution blue. The reverse reaction must have happened faster than the forward reaction.
f) The solution will turn pink.
g) A whitish precipitate forms and the solution turns pink.
h) The silver ions in silver nitrate form a white precipitate with the chloride ions. Silver chloride is insoluble. When chloride ions are removed from the solution, the $[Cl^-]$ decreases. The forward reaction must happen faster because the solution turns pink.
i) During dry weather the cobalt chloride crystals will be blue. When there is moisture in the air, the water vapour will shift the equilibrium to the right and the crystals will turn pink.

Experiment 2: $CrO_4^{2-}/Cr_2O_7^{2-}$ equilibrium

The addition of HNO_3 to a yellow K_2CrO_4 solution turns the solution orange, which means that the forward reaction happens faster and more orange $Cr_2O_7^{2-}$ ions form. HNO_3 ionises to form $H^+(aq)$ and $NO_3^-(aq)$. There are already H^+ ions in solution, and increasing the $[H^+]$ favours the forward reaction. A NaOH solution contains $Na^+(aq)$ and $OH^-(aq)$. The OH^- ions react with the H^+ ions already in solution to form water. In this way H^+ ions are removed from the system, which favours the reverse reaction because the solution turns yellow.

Teacher demonstrations

1 NO_2/N_2O_4 equilibrium

The reversible reaction between nitrogen dioxide and dinitrogen tetroxide can be used to demonstrate the effect of temperature changes on an equilibrium. $NO_2(g)$ is brown, whereas $N_2O_4(g)$ is colourless. An equilibrium is quickly established in a closed system. The forward reaction is exothermic.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) + \text{Heat}$$
brown colourless

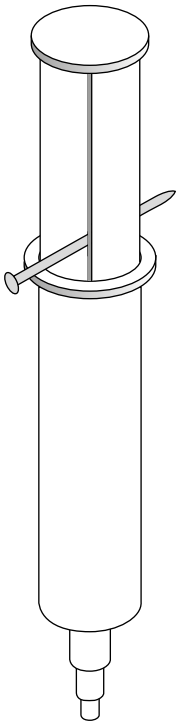
1 Place a spatula of copper turnings in a conical flask.
2 Add a few drops of concentrated nitric acid and stopper the flask. Brown NO_2 gas will form.
3 Pour the brown gas into a small round-bottomed flask and stopper. **Note:** NO_2 is poisonous – work in a fume cupboard.
4 When the flask is cooled, the forward reaction will be favoured and more N_2O_4 will be formed. The colour of the gas in the flask will become lighter.
5 When the flask is heated, the colour will turn darker brown. The reverse (endothermic) reaction is now favoured and more brown NO_2 is formed.

The forward reaction is exothermic. When the temperature decreases, the forward exothermic reaction will be favoured and more colourless N_2O_4 will form. When the temperature increases, the reverse endothermic reaction will be favoured and more brown NO_2 will form. The contents of the flask will never turn colourless. This is a reversible reaction and there will always be some brown NO_2 molecules present.

2 CO_2 equilibrium

Soda water can be used to illustrate the effect of pressure in an equilibrium. Soda water is placed in a syringe and the plunger pulled out to reduce the pressure in it. Bubbles of carbon dioxide are seen forming as its solubility decreases. Methyl red indicator added to the soda water turns from red to yellow, showing that the solution has become less acidic as the equilibrium in solution adjusts.

Note that the colour change of methyl red is red below pH 4,2 and yellow above pH 6,3.



You will need: fresh bottle of soda water, methyl red indicator, 50 cm^3 plastic syringe, 5 cm nail, 100 ml beaker

Method

1 Modify the syringe: pull out the plunger so that the volume of air in the syringe is 50 cm^3. Warm the nail in a Bunsen flame and push through the stem of the plunger as shown in the diagram. When the nail is in place, the plunger can be locked at the 50 cm^3 mark.
2 Pour 10–20 ml of soda water into the beaker and add a few drops of methyl red indicator to give a red solution.
3 Remove the nail from the syringe and insert the plunger completely. Draw about 5 ml of the soda water solution into the syringe. Close the end of the syringe with your finger. Pull the plunger out to the 50 cm^3 mark and lock it with the nail. Bubbles of CO_2 will be seen

escaping from the water and the indicator will begin to turn orange. Shake the syringe to speed up the 'out-gassing'.

4 Hold the syringe in a vertical position with the nozzle pointing upwards, remove your finger and the nail and push in the plunger to expel the gas but not the solution. Seal the syringe again and repeat the process in step 3. More bubbles will be seen and the indicator will turn further towards a yellow colour. Several more cycles can be repeated until the indicator becomes completely yellow.

Soda water contains carbon dioxide that has been dissolved under pressure. The equilibria are:

1 $CO_2(g) \rightleftharpoons CO_2(aq)$

2 $CO_2(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq)$

3 $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

Learners have not done acid-base reactions at this stage, but they should have a background knowledge from acid-base done in Grade 11. They should remember that a solution of CO_2 in water is acidic because of the increase in $[H^+]$. Reducing the pressure causes the CO_2 to come out of solution and the equilibrium in 1 moves to the left. The result is that the other two equilibria also move to the left, removing H^+ ions from the solution and making the solution less acidic.

(Adapted from experiment developed by Nuffield Foundation/Royal Society of Chemistry)

Test yourself 3 (LB p. 213)

Learners should follow the steps in example 1 on page 211 to do question 1, and example 2 on page 212 to do question 2.

1

	$H_2(g)$ +	$CO_2(g) \rightleftharpoons$	$H_2O(g)$	$CO(g)$
molar ratio	1	1	1	1
n initially (mol)	0,80	0,80		
n change (mol)	0,55	0,55	0,55	0,55
n at equilibrium (mol)	0,25	0,25	0,55	0,55
$c = \frac{n}{V}$ (mol·dm^{-3})	$\frac{0,25}{5,00} = 0,05$	$\frac{0,25}{5,00} = 0,05$	$\frac{0,55}{5,00} = 0,11$	$\frac{0,55}{5,00} = 0,11$

$$K_c = \frac{[CO][H_2O]}{[H_2][CO_2]}$$
$$= \frac{(0,11)(0,11)}{(0,05)(0,05)}$$
$$= 4,84$$

2

	$H_2(g)$ +	$I_2(g) \rightleftharpoons$	$2HI(g)$
molar ratio	1	1	2
n initially (mol)	6	*x*	
n change (mol)	4	4	8
n at equilibrium (mol)	2	$x - 4$	8
$c = \frac{n}{V}$ (mol·dm^{-3})	$\frac{2}{2} = 1$	$x - \frac{4}{2}$	$\frac{8}{2} = 4$

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{4^2}{(1)(\frac{(x-4)}{2})} = 57$$
$$x = 4,56 \text{ mol}$$

Activity 6 Research activity

1 a) The reaction is endothermic. An increase in temperature increases the K_c value, so the forward reaction was favoured. Endothermic reactions are favoured when there is an increase in temperature.

b) Although the K_c value is low, the number of NO molecules in the air is still vast and will further react to form other pollutants.

c) The high temperatures inside vehicle engines cause atmospheric nitrogen to react with oxygen to form nitrogen monoxide.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

In the atmosphere, nitrogen monoxide quickly oxidises to form brown nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Sunlight causes the decomposition of nitrogen dioxide into nitrogen monoxide and atomic oxygen.

$$NO_2(g) \rightarrow NO(g) + O(g)$$

Atomic oxygen is highly reactive and can initiate a number of reactions, one of which is the formation of ozone.

$$O(g) + O_2(g) \rightarrow O_3(g)$$

Ozone is a highly reactive substance which can further combine with unburnt hydrocarbons in the air. These substances eventually condense into small droplets of liquid in the air, called aerosol, which scatter sunlight to make the air look hazy. This is known as photochemical smog.

d) A catalytic converter is fitted to the exhaust system of an engine. It looks like a metal canister and has no moving parts. The inside of the converter has a honeycomb structure which provides a very large surface area. The honeycomb structure is covered with a catalyst on which the reactions take place. The catalyst is made of alloys of platinum, rhodium and palladium. A catalytic converter reduces a vehicle's toxic exhaust emissions by approximately 90%.

Incomplete fuel combustion takes place in vehicle engines. Incomplete combustion of octane is represented by the equation:

$$2C_8H_{18}(g) + 17O_2(g) \rightarrow 9{,}2CO_2(g) + 8{,}8H_2O(g) + 9{,}2H_2(g) + 6{,}8CO(g)$$

A catalytic converter helps to promote the following overall reactions.

The oxidation of carbon monoxide to carbon dioxide:

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

The reduction of nitrogen monoxide back to nitrogen:

$$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$$

The oxidation of unreacted hydrocarbons to water and carbon dioxide, for example:
$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

The products that leave the exhaust are N_2, CO_2 and H_2O. Although the CO_2 contribute to global warming, these products are less polluting than the original gases from the vehicle engine.

2 a) $K_c = \frac{[HbO_2]}{[Hb][O_2]}$

b) At a high altitude, air pressure decreases and the oxygen concentration in the atmosphere therefore also decreases. A decrease in oxygen concentration will shift the equilibrium position shown in the equation, to the left. This change depletes the supply of oxyhaemaglobin. Not enough oxygen can reach the vital organs and altitude sickness sets in.

c) The body starts to produce more haemaglobin molecules to rectify the shift in equilibrium position and the equilibrium will then gradually shift back towards the formation of oxyhaemaglobin. It takes two to three weeks for the increase in haemaglobin production to meet the body's basic needs. Studies show that residents of high-altitude areas have higher haemaglobin levels in their blood than people living at lower altitudes.

3 The reaction is irreversible and only the forward reaction takes place. The products are gases and will not react with each other under normal conditions of temperature and pressure to form the liquid octane again.

Test yourself 4 (LB p. 221)

1 a) Adding NaCl will increase the $[Cl^-]$. The equilibrium will shift to the right and more AgCl will precipitate.

b) Adding $AgNO_3$ will increase the $[Ag^+]$. The equilibrium will shift to the right and more AgCl will precipitate.

c) Removing Cl^- will decrease the $[Cl^-]$. The equilibrium will shift to the left and more AgCl will dissolve.

d) Adding NH_3 will decrease the $[Ag^+]$. The equilibrium will shift to the left and more AgCl will dissolve.

2 a) Number of moles of product decreases.

b) Number of moles of product remains the same.

c) Number of moles of product increases.

3 a) The amount of methanol decreases.

b) The amount of methanol increases.

c) The amount of methanol remains the same.

d) The amount of methanol increases.

e) The amount of methanol remains the same.

4 a) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H < O$

b) $K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$

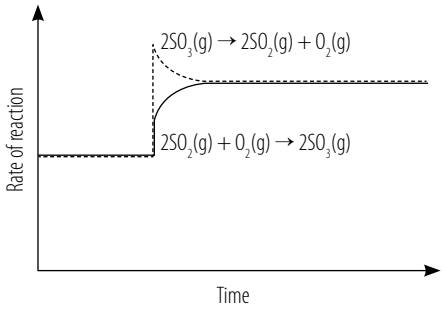
$= \frac{(5{,}0 \times 10^{-2})^2}{(3{,}0 \times 10^{-3})^2(3{,}5 \times 10^{-3})}$

$= 7{,}94 \times 10^4$

c) The forward reaction is exothermic. When the temperature is increased, the endothermic reaction is favoured. The concentration of the product, $[SO_3]$, will decrease and the concentrations of the reactants, $[SO_2]$ and $[O_2]$, will increase.

d) The K_c value will decrease.

e)



f) When the pressure is increased the reaction that results in a decrease in volume is favoured. This is the forward reaction. The reaction shifts to the right and the $[SO_3]$ increases and the $[SO_2]$ and $[O_2]$ decrease.

g) i) The rate of reaction of the reverse reaction will increase: a catalyst increases the rates of the forward and reverse reactions.

ii) The equilibrium concentrations of the reactants and products will be the same: a catalyst does not shift the equilibrium.

5 a) Such a small K_c value indicates that virtually no product, NO(g), has formed.

b)

	$N_2(g)$ +	$O_2(g) \rightleftharpoons$	2NO(g)
molar ratio	1	1	2
n initially (mol)	7,0	2,0	
n change (mol)	0,20	0,20	0,40
n at equilibrium (mol)	6,80	1,80	0,40
$c = \frac{n}{V}$ (mol·dm^{-3})	$\frac{6,80}{2} = 3,40$	$\frac{1,80}{2} = 0,90$	$\frac{0,40}{2} = 0,20$

$$K_c = \frac{[NO]^2}{[N_2][O_2]}$$
$$= \frac{0,20^2}{(3,40)(0,90)}$$
$$= 0,013$$

c) The forward reaction is endothermic. The K_c value increased when the temperature was increased. This means that the forward reaction was favoured to form more product. According to Le Chatelier's principle the endothermic reaction is favoured when temperature is increased.

LB p. 210

Activity 7 Investigation

Investigate acids and bases

Learner's own research. A table of acids and bases in food, drink and our bodies follows on the next page. It is taken from a table on the Australian website: sydney.edu.au.

Name	Also known as	Commonly found in	Composition	Description
acetic acid	ethanoic acid	vinegar, fruit, vegetables, cocoa, coffee, milk, wine	CH_3COOH	clear colourless liquid with distinctive odour, dissolves in water
ascorbic acid	vitamin C	fruit (citrus) and vegetables (tomato)	$C_6H_8O_6$	water-soluble antioxidant
butyric acid	butanoic acid	animal fats and oils	$CH_2(CH_2)_2CO_2H$	foul-smelling liquid (rancid butter)
carbonic acid	acid rain	rain water; carbonated beverages	H_2CO_3	only found as solution in water
citric acid	2-hydroxypropane-1,2,3-tricarboxylic acid	citrus fruit	$C_3H_4OH(COOH)_3$	soluble white powder
folic acid	vitamin B9	green leaves, beans, apricots	$C_{19}H_{19}N_7O_6$	Yellowish orange crystals not very soluble
formic acid	methanoic acid	poison in ants, stinging nettles	$HCOOH$	colourless liquid with irritating odour
hydrochloric acid	muriatic acid	gastric juice in stomach	HCl	strong acid, clear solution when diluted
lactic acid	2-hydroxypropanoic acid	soured milk, wine, blood and muscles	$CH_3CHOHCOOH$	colourless powder
malic acid	L-hydroxy butanedioic acid	wine, cranberries, grapes, apples	$C_4H_6O_5$	white, odourless crystals
oxalic acid	ehtanedioc acid	spinach and rhubarb leaves	$(COOH)_2.2H_2O$	transparent crystals
salicylic acid	coal tar, 2-hydroxybenzoic acid	aspirin	$C_6H_4(OH)COOH$	fine, white crystals
tartaric acid	dicarboxylic acid	wine, grapes	$HO_2CCHOHCHOHCO_2H$	white crystals
tannic acid	tannin	wood, bark, tea, coffee	$C_{14}H_{14}O_{11}$; $C_{14}H_{10}O_9$	dark brown powder, astringent taste
ammonia (base)		volcanic gas, product of decomposition of animal and vegetable matter	NH_3	colourless, very sharp odour
cadaverine (base)	1,5-diaminopentane	seafood, odour of bad breath, rotten food	$C_5H_{14}N_2$	colourless, unpleasant odour
caffeine (base)	trimethylxanthine	coffee, tea	$C_8H_{10}N_4O_2$	very bitter, white crystalline powder
putrescine (base)	1,4-diaminobutane	seafood, odour of bad breath, rotten food	$H_2N(CH_2)_3NH_2$	colourless, volatile, unpleasant odour
nicotine (base)		cigarettes	$C_8H_{14}N_2$	liquid

Test yourself 5 (LB p. 226)

1 a) An acid is a proton donor.
b) A base is a proton acceptor.

2 Acids: HCl; CH_3COOH; HNO_3; H_3PO_4; H_2SO_4
Bases: NaOH; NH_3; KOH; Na_2CO_3; $NaHCO_3$

3 a) $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$
acid 1 base 2 conj. base 1 conj. acid 2

b) $NH_3 + HCl \rightarrow NH_4^+ + Cl^-$
base 1 acid 2 conj. acid 1 conj. base 2

c) $H_3PO_4 + 3H_2O \rightarrow PO_4^{3-} + 3H_3O^+$
acid 1 base 2 conj. base 1 conj. acid 2

d) $HNO_2 + H_2O \rightarrow NO_2^- + H_3O^+$
acid 1 base 2 conj. base 1 conj. acid 2

e) $CO_3^{2-} + H_2O \rightarrow OH^- + HCO_3^-$
base 1 acid 2 conj. base 2 conj. acid 1

4 a) An ampholyte acts as an acid and a base, depending on the other reactants in the reaction.
b) $H_2PO_4^-$ as a base: $H_2PO_4^- + H^+ \rightarrow H_3PO_4$
$H_2PO_4^-$ as an acid: $H_2PO_4^- \rightarrow HPO_4^{2-} + H^+$

Test yourself 6 (LB p. 230)

1 a) $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$
b) $2HNO_3 + K_2O \rightarrow 2KNO_3 + H_2O$
c) $H_2SO_4 + MgCO_3 \rightarrow MgSO_4 + H_2O + CO_2$
d) $2H_3PO_4 + 3Mg(OH)_2 \rightarrow Mg_3(PO_4)_2 + 6H_2O$
e) $2CH_3COOH + CuO \rightarrow Cu(CH_3COO)_2 + H_2O$
f) $HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$
g) $H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$

2 a) $NH_4Cl(s) + H_2O(\ell) \rightarrow NH_4^+(aq) + Cl^-(aq)$
b) Cl^- does not hydrolyse in water. NH_4^+ hydrolyses in water to form hydronium ions that make the solution acidic.
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

LB p. 230 » **Activity 8 Experiment** G

Investigate the reactions of acids and bases

The experiments that follow are simple reactions that learners have come across in previous grades.

Experiment 1: Investigate the reaction of acids with metals

The metals react with the acids to liberate hydrogen gas. The temperature of the solutions will increase.

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$

$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

Experiment 2: Investigate the reaction of acids with metal oxides
Both MgO and CuO will react with acids on heating. The powders will dissolve slowly. $MgCl_2(aq)$ is a colourless solution, but $Cu(NO_3)_2(aq)$ contains blue Cu^{2+} ions. No gas is liberated.

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(\ell)$

$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(\ell)$

Experiment 3: Investigate the reaction of acids with metal carbonates and metal hydrogen carbonates
All carbonates and hydrogen carbonates react with acids to liberate large bubbles of CO_2. CO_2 turns clear lime water milky.

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(\ell) + CO_2(g)$

$NaHCO_3(s) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(\ell) + CO_2(g)$

Experiment 4: Investigate the reaction of acids with metal hydroxides
Reaction:

$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(\ell)$

The acid is neutralised when the litmus paper turns purple and not blue. The final pH of the solution should be 7.

Experiment 5. Investigate the reaction of bases with metal ion solutions
Both copper hydroxide and zinc hydroxide are insoluble precipitates. When NaOH is added to the test tubes a blue precipitate of $Cu(OH)_2$ forms in the one test tube and white $Zn(OH)_2$ in the other.
$CuSO_4(aq) + 2NaOH \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$

$ZnSO_4(aq) + 2NaOH \rightarrow Zn(OH)_2(s) + Na_2SO_4(aq)$

LB p. 232

» Activity 9 Teacher demonstration

Demonstrate the action of household acids and bases

Hydrogen chloride gas dissolved in water is known as hydrochloric acid. It is also known as muriatic acid or spirits of salts. It is a highly corrosive strong mineral acid and both the mist and the solution have a corrosive effect on human tissue, with the potential to damage respiratory organs, eyes, skin, and intestines. Wear rubber or PVC gloves, protective eye goggles and chemical-resistant clothing and shoes when handling concentrated acids.

Hydrochloric acid is used in household cleaning products, swimming pool treatment to adjust the pH, and in the building industry to remove cement and mortar from metal and bricks.

Sulfuric acid is a colourless to slightly yellow viscous liquid which is soluble in water at all concentrations. Sometimes it is dyed dark brown to alert people to its hazards. Historically it was known as oil of vitriol. Concentrated sulfuric acid has strong dehydrating and oxidising properties. At high concentration the acid can cause very serious damage upon contact, as it causes chemical burns via hydrolysis and dehydration. It will lead to blindness if splashed onto the eyes. So, strict safety precautions should be taken when using it. Sulfuric acid is hygroscopic and absorb water vapour form the air.

Sulfuric acid has a wide range of applications including domestic acidic drain cleaner, electrolyte in lead-acid car batteries and various cleaning agents.

Sodium hydroxide, also known as lye or caustic soda is a highly caustic metallic base. It is a white solid available in pellets, flakes, granules, and as a 50% saturated solution. Sodium hydroxide is soluble in water and ethanol. It is hygroscopic and readily absorbs moisture from the air. Similar to the hydration of sulfuric acid, dissolution of solid sodium hydroxide in water is a highly exothermic reaction in which a large amount of heat is liberated, posing a threat to safety through the possibility of splashing. The resulting solution is usually colourless and odourless with a slippery feeling.

Sodium hydroxide is frequently used as a home drain cleaning agent. It dissolves grease, oils, fats and protein deposits in pipes under sinks and drains. Sodium hydroxide is used in some relaxers to straighten hair. It is also used as a paint stripper on wooden objects.

Ammonia is also known as azane and is a colourless gas with a characteristic pungent smell. Ammonia is both caustic and hazardous. Household ammonia is a solution of NH_3 in water used as a general purpose cleaner for many surfaces. Because ammonia results in a relatively streak-free shine, one of its most common uses is to clean glass, porcelain and stainless steel. It is also frequently used for cleaning ovens and soaking items to loosen baked-on grime. Household ammonia ranges in concentration by weight from 5% to 10% ammonia.

Test yourself 7 (LB p. 224)

1 a) $Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$

b) $c_b = \frac{m}{MV} = \frac{1{,}06\ \cancel{g}}{(106{,}0\ \cancel{g}\cdot mol^{-1})(0{,}2\ dm^{-3})} = 0{,}05\ mol\cdot dm^{-3}$

$\frac{n_a}{n_b} = \frac{c_a V_a}{c_b V_b}$

$\frac{2}{1} = \frac{c_a \times 40\ \cancel{cm^3}}{0{,}05\ mol\cdot dm^3 \times 25\ \cancel{cm^3}}$

$c_a = 0{,}06\ mol\cdot dm^{-3}$

2 a) hydrochloric acid: strong acid; sodium hydroxide: strong base

b) bromothymol blue

c) the end point of the reaction

d) $HCl + NaOH \rightarrow NaCl + H_2O$

e) $\frac{n_a}{n_b} = \frac{c_a V_a}{c_b V_b}$

$\frac{1}{1} = \frac{c_a \times 25{,}0\ \cancel{cm^3}}{0{,}12\ mol\cdot dm^3 \times 18{,}8\ \cancel{cm^3}}$

$c_a = 0{,}09\ mol\cdot dm^{-3}$

f) 50 cm^3 and 250 cm^3 of NaOH solution contain the same number of moles of NaOH, because only water is added in the dilution.
Number of moles of NaOH in 50 cm^3 water = number of moles of NaOH in 250 cm^3 water

$n_1 = n_2$

$c_1V_1 = c_2V_2$

$0{,}21\ mol{\cdot}dm^3 \times 0{,}05\ dm^3 = c_2 \times 0{,}25\ dm^3$

$c_2 = \frac{0{,}12\ mol{\cdot}dm^{-3} \times 0{,}05\ \cancel{dm^3}}{0{,}25\ \cancel{dm^3}}$

$= 0{,}024\ mol{\cdot}dm^{-3}$

3 a) weak acid

b) pH higher than 7

c) phenolphthalein

d) $(COOH)_2 + 2KOH \rightarrow K_2(COO)_2 + 2H_2O$

e) $\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$

$\frac{1}{2} = \frac{0{,}12\ mol{\cdot}dm^{-3} \times 20{,}0\ \cancel{cm^3}}{c_b \times 25\ \cancel{cm^3}}$

$c_b = 0{,}19\ mol{\cdot}dm^{-3}$

LB p. 239

Activity 10 Prescribed experiment for formal assessment

Use acid-base titration in neutralisation reactions

$2NaOH(aq) + (COOH)_2(aq) \rightarrow Na_2(COO)_2(aq) + 2H_2O(\ell)$

From the stoichiometric equation we have 1 mol $(COOH)_2$ reacts with 2 mol NaOH. The mol ratio is $\frac{\text{number of mol of acid}}{\text{number of mol of base}} = \frac{1}{2}$, so number of mol of acid must be $\frac{1}{2}$ that of the base.

The CAPS prescribes 25 ml volumetric flasks, which are very small. Normally we would suggest using a 0,05 $mol{\cdot}dm^{-3}$ $(COOH)_2$ solution to neutralise a 0,1 $mol{\cdot}dm^{-3}$ NaOH solution. The method that follows uses a 0,5 $mol{\cdot}dm^{-3}$ $(COOH)_2$ solution to neutralise a 1 $mol{\cdot}dm^{-3}$ NaOH solution. The reason is that it is very difficult to weigh 0,157 g of oxalic acid accurately on a normal school mass meter/balance. If larger volumetric flasks are available, it would be better to use them and use more dilute solutions. Use the table below to adjust the weights and concentrations of solutions.

Experiment 1: Prepare a standard solution for volumetric analysis

We want to neutralise a 1 $mol{\cdot}dm^{-3}$ NaOH solution, so learners must make up a 0,5 $mol{\cdot}dm^{-3}$ solution of oxalic acid. It is not necessary for the learners to weigh exactly 1,57 g, but they must know the weight of their sample accurately. If you have larger volumetric flasks available, use the table below to calculate the mass of oxalic crystals needed. Remember: 1 mol acid neutralises 2 mol base.

Table to make up an oxalic acid solution

Conc. ($mol{\cdot}dm^{-3}$)	0,05 (will neutralise 0,1 $mol{\cdot}dm^{-3}$ NaOH)				0,25 (will neutralise 0,5 $mol{\cdot}dm^{-3}$ NaOH)				0,5 (will neutralise 1 $mol{\cdot}dm^{-3}$ NaOH)			
Vol (cm^3)	25	100	200	250	25	100	200	250	25	100	200	250
Mass (g)	0,1575	0,63	1,26	1,575	0,7875	3,15	6,3	7,875	1,575	6,3	12,6	15,75

Table to make up a sodium hydroxide solution

Conc. ($mol \cdot dm^{-3}$)	0,1 (will neutralise 0,05 $mol \cdot dm^{-3}$ $(COOH)_2$)			0,5 (will neutralise 0,25 $mol \cdot dm^{-3}$ $(COOH)_2$)			1,0 (will neutralise 0,5 $mol \cdot dm^{-3}$ $(COOH)_2$)		
Vol (cm^3)	250	500	1 000	250	500	1 000	250	500	1 000
Mass (g)	1	2	4	5	10	20	10	20	40

Explain to learners that the water of crystallisation must be added in when calculating the molar mass, as it forms part of the crystals that are weighed off.

The method for making up the standard solution is in the Learner's Book.

5 $c = \frac{m}{MV} = \frac{1{,}57\ \cancel{g}}{126{,}0\ \cancel{g}\ mol^{-1} \times 0{,}025\ dm^3} = 0{,}50\ mol \cdot dm^{-3}$

Experiment 2: Perform an acid–base titration

Demonstrate to learners how to use a pipette correctly.

- Use a pipette filler to fill the pipette. Do not allow learners to suck up the liquid with their mouths.
- Rinse the pipette with the oxalic acid solution.
- Fill the pipette by sucking up liquid past the filling line. Slowly let the liquid out until the bottom curve of the meniscus touches the filling line.
- Release the liquid in a volumetric flask with gravity. Do not blow on the pipette. Allow a few seconds for the liquid to drain. A drop will stay behind in the tip of the pipette. This is normal.

Demonstrate to learners how to operate a burette correctly.

- Make sure the burette and its tap are clean. The tap must be able to turn with ease. If not, grease the tap lightly with petroleum gel.
- Rinse the burette with NaOH solution.
- Fill the burette by using a small funnel and beaker.
- Allow some liquid to run out to fill the bottom part of the burette below the tap. Make sure that there are no trapped air bubbles.
- Adjust the volume by opening the tap to zero the burette. The bottom of the meniscus must be on the zero line.
- Manipulate the tap with the left hand while shaking the flask with the right hand after each addition of alkali.

The titration method can be found in the Learner's Book.

7 $2NaOH(aq) + (COOH)_2(aq) \rightarrow Na_2(COO)_2(aq) + 2H_2O(\ell)$

8 $\frac{n_a}{n_b} = \frac{c_a V_a}{c_b V_b}$

$\frac{1\ mol}{2\ mol} = \frac{0{,}50\ mol \cdot dm^{-3} \times V_a}{c_b \times 25{,}0\ cm^3}$

$c_b = \frac{2\ \cancel{mol} \times 0{,}50\ mol \cdot dm^{-3} \times V_a\ \cancel{cm^3}}{1\ \cancel{mol} \times 25{,}0\ \cancel{cm^3}}]$

$= x\ mol \cdot dm^{-3}$

Experiment 3: Determine the concentration of acetic acid in vinegar

Use exactly the same method as for the previous experiment. Learners can use the same burette and NaOH solution and just replace the oxalic acid with vinegar (after they have rinsed the volumetric flask very well).

To calculate percentage acetic acid in vinegar:

$\frac{\text{titration volume of acetic acid}}{25{,}0\ cm^3\ \text{vinegar}} \times 100\%$

Experiment 4: Determine the concentration of sodium hydroxide in drain cleaner

In this experiment the base goes in the volumetric flask and the acid in the burette. Make sure to clean and rinse the burette well to remove all traces of sodium hydroxide.

Drain cleaner can be very corrosive and it must be handled with great care. Learners must never suck up drain cleaner solution with their mouths.

Follow the same procedure as in the previous experiments.

To calculate percentage sodium hydroxide in drain cleaner:

$$\frac{\text{titration volume of drain cleaner}}{25{,}0\ \text{cm}^3\ \text{drain cleaner}} \times 100\%$$

Assessment of experimental part of activity 10 **Total allocated marks: 15**

Assessment criteria	Rating					
	5	4	3	2	1	0
Organisation – worked through methods in orderly manner	Methods followed; efficiently organised; neat	Most methods followed; reasonably organised; neat	Some methods followed; not well organised	Few methods followed; disorgan-ised; untidy	No idea how to follow methods; disorgan-ised; messy	No attempt to do experiments
Efficient use of allocated time			All experiments completed efficiently and in time	Some experiments completed in time; could be more efficient	Experiments not completed; inefficient	Not attempted
Teamwork and enthusiasm				Effective and enthusiastic teamwork; good spirit	Some effort made, but lacking in enthusiasm	Does not participate
Ability to use apparatus and equipment	All apparatus used correctly and with care	Apparatus used correctly	Apparatus sometimes used incorrectly	Apparatus sometimes used correctly	Apparatus used incorrectly	No attempt to use apparatus

Assessment of learner report **Total allocated marks: 10**

Assessment criteria	Rating					
	5	4	3	2	1	0
Presentation of results and neatness	Results neatly presented in a suitable report; handed in on time	Results presented in a report; handed in on time	Some results presented in a report; neat, but late	Some results presented but confusing, late	Report late and untidy	No results presented

Processing and accuracy of results	Results correctly processed and accurate	Most results correctly processed and reasonably accurate	Some results processed; reasonably accurate	Results processed but inaccurate	Few results processed; inaccurate	No calculations done

Use the answers above as a marking memo for the report.

Test yourself 8 (LB p. 247)

1 a) $pH = -\log[H^+] = -\log(0{,}0025) = -(-2{,}60) = 2{,}60$

b) $0{,}00175$ mol $Ba(OH)_2(aq)$ yield $2(0{,}00175)$ mol $OH^-(aq)$

$[H^+][OH^-] = 1 \times 10^{-14}$

$[H^+] = \frac{1 \times 10^{-14}}{[OH^-]} = \frac{1 \times 10^{-14}}{0{,}0035} = 2{,}86 \times 10^{-12}$

$pH = -\log[H^+] = -\log(2{,}86 \times 10^{-12}) = -(-11{,}54) = 11{,}54$

2 a) $pH = -\log[H^+]\ 2{,}5 = -\log[H^+]$

$[H^+] = 0{,}0032 \text{mol}\cdot\text{dm}^{-3}$

$[H_2SO_4(aq)] = \frac{0{,}0032}{2} = 0{,}0016 \text{ mol}\cdot\text{dm}^{-3}$

b) $pH = -\log[H^+]$

$13{,}2 = -\log[H^+]$

$[H^+] = 6{,}31 \times 10^{-14} \text{mol}\cdot\text{dm}^{-3}$

$[H^+][OH^-] = 1 \times 10^{-14}$

$[OH^-] = \frac{1 \times 10^{-14}}{[H^+]} = \frac{1 \times 10^{-14}}{6{,}31 \times 10^{-14}} = 0{,}16 \text{ mol}\cdot\text{dm}^{-3}$

$[KOH] = 0{,}16 \text{mol}\cdot\text{dm}^{-3}$

Learner's Book pages 250–258

Unit 1–3 Summative assessment: Chemical change

TERM 2, MODULE 4

1 a) collision theory
b) activation energy
c) activated complex
d) electrolyte
e) endothermic
f) dynamic
g) catalyst
h) Le Chatelier's Principle
i) equilibrium constant
j) chlor-alkali process
k) acid
l) indicator
m) titration
n) equivalence point
o) ionic product
p) dilute solution
q) pH

2 Correct the following false statements:
a) The factors that increase the number of collisions are an increase in temperature, concentration and pressure; OR the factor that does not increase the number of collisions is an increase in volume.

b) A catalyst increases the rate of a chemical reaction.
c) The reaction rate is the change in reactant or product concentration in a certain time period.
d) All reactions, endothermic and exothermic reactions, need activation energy to proceed.
e) When the reaction $CuO(s) + H_2(g) \rightleftharpoons Cu(s) + H_2O(g)$ is in equilibrium, then $K_c = \frac{[H_2O]}{[H_2]}$.
f) The equilibrium constant for an exothermic reaction decreases with an increase in temperature; OR the equilibrium constant for an endothermic reaction increases with an increase in temperature.
g) The reaction reaches equilibrium when the concentrations of the products and reactants remain constant.
h) If sulfur is burnt in a closed container, equilibrium is reached after a while.
i) When the solution in equilibrium represented below is heated, it turns green.
j) If at equilibrium $K_c = 10^{-4}$, then [A][B]>[C][D]
k) The reaction $2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$ is an example of a redox reaction.
OR
The reaction $2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(\ell)$ is an example of an acid-base reaction.
l) The following acids are considered strong acids: HCl; HNO_3; H_2SO_4. $(COOH)_2$ and H_2CO_3 are weak acids.
m) In the reaction $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$, the conjugate acid-base pair is H_2O; OH^- or CO_3^{2-}; HCO_3^-.
n) Ammonium chloride dissolves in water to form an acidic solution because hydronium ions form.
o) Indicators are acids or bases and the colour of the acid and its conjugate base must be different.
p) The pH of a 0,02 mol·dm^{-3} hydrochloric acid solution is 1,7.

3 a) C e) C i) B m) C
b) B f) A j) D n) B
c) D g) D k) D o) C
d) A h) C l) D p) C

4 Matching items Table 1: a) E b) H c) G d) A
e) F f) D g) B h) C
Matching items Table 2: a) D b) E (or D) c) G d) F
e) C f) H g) B

5 a) Copper is a catalyst.
b) A catalyst lowers the activation energy that is needed for the reaction and more particles can acquire the activation energy for the reaction. The reaction rate increases.
c) Caroline can heat the mixture, use more concentrated acid or use zinc powder.
d) The reaction is exothermic because heat is given off.

6 a) i) The reaction proceeds in both directions: N_2 and H_2 react to form NH_3, and NH_3 decomposes to form N_2 and H_2.
ii) In a dynamic equilibrium the macroscopic changes have stopped, but the reactions continue on microscopic level. For each two molecules of NH_3 that form, two molecules NH_3 decompose. The rates of the forward and reverse reactions are equal.

b) Le Chatelier's Principle: A change in any of the factors that determine equilibrium conditions of a system will cause the system to change in such a manner as to reduce or counteract the effect of the change.

c) From the balanced equation:
4 volumes reactants ⇌ 2 volumes product
An increase in pressure will favour the reaction that causes a decrease in volume; that is the forward reaction. The equilibrium shifts to the right and more product forms.

d) At a temperature below 450 °C the rate of the reaction decreases and the time to make product is too long to be economical.

e) The forward reaction is exothermic and a higher temperature favours the reverse endothermic reaction. Less product forms.

7 a) When the temperature is raised the equilibrium will shift to the right to make more product.

b) When more chlorine gas is added to the reaction mixture the equilibrium will shift to the left to make more reactants.

c) When the pressure on the gases is increased the equilibrium will shift to the left.

d) A catalyst will have no effect on the equilibrium.

8 a) $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

b) The concentration is lower. Water was added to dilute the acid.

c) Reaction rate (or volume of hydrogen gas produced per unit time) increases with increase in concentration; OR the higher the concentration of HCl, the faster the rate of the reaction.

d) To make a fair comparison and ensure that there is only one independent variable.

e) Magnesium is the limiting reagent; when the magnesium is used up the reaction will stop.

f) i) 60 cm^3 ii) 42 cm^3

g) Experiment 1: The gradient of the graph is steeper.

h) The number of moles used in both experiments was the same.

i) The reaction rate increases with an increase in concentration.

j) i) Remains the same; the final volume of product is determined by the amount of reactants and the temperature has no influence on that.

ii) Increases; the reaction rate increases for all reactions as the temperature rises.

9 a) The reverse reaction is endothermic.

b) $[NO_2] = \frac{0,2}{0,5} = 0,4 \text{ mol·dm}^{-3}$

$[N_2O_4] = \frac{0,8}{0,5} = 1,6 \text{ mol·dm}^{-3}$

$K_c = \frac{[N_2O_4]}{[NO_2]^2} = \frac{1,6}{0,4^2} = 10$

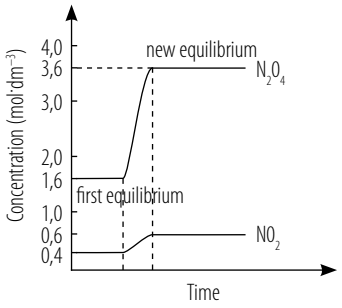
c) By halving the volume, the concentration is doubled ($c = \frac{n}{V}$) and should therefore be 0,8 mol·dm^{-3}. The increase in pressure favours the forward reaction according to Le Chatelier and $[NO_2]$ decreases as $[N_2O_4]$ increases.

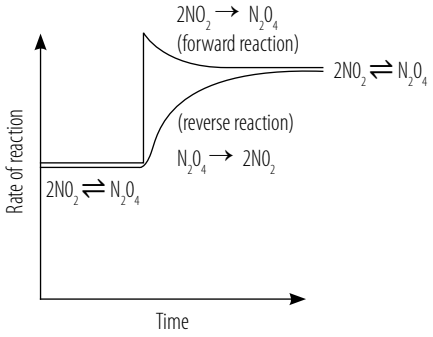
d) $K_c = \frac{[N_2O_4]}{[NO_2]^2} = \frac{[N_2O_4]}{0,6^2} = 10$

$[N_2O_4] = 3,6 \text{ mol·dm}^{-3}$

$N_2O_4 = cV = 3,6 \text{ mol·dm}^{-3} \times 0,25 \text{ dm}^3 = 0,9 \text{ mol}$

e)





10 a) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

b) The reactant and products are in different phases.

c) $K_c = [CO_2] = 0{,}0108$

$[CO_2] = 1{,}08 \times 10^{-2}\ mol{\cdot}dm^{-3}$

$(CO_2) = cV = 1{,}08 \times 10^{-2}\ mol{\cdot}dm^{-3} \times 0{,}5\ dm^3 = 5{,}4 \times 10^{-3}\ mol$

$(CaCO_3)$ used $= n(CO_2)$

$(CaCO_3)$used $= nM = 5{,}4 \times 10^{-3}\ mol \times 100{,}0\ g{\cdot}mol^{-1} = 0{,}54\ g$

Mass at equilibrium $= 5 - 0{,}54 = 4{,}46\ g$

d) Endothermic; according to Le Chalelier's Principle an increase in temperature will favour the endothermic reaction or the reaction that uses energy. When the temperature was increased, K_c increased and therefore the concentration of carbon dioxide increased and more product formed. The forward reaction had to be favoured.

e) i) Remains the same; K_c is not affected by a change in volume.

ii) Increases; a higher pressure shifts the equilibrium to the left.

iii) Remains the same; the smaller volume increased the initial concentration, which was counteracted by the shift in equilibrium to the left.

11 a) The reaction is exothermic. Lowering the temperature favours a higher yield of ammonia, but the rate of the reaction is drastically reduced. Production is unprofitable.

b) i)

	$NH_3(g)$ +	$O_2(g) \rightleftharpoons$	NO(*g*) +	$H_2O(g)$
Molar ratio	1	1	1	1
Initial [ ]	1	1	0	0
Change in [ ]	0,25	0,3125	0,25	0,375
Equilibrium [ ]	0,75	0,6875	0,25	0,375

$$K_c = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$
$$= \frac{(0{,}25)^4(0{,}375)^6}{(0{,}75)^4(0{,}6875)^5}$$
$$= 2{,}2 \times 10^{-4}$$

ii) low; K_c value is very small and indicated that there are more reactants than product molecules in the reaction mixture at equilibrium.

12 a) HCl(*aq*) and $Na_2CO_3(aq)$, because the concentrations of both are known.

b) Methyl orange: reaction between a strong acid and a weak base.

c) $\frac{n_a}{n_b} = \frac{c_a V_a}{c_b V_b}$

$\frac{2}{1} = \frac{0{,}4\ mol{\cdot}dm^{-3} \times 20\ cm^3}{0{,}25\ mol{\cdot}dm^{-3} \times V_b}$

$V_b = 16\ cm^3$

13 a) A
b) C
c) C
d) D
e) E

14 a) H
b) G
c) G
d) I
e) $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$
$\frac{n_a}{n_b} = \frac{c_a V_a}{c_b V_b}$
$\frac{2}{1} = \frac{0{,}1 \text{ mol·dm}^{-3} \times V_a}{0{,}1 \text{ mol·dm}^{-3} \times 15 \text{ cm}^3}$
$V_a = 30 \text{ cm}^3$

15 a) $M(HCl) = 1{,}0 + 35{,}5 = 36{,}5 \text{ g·mol}^{-1}$
$c = \frac{n}{V} = \frac{m}{MV} = \frac{7{,}3 \text{ g}}{36{,}5 \text{ g·mol}^{-1} \times 0{,}25 \text{ dm}^3} = 0{,}8 \text{ mol·dm}^{-3}$
b) The concentration is known precisely.
c) $pH = \log[H^+] = \log 0{,}8 = 0{,}1$
d) HCl ionises completely in water to form a high percentage of H_3O^+ ions.
e) NaCl solution is neutral with a pH = 7; HCl solution is acidic with a pH below 7.
f) $HCl(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + Cl^-(aq)$
Acid: HCl; Conjugate base: Cl^-
Base: H_2O; Conjugate acid: H_3O^+
g) Yes; there are ions which can act as charge carriers in the solution.

16 a) The point during a titration where an exact number of moles of acid neutralises an exact number of moles of base, according to the coefficients in the balanced equation.
b) Phenolphthalein
c) For NaOH: $(cV)_{dilute} = (cV)_{conc}$
$c_{dilute} = \frac{(cV)_{conc}}{V_{dilute}} = \frac{1{,}63 \text{ mol·dm}^{-3} \times 0{,}05 \text{ dm}^3}{1{,}0 \text{ dm}^3} = 0{,}08 \text{ mol·dm}^{-3}$
$n(NaOH) = cV = 0{,}08 \text{ mol·dm}^{-3} \times 0{,}04 \text{ dm}^3 = 3{,}2 \times 10^{-3} \text{ mol}$
2 mol NaOH react with 1 mol acid
$n(acid) = 1{,}6 \times 10^{-3} \text{ mol}$
$m(acid) = nM = 1{,}6 \times 10^{-3} \text{ mol} \times 90{,}0 \text{ g·mol}^{-1} = 0{,}144 \text{ g}$
$\%\text{ purity} = \frac{0{,}144 \text{ g}}{0{,}25 \text{ g}} \times 100 = 57{,}6\%$

17 a) $pH = \log[H^+]$
$3 = -\log[H^+]$
$[H^+] = 10^{-3} \text{ mol·dm}^{-3}$
b) No, since the $[H^+]$ is smaller than $0{,}01 \text{ mol·dm}^{-3}$ the acid does not ionise completely. HCl is a strong acid that ionises completely.

18 $n(NaOH) = cV = 0{,}5 \text{ mol·dm}^{-3} \times 0{,}028 \text{ dm}^3 = 0{,}014 \text{ mol}$
$n(HCl)_{excess} = n(NaOH) = 0{,}014 \text{ mol}$
$n(HCl)_{total} = cV = 1{,}0 \text{ mol·dm}^{-3} \times 50 \times 10^{-3} \text{ dm}^3 = 0{,}05 \text{ mol}$
$n(HCl)$ reacting with $CaCO_3 = 0{,}05 - 0{,}014 = 0{,}036 \text{ mol}$
$n(CaCO_3) = \frac{0{,}036}{2} = 0{,}018 \text{ mol}$
$m(CaCO_3) = nM = 0{,}018 \text{ mol} \times 100{,}0 \text{ g·mol}^{-1} = 1{,}8 \text{ g}$

MODULE 5: ELECTRICITY AND MAGNETISM

Do a brief review of magnetism, electrostatics and electric circuits taught in Grade 10 before commencing this module. This can then be followed up by the revision of electric circuits in Unit 1.

This unit places emphasis on electric circuits with real batteries where the internal resistance of the battery is included in calculations. Unit 1 has a prescribed experiment for formal assessment which consists of two parts. The first part is an experiment to determine the internal resistance of a battery, while the second part is to experimentally determine the equivalent resistance of a series-parallel network of resistors and compare this result with a theoretical value. This unit also has a recommended practical investigation for informal assessment, where short circuits and open circuits are investigated.

Test yourself 1 (LB p. 265)

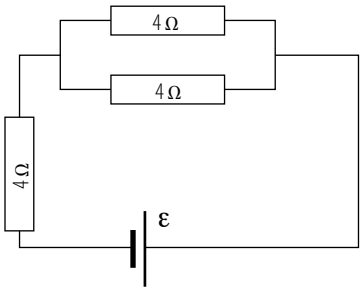
1 From $\varepsilon = V_{terminal} + Ir$ we see that emf is equal to the terminal potential difference when a battery has no internal resistance (ideal battery) or when there is no current flowing through the battery.

2 From $\varepsilon = V_{terminal} + Ir$, we have $V_{terminal} = \varepsilon - Ir = 9\text{ V} - 2\text{ V} = 7\text{ V}$
The current through the 4,0 Ω resistor is $I = \frac{V_{terminal}}{R} = \frac{7\text{ V}}{4\ \Omega} = 1{,}75\text{ A}$
The internal resistance is then $r = \frac{V_{int}}{I} = \frac{2{,}0\text{ V}}{1{,}75\text{ A}} = 1{,}1\Omega$

3 $\varepsilon = I(R + r) = 1{,}2\text{ A}\ (9{,}5\Omega + 0{,}5\Omega) = 12\text{ V}$

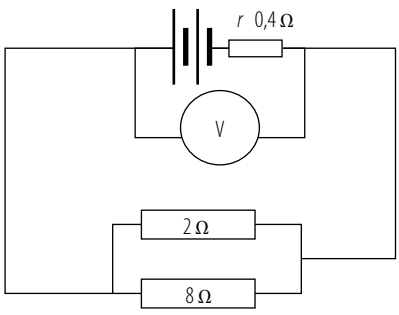
Test yourself 2 (LB p. 267)

1 He can connect two of the resistors in parallel and then connect this combination in series with the third as shown below.



The two parallel resistors have a combined resistance of 2 Ω from $\frac{1}{R_p} = \frac{1}{4} + \frac{1}{4} \rightarrow R_p = \frac{4}{2} = 2\ \Omega$
The total resistance is then the sum of parallel combination and the series 4 Ω resistor, i.e $R_{eq} = 2\ \Omega + 4\ \Omega = 6\ \Omega$

2 The circuit diagram for the given arrangement is:



The equivalent resistance of the parallel network is: $\frac{2\Omega \times 8\Omega}{2\Omega + 8\Omega} = 1{,}6\ \Omega$

The current in the circuit is: $I = \frac{\varepsilon}{R_{eq} + r} = \frac{12\text{V}}{1{,}6\ \Omega + 0{,}4\ \Omega} = 6\ \text{A}$

The potential difference across the parallel branch is:

$V = IR = 6\ \text{A} \times 1{,}6\ \Omega = 9{,}6\ \text{V}$

The current in the 8 Ω resistor is: $I = \frac{V}{r_8} = 9{,}6\ \text{V} / 8\ \Omega = 1{,}2\ \text{A}$

LB p. 267

Activity 1 Prescribed experiment for formal assessment

This activity can either be performed as an individual activity or as a group activity depending on the availability of equipment.

Part 1 Determine the internal resistance of a cell

Explain to learners how closing the switch creates a new circuit, but that the emf and internal resistance of the cell remain constant. The circuit is set up as shown in the diagram in the Learner's Book. The table below shows the readings taken when an *Energiser* AA cell was used. The resistances used were $R_1 = 4{,}7\ \Omega$ and $R_2 = 5{,}5\ \Omega$. It is preferable to have the values of R_1 and R_2 as close as possible to each other so that the difference between V_{ext1} and V_{ext2} is as large as possible. Note that larger values of the resistances will result in the current readings being smaller.

	Voltmeter, in volts	Ammeter, in amperes
Switch open	0,80	0,126
Switch closed	0,75	0,155

$$r = \frac{V_{ext1} - V_{ext2}}{I_2 - I_2}$$
$$= \frac{(0{,}80 - 0{,}75)\ \text{V}}{(0{,}155 - 0{,}126)\ \text{A}} = 1{,}7\ \Omega$$

Answers to questions

The answers below refer to the experiment conducted with the *Energiser* AA cell. Make use of these answers if it is not possible to conduct the practical experiment.

1 The cell was old and hence had a large internal resistance.

2 A fresh cell has an internal resistance of almost zero ohms. The results of the experiment depends on the type of cell used and also how often the cell was used prior to the experiment.

3 The emf is:
$\varepsilon = V_{ext1} + I_1 r$
$= 0{,}80\ \text{V} + 0{,}126\ \text{A} \times 1{,}7\ \Omega = 1{,}01\ \text{V}$
The battery used had 1,5 V as its rated emf.

4 By varying the rheostat, a number of different readings of V_{ext} and the corresponding current (I) readings can be taken. A graph of V_{ext} on the x-axis *vs.* I on the y-axis results in a straight line.

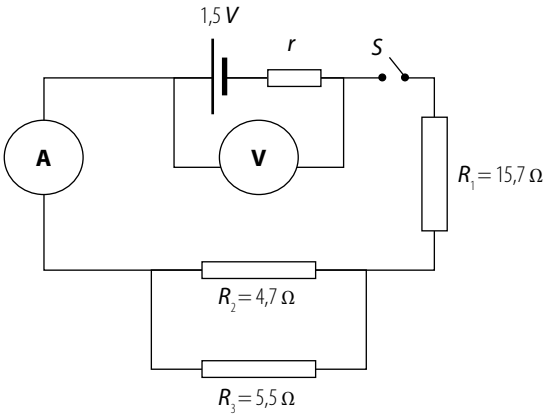
From the equation:
$\varepsilon = V_{ext} + Ir$,

we have
$I = -(\frac{1}{r})V_{ext} + \frac{\varepsilon}{r}$

The slope of the V_{ext} *vs.* I graph is then $\frac{-1}{r}$, and the intended resistance, r, can be determined from $r = \frac{1}{-\text{slope}}$

Part 2 Determine the equivalent resistance of a series-parallel network of known resistors using an ammeter and a voltmeter and compare with the theoretical value

The experiment was conducted with a 1,5 V AA *Duracell* battery and resistors as marked on the circuit diagram below.



The following results were obtained.

Voltmeter reading, in volts	1,26
Ammeter reading, in amperes	0,066
Equivalent resistance (measured), in ohms	19,09 (though only 19 Ω is practical)
Resistance, R_1, in ohms	15,7
Resistance, R_2, in ohms	4,7
Resistance, R_3, in ohms	5,5
Parallel resistance, R_p, in ohms	2,53
Equivalent resistance (from theory), in ohms	18,23 (known only to 18,2 Ω)

Answers to questions

1 The experimental results are close to the calculated value with an error of about 5%. The main source of error is in the accuracy of the measuring instruments. It is advisable to repeat the measurements, and if digital multi-meters are being used, to switch the two meters around.

2 The two advantages of a parallel circuit over a series circuit are: Components connected in parallel work independently of each other. If however one of the components in a series network malfunctions, the others stop working.

The potential difference of the source is divided amongst all the components connected in series with it, while all the components connected in parallel to a source have the same source potential difference across them.

Assessment of experimental part of activity

Assessment criteria	Rating				
	4	3	2	1	0
Organisation – works through procedure in orderly manner	Methods followed efficiently without assistance	Methods followed efficiently but with some assistance	Method followed but with some assistance from teacher	Little knowledge of setting up electric circuits, lots of assistance from teacher	No knowledge of circuits and had every step completed by teacher
Efficient use of allocated time		Both experiments completed in allocated time	The first experiment completed and second partly done	First experiment completed, but did not attempt second	First experiment partly completed, did not attempt second
Ability to use ammeter and voltmeter		All readings correctly taken and with correct number of significant figures	All readings correctly read	Some of the readings incorrectly taken	Meters read incorrectly
Results		All results correct	Partly correct results	Results inaccurate	No results
Responses to questions based on experimental work			All answers correct	Some answers incorrect	No answers provided

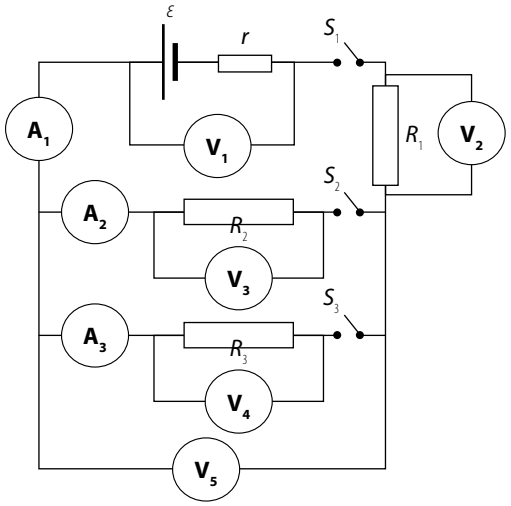
Total allocated marks: 15

LB p. 270

Activity 2 Recommended practical investigation for informal assessment

Investigating short circuits and open circuits in a series-parallel network of resistors

The circuit is connected as shown below with the following values: emf = 1,30 V, $R_1 = 4{,}7\ \Omega$, $R_2 = 15{,}7\ \Omega$ and $R_3 = 5{,}5\ \Omega$.



The following sets of readings were obtained.

	V_1, in volts (V)	V_2, in volts (V)	V_3, in volts (V)	V_4, in volts (V)	V_5, in volts (V)	A_1, in amperes (A)	A_2, in amperes (A)	A_3, in amperes (A)
All 3 switches open	1,30	0	0	0	0	0	0	0
Switch S_1 closed (S_2 and S_3 open)	1,30	0	0	0	1,30	0	0	0
Switch S_1 and S_2 closed (S_3 open)	1,27	0,22	0,94	0	0,94	60,6	60,6	0
All three switches closed	1,22	0,65	O,48	0,48	0,48	0,138	0,035	0,086
All three switches closed, and R_2 removed	1,20	0,43	0,68	0,68	0,68	0,116	0	0,116
All three switches closed and with short circuit	1,17	0,66	0,10	0	0	0,170	0,005	0,120

Note to the teacher:

1 In theory, with all the switches closed, voltmeters V_3, V_4, and V_5 should all have the same readings, since they are connected in parallel to each other. However, in practice the readings may not be the same because the reading instruments are not idealised meters.

2 The sum of the currents in ammeters A_2 and A_3 should be equal to the reading on A_1. This may not be achieved due to inaccuracies in the reading instruments or due to the current in the circuit fluctuating with time because of heat being developed in the conductors.

Answers to questions

1 The voltmeter V_1 reads the emf of the cell.

2 The voltmeter V_5 is connected in series with the resistor R_1 and the battery. Since voltmeters have very large resistances, the battery delivers almost zero current to the circuit. Thus V_5 measures the emf of the battery.

3 The resistors R_1 and R_2 are connected in series so the potential difference across each should add up to give the reading on V_1.

4 a) When R_2 is removed from the circuit, the effective resistance of the parallel branch and the total resistance of the circuit both increase. This results in a decrease in the current through the cell, and also through resistor R_1. The voltmeter reading $V_2 = IR_1$ will decrease with this decrease in current. The decrease in current also results in a decrease in the 'lost volts' ($V_{int} = Ir$). Since the emf of the battery remains constant, the decrease in voltages across R_1 and the internal

resistance is accompanied by a corresponding increase in voltage across the resistor R_3. Thus the reading on V_4 increases.

b) This is explained in (a) above.

c) The voltmeter V_3 reads the potential difference across the points to which the resistor R_2 was attached. Without the resistor, a potential difference still exists between the points, but this potential difference will now be larger because the resistance in this parallel branch has increased.

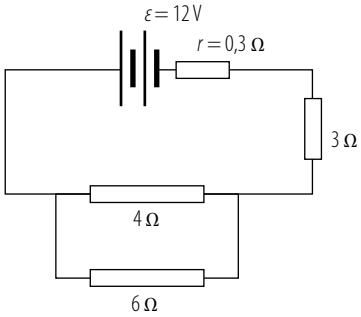
5 Connecting a low resistance wire across R_3 provides an alternative path for the current in the circuit. Resistors R_2 and R_3 are effectively bypassed by the current and the readings on A_2 and A_3 will be close to zero.

6 The external resistance of the circuit has now decreased. This results in an increase in the current through the battery (reading on A_1).

LB p. 275

Activity 3 Application exercise on circuits and internal resistance

1 a) The circuit diagram is as follows.



b) $R_{eq} = \frac{4\Omega \times 6\Omega}{4\Omega + 6\Omega} + 3\ \Omega = 5{,}4\ \Omega$

$I = \frac{\varepsilon}{R_{eq} + r} = \frac{12\text{V}}{5{,}4\ \Omega + 0{,}3\ \Omega} = 2{,}1\ \text{A}$

c) The potential difference across the parallel branch is the same as that across the 4Ω resistor and is $V = IR = 2{,}1\ \text{A} \times 2{,}4\Omega = 5{,}0\ \text{V}$

The power in the 4Ω resistor is $P = \frac{V^2}{R} = \frac{(5{,}0\ \text{V})^2}{4\ \Omega} = 6{,}25\ \text{W} \approx 6\ \text{W}$

2 a) We are given both the power dissipated in R and the voltage across it.

We use the power equation to find R: $R = \frac{V^2}{P} = \frac{(18\text{V})^2}{13{,}5\ \text{W}} = 24\ \Omega$

b) We first find the resistance of the parallel network and then use this and the given voltage to find the current in this network.

The 4 Ω and 8 Ω are in series and their equivalence is 12 Ω and this is in parallel with $R = 24\Omega$.

$R_{equiv.} = \frac{12\Omega \times 24\Omega}{12\Omega + 24\Omega} = 8\ \Omega$

The current through the parallel branch R_{eq} is then $I = \frac{V}{R_{eq}} = \frac{18\ \text{V}}{8\ \Omega} = 2{,}25\ \text{A}$

Or: The current through R is $I = \frac{V}{R} = \frac{18\ \text{V}}{24\ \Omega} = 0{,}75\ \text{A}$ and the current through the (8 Ω + 4 Ω) combination is twice the current through R since its resistance (12 Ω), is half of that of R. Therefore the current in the upper half of the parallel branch is $2 \times 0{,}75\ \text{A} = 1{,}5\ \text{A}$.

The current in the parallel branch is the sum of the current through each of the branches and is

$I = 0{,}75\ \text{A} + 1{,}5\ \text{A} = 2{,}25\ \text{A}$.

The reading on the ammeter is then 2,25 A.

c) When the switch is open there is no current in the circuit, and the reading on the voltmeter V_1 (the terminal voltage) is the emf of the battery. With the switch closed, the equivalent external resistance of the circuit is $R_{eq} = 8\ \Omega + 10\ \Omega = 18\ \Omega$

The current through the circuit is 2,25 A (calculated in (b)). We can then find the internal resistance from $\varepsilon = I(R + r)$:

$$r = \frac{\varepsilon - IR}{I} = \frac{45{,}9\ \text{V} - 2{,}25\ \text{A}(18\ \Omega)}{2{,}25\ \text{A}} = 2{,}4\ \Omega$$

Start by revising the electricity and magnetism concepts from Grade 10 and 11. There are two projects in this section. In the first, learners build a simple generator. In the second experiment, learners build a simple electric motor.

Test yourself 3 (LB p. 283)

1 a) The plane of the coil must be parallel to the magnetic field (the normal to the coil makes an angle of 90^0 with the magnetic field).
b) The plane of the coil must be perpendicular to the magnetic field (the normal to the coil makes an angle of 0^0 or 180^0 with the magnetic field).
2 electrical
3 The brushes maintain electrical contact between the rotating coil and the external resistor.
4 Replace the slip rings with a split ring commutator.
5 Similarity: Both the emfs fluctuate between maximum values and zeros.
Difference: The emf from a DC generator is always positive, while the AC emf can be both positive and negative.

LB p. 283

Activity 4 Project: Build a simple generator

Answers to questions

1 AC
2 • Use stronger magnets.
• Use a longer piece of enamelled wire.
• Spin the nail faster.
3 The emf generated is very small and an ordinary torch bulb, which has a relatively large resistance, will not light up.
4 The strength of the magnetic field produced by field coils can be controlled by adjusting the amount of current passing through them. Field coils can produce multi-pole magnetic fields, which result in greater magnetic flux penetrating the armature.

Test yourself 4 (LB p. 286)

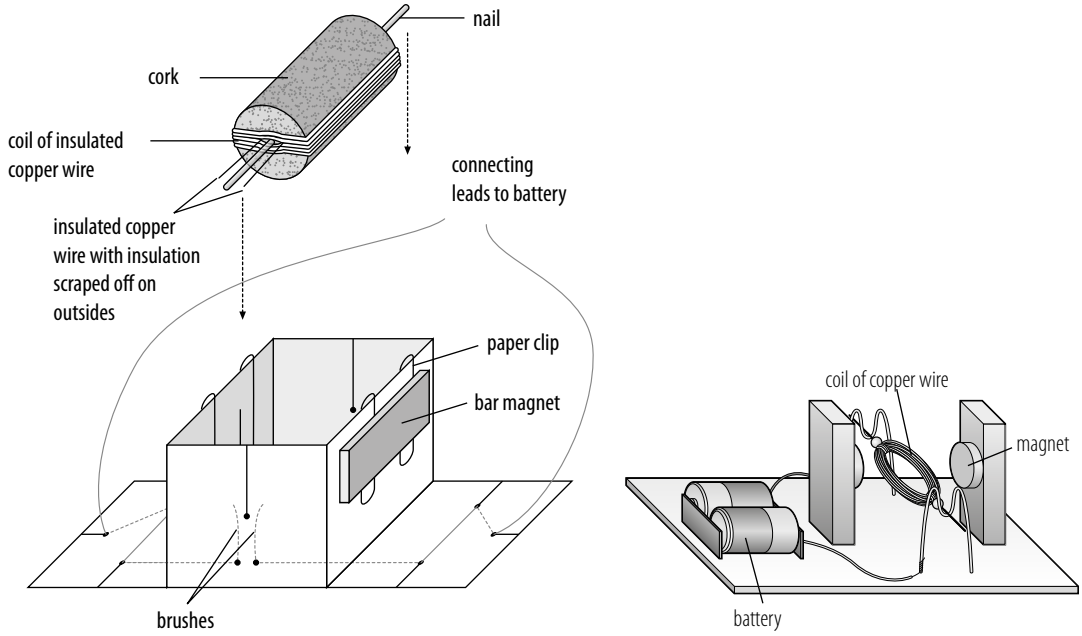
1 mechanical
2 The commutator changes the direction of the current in the coil after every half a cycle of rotation. This allows the coil to rotate in one continuous direction.

3 Replace the slip rings with a split ring commutator and replace the external resistor with a battery.
4 Practical DC motors have many coils and multiple splits to have a smoother running motor.

LB p. 286

Activity 5 Project: Build a simple electric motor

Below are diagrams for other types of simple motors.



Answers to questions

1 The portions of the coil making contact with the safety pins (which are connected to the battery) have the upper part scraped free of insulation. When this bare part makes contact with the safety pin, current flows through the coil, and the coil rotates. After half a cycle of rotation, the insulated part makes contact with the pins, and no current flows through the coil. The coil continues to rotate in the same direction because of the momentum gained. After this half cycle the insulation free part comes again in contact with safety pins and current flows through the coil. Thus current flows through the coil for every half a cycle, and the direction of rotation is constant.
2 a) Turn the battery around so that the polarity of the current in the coil is reversed.
b) Add another battery in series with the first or increase the number of loops in the coil or use stronger magnets.

LB p. 291

Activity 6 Application exercise on practical motors

1 Increasing the number of coils in the motor leads to a smoother running motor.
2 Commutators change the direction of the current in the coil so that the coil always rotates in the same direction.
Brushes are used to lead the current into and out of the coil.

3 Friction between the carbon brushes and the commutator leads to the creation of sparks. The heat generated by the frictional forces can sometimes convert the oxygen in the air into ozone, which gives off the strange smell.

4 a) DC motors because they can run off small batteries such as torch cells.
   b) DC motor because of the high speed required and the portability.
   c) AC universal motor because of the high speed required for cutting timber.
   d) DC motor because of the high speed required and the portability.
   e) DC motors because they can run off small batteries such as torch cells.

5 Induction motors give off less noise than universal motors. Because induction motors do not have brushes and commutators, they have less wear and tear and are less expensive to maintain.

6 No. Most induction motors run at one speed. Different speeds are possible by having more than one set of coils in the stator. Recent developments in power electronics have resulted in the making of variable speed induction motors.

7 The current (and hence the speed) can be controlled by using rheostats or electronic devices.

8 The advantages of DC motor is variable speeds and portability. The disadvantages are that batteries need replacing or charging; wear and tear and noise due to commutators and brushes.

LB p. 292

Activity 7 Application exercise on electricity generation in South Africa

1 The rotating shaft of the turbine is connected to the rotor of the generator. The generator rotor is a cylindrical electromagnet. As it turns, the magnet poles cross the copper coils of the stator of the generator. An emf is induced in the stator coils, allowing a current to flow. (Faraday's law of electromagnetic induction.)

2 Electricity generation is based on the phenomenon of electromagnetic induction. When there is a change in magnetic flux linkage within a conductor, an emf is induced in the conductor. The change in magnetic flux linkage is brought about either by turning a conducting coil in a magnetic field, or by turning an electromagnet that is surrounded by coils of conducting wire. The magnitude of the induced emf in the conductor is proportional to the rate of change of magnetic flux linkage within the conductor.

3 Nuclear energy (from nuclear fission) is transformed into heat (thermal) energy used to convert water into steam. The thermal energy is transformed into mechanical energy of the rotating turbine, which is converted into electrical energy.

4 Some disadvantages of coal-fired power generation.
   - The combustion of coal results in the release of pollutants into the air, mainly from the impurities in the coal.
   - Vast quantities of coal have to be burnt to generate electricity, and coal is a non-renewable energy resource.
   - Disposal of the ash from the burnt coal can result in environmental pollution.

- Release of CO_2, a greenhouse gas, into the atmosphere, may contribute to global warming.

5 Wind energy is free, renewable and clean (no pollutants). However, wind turbines are expensive to construct; tend to be unpopular because of their noise and size. They rely on the wind, which is variable and unpredictable.

Test yourself 5 (LB p. 297)

1 AC power is always positive and therefore its average value is not zero. Since AC voltages and currents have negative values for the same period of time as they have positive values, their average values will always be zero.

2 We are given $V = 34\ \text{V}\sin(\omega t)$, from which we can deduce that $V_{max} = 34$ V.

a) The rms voltage is then $V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} = \frac{34\text{V}}{\sqrt{2}} = 24$ V

b) The average power is:

$P_{\text{avg}} = \frac{V^2_{\text{rms}}}{R} = \frac{(24\ \text{V})^2}{100\ \Omega} = 5{,}8\text{W}$

c) The rms current in the source is $I_{\text{rms}} = \frac{V_{\text{rms}}}{\text{R}} = \frac{24\text{V}}{100\ \Omega} = 0{,}24$ A

Learner's Book pages 299–303

Unit 1 and 2 Summative Assessment

TERM 3, MODULE 5

1 a) commutator
b) generator or dynamo
c) parallel
d) terminal voltage
e) short circuit

2 a) C b) C c) D d) C e) A

3 Both the emf and the internal resistance are unknowns, and thus we have to set up two equations to solve for both of them.

We use the equation $\varepsilon = I(R + r)$

to get $\varepsilon = 200 \times 10^{-3}(18 + r)$ … (1)

and $\varepsilon = 500 \times 10^{-3}(7{,}0 + r)$ … (2)

Equating the two equations we have:

$200 \times 10^{-3}(18 + r) = 500 \times 10^{-3}(7{,}0 + r)$

$\therefore (36 + 2r) = (35 + 5r)$

$3r = 1$

$r = 0{,}3\ \Omega$

Substituting this value for r into equation (1), we get:

$\varepsilon = 200 \times 10^{-3}(18 + 0{,}3) = 3{,}7$ V

4 a) The voltmeter will read 12 V which is the emf of the battery. Since the voltmeter has a high resistance, the current through the battery will be 0. The terminal voltage is thus the same as the emf, *i.e.* 12 V.

b) The ammeter effectively provides a short circuit for the current. The only resistance in the circuit is the internal resistance since R = 0. We then have $\varepsilon = I(R + r) = Ir$

$I = \frac{\varepsilon}{r} = \frac{12\ \text{V}}{1{,}5\ \Omega} = 8$ A

The terminal voltage will be zero since $R = 0$

c) Using $\varepsilon = I(R + r)$, we have:

$I = \frac{\varepsilon}{(R + r)} = \frac{12\ \text{V}}{(25 + 1{,}5)\ \Omega} = 0{,}45$ A

The terminal voltage is then $V_{\text{XY}} = IR = 0{,}45\ \text{A} \times 25\ \Omega = 11{,}3$ V

5 a) The 2 Ω resistor and 5 Ω resistor are in series (the current is the same in each), and their equivalent is 2 Ω + 5 Ω = 7 Ω. This 7 Ω resistor is in parallel with the 3 Ω resistor and their equivalent is:

$R_{||} = \frac{7\ \Omega \times 3\ \Omega}{7\ \Omega + 3\ \Omega}$
$= 2{,}1\ \Omega$

The effective resistance of the circuit (including the internal resistance) is then $R_{eff} = 2{,}1\ \Omega + 0{,}9\ \Omega + 9\ \Omega = 12\ \Omega$

b) The current through the battery is $I = \frac{\varepsilon}{R_{eff}} = \frac{24\ V}{12\ \Omega} = 2\ A$

c) In order to find the current in the 5 Ω resistor, we first find the voltage across the parallel branch. $V_{||} = IR_{||} = 2\ A \times 2{,}1\ \Omega = 4{,}2V$
We use this voltage to find the current in the 7 Ω parallel branch:
$I = \frac{V_{||}}{R_{7\Omega}} = \frac{4{,}2\ V}{7\ \Omega} = 0{,}6\ A$
Thus the current in the 5 Ω resistor is 0,6 A.

6 a) The voltage across the 6 Ω resistor is given. We use this to find the current through the 6 Ω resistor. $I_{6\Omega} = \frac{V_{6\Omega}}{R_{6\Omega}} = \frac{3\ V}{6\ \Omega} = 0{,}5\ A$

Since the 3 Ω resistor is in series with the 6 Ω resistor, the resistance in this parallel branch is 3 Ω + 6 Ω = 9 Ω and the current in the branch is 0,5 A.

The upper parallel branch has a resistance of 4 Ω + 5 Ω = 9 Ω. Since both parallel branches have the same resistance and voltage, they must have the same current *i.e.* the current in the upper parallel branch is also 0,5 A. The current through the ammeter is the sum of the currents through the parallel branches:
$I_{ammeter} = 0{,}5\ A + 0{,}5\ A = 1{,}0\ A$

b) The voltage across any parallel branch is
$V_{||} = I_{9\Omega} \times R_{9\Omega} = 0{,}5\ A \times 9\ \Omega = 4{,}5\ V$
The emf of the battery is:
$\varepsilon = V_{||} + Ir = 4{,}5\ V + 1{,}0\ A \times 0{,}5\ \Omega = 5\ V$

c) If the 5 Ω resistor is removed from the circuit, we are removing a parallel branch, and hence the total resistance of the circuit will increase. This will decrease the ammeter reading and in turn increase the reading on the voltmeter.

7 a) The 4 Ω resistor and the 5 Ω resistor are in parallel. We can first determine the voltage across the 4 Ω resistor and then use this to find the current through the 5 Ω resistor:

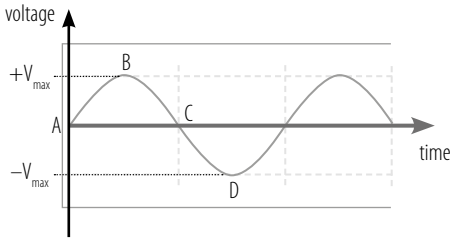
$V_{||} = V_{4\Omega} = I_{4\Omega}R_{4\Omega} = 2{,}0\ A \times 4{,}0\ \Omega = 8{,}0\ V$
$I_{5\Omega} = \frac{V_{||}}{R_{5\Omega}} = \frac{8{,}0\ V}{5{,}0\ \Omega} = 1{,}6\ A$
The total current in the circuit is:
$I = 1{,}6\ A + 2{,}0\ A = 3{,}6\ A$
The voltage drop across the internal resistor is:
$V_r = I_r r = 3{,}6\ A \times 0{,}6\ \Omega = 2{,}16\ V$
The voltage across the unknown resistor is:
$V_R = 24\ V - 8\ V - 2{,}16\ V = 13{,}84\ V$
The unknown resistance is then: $R = \frac{V_R}{I_R} = \frac{13{,}84\ V}{3{,}6\ A} = 3{,}8\ \Omega$

b) The power generated in the internal resistance is
$P = \frac{V_r^2}{r} = \frac{(2{,}16\ V)2}{0{,}6\ \Omega} = 7{,}8\ W$

8 a) The AC generator has slip rings whereas the DC motor will have split-ring commutators.

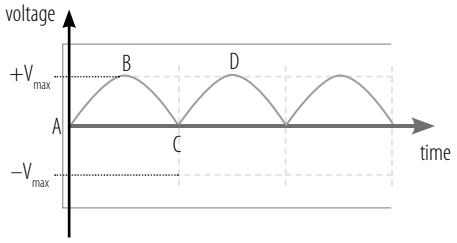
Mechanical action is used in the AC generator to generate an emf, whereas a battery or other source of emf will be used in a DC motor to generate motion.

b)



c) To replace the direct current generator with an alternating current generator, replace the slip rings with a split ring commutator.

d)



9 a) Given $R = 8\ \Omega$, $P_{avg} = 100$ W. We are required to find I_{rms}.

From $P_{avg} = I^2_{rms}R$, we have $I_{rms} = \sqrt{\frac{P_{avg}}{R}} = \sqrt{\frac{100\ \text{W}}{8\ \Omega}} = 3{,}5$ A

b) We first find the rms voltage from the equation:

$V_{rms} = I_{rms}R = 3{,}5\ \text{A} \times 8\ \Omega = 28$ V

The peak voltage is then $V_{peak} = \sqrt{2}V_{rms} = \sqrt{2} \times 28$ V $= 40$ V

10 a) To find the rms current we first need the average power and the rms voltage: $P_{avg} = \frac{1}{2}P_{peak} = \frac{1}{2} \times 150$ W $= 75$ W

From the voltage graph:

$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{60\ \text{V}}{\sqrt{2}} = 42{,}4$ V

From $P_{avg} = V_{rms}I_{rms}$, we have:

$I_{rms} = \frac{P_{avg}}{V_{rms}} = \frac{75\ \text{W}}{42{,}4\ \text{V}} = 1{,}8$ A

b) The resistance is $R = \frac{V_{rms}}{I_{rms}} = \frac{42{,}4\ \text{V}}{1{,}8\ \text{A}} = 24\ \Omega$

c) From the power graph the period of the wave is 0,10 s and the frequency of the source is then $f = \frac{1}{T} = \frac{1}{0{,}10\ \text{s}} = 10$ Hz

11 a) The rms current in each of the devices is:

$$I_{rms(bulbs)} = 4 \times \frac{P_{avg}}{V_{rms}} = \frac{4 \times 60\ \text{W}}{240\ \text{V}} = 4 \times 0{,}25\ \text{A} = 1{,}0\ \text{A}$$

$$I_{rms(hot\ plates)} = \frac{P_{avg}}{V_{rms}} = \frac{2\,200\ \text{W} + 1\,800\ \text{W}}{240\ \text{V}} = 16{,}67\ \text{A}$$

$$I_{rms(radio)} = \frac{P_{avg}}{V_{rms}} = \frac{200\ \text{W}}{240\ \text{V}} = 0{,}83\ \text{A}$$

The total current in the wires is:

$I_{rms(total)} = 1{,}0\ \text{A} + 16{,}67\ \text{A} + 0{,}83\ \text{A} = 18{,}5$ A

The total resistance of both the connecting wires is:

$R = 2 \times 8{,}3 \times 10^{-3}\ \Omega/\text{m} \times 70\ \text{m} = 1{,}16\ \Omega$

The power generated in the total length of wire is:

$P = I^2_{rms}R = (18{,}5\ \text{A})^2 \times 1{,}16\ \Omega = 397$ W

The heat generated in the wires is greater than the safety limit.

b) Safety hazards:
   - electrical wires joined by insulating tape exposed when insulating tape falls off when exposed to heat and rain.
   - no earth wire to prevent short circuits
   - no trip switch to prevent overloading of circuit
   - exposed wires within reach of children.

MODULE 2: MATTER & MATERIALS (CONTINUED)

This module focuses on the particle properties of light. Learners encountered the wave properties of light when they studied interference and diffraction. The photoelectric effect provides an opportunity to demonstrate the scientific process. The history of science shows how many experimental observations could not be explained using the existing knowledge available at that time, and how new hypotheses had to be made. The photoelectric effect was discovered in 1887 but could not be explained in terms of the wave theory of light. According to the wave theory, the energy of a light wave is proportional to its amplitude. If white light radiated on a metal does not eject electrons from its surface, then increasing the intensity of the light should. By increase in intensity of the light one is increasing its amplitude and thus more energy is falling on the surface, which should result in the ejection of electrons from the metal. However, experimental evidence showed that this was not true. Thus a radical departure from the wave theory of light had to be made by Albert Einstein 15 years later to explain the photoelectric effect. He drew upon the quantum theory of Max Planck to introduce the concept of photons of light.

The second part of this module focuses on the emission and absorption spectra of atoms. The emission and absorption spectra confirm the existence of discrete energy levels in atoms, and the quantisation of these energy levels.

LB p. 306 »

Activity 10 Teacher demonstration

The photoelectric effect

Photodiodes are not always readily available. Make use of the results in the table below if it is not possible to perform the experiment.
Observations:

Colour of Light	Ammeter Reading, in μA	
	Far from phototube	Close to phototube
White	0	0
Red	0	0
Yellow	0	0
Green	0	0
Blue	0	0
Violet	0,18	3,22

Test yourself 8 (LB p. 309)

1 The photoelectric effect is the ejecting of electrons from the surface of a material when light of certain frequency is radiated on the material.

2 a) $E = hf = 6{,}63 \times 10^{-34}\ \text{J·s} \times 5{,}0 \times 10^{14}\ \text{Hz} = 3{,}3 \times 10^{-19}\ \text{J}$

b) Since the energy of the photon ($3{,}3 \times 10^{-19}$ J) is less than the work function ($4{,}0 \times 10^{-19}$ J), no photoelectrons will be emitted from the metal.

c) Increasing the intensity does not increase the energy of the photons, and therefore no photoelectrons will be ejected.

d) Red light has a smaller frequency than yellow light and therefore its photons will carry less energy than that of the yellow light. No photoelectrons will be ejected.

3 For a given frequency of light the photon energy will always be larger than the maximum kinetic energy of the photoelectron, because some of the photon energy is converted into the work function of the material. It can be seen from $hf = W_0 + KE_{max}$ that hf is always larger than KE_{max}.

Test yourself 9 (LB p. 314)

1 a) From $hf = W_0$, we have $1{,}5 \times 10^{-19}\ \text{J} / 6{,}63 \times 10^{-34}\ \text{J·s} = 2{,}3 \times 10^{14}\ \text{Hz}$

b) $E = hf = \frac{hc}{\lambda} = \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3{,}0 \times 10^{8}\ \text{m.s}^{-1}}{310 \times 10^{-9}\ \text{m}} = 6{,}4 \times 10^{-19}\ \text{J}$

c) $KE_{max} = hf - W_0 = 6{,}4 \times 10^{-19}\ \text{J} - 1{,}5 \times 10^{-19}\ \text{J} = 4{,}9 \times 10^{-19}\ \text{J}$

d) i) No change.

ii) Decreasing the wavelength of the light implies that the frequency is increased. This will result in an increase in the photon energy, and a subsequent increase in the maximum kinetic energy of the photoelectrons.

2 a) $W_0 = hf_0 = 6{,}63 \times 10^{-34}\ \text{J·s} \times 6{,}8 \times 10^{14}\ \text{Hz} = 3{,}58 \times 10^{-19}\ \text{J}$

b) $KE_{max} = hf - W_0 = 6{,}63 \times 10^{-34}\ \text{J·s} \times 6{,}8 \times 10^{14}\ \text{Hz} - 3{,}58 \times 10^{-19}\ \text{J}$
$= 9{,}3 \times 10^{-20}\ \text{J}$

c) i) Reading on the ammeter will increase.

ii) No change on ammeter reading.
iii) Ammeter reading will become zero. Increasing the wavelength results in a decrease in the frequency, and if the frequency becomes smaller than the cut-off frequency, there will be no photoelectrons ejected.

Test yourself 10 (LB p. 319)

1 a) False. When light is passed through a cold gas, an absorption spectrum is observed.
b) False. Emission spectra are observed when atoms move from higher energy levels to lower energy levels.

2 The change in energy of the atom is
$\Delta E = -3{,}40 \text{ eV} - (-0{,}85 \text{ eV}) = -2{,}55 \text{ eV}$
From $\Delta E = hf$ we have $f = \frac{\Delta E}{h} = \frac{2{,}55 \times 1{,}6 \times 10^{-19} \text{ J}}{6{,}63 \times 10^{-34} \text{ J·s}} = 6{,}2 \times 10^{14} \text{ Hz}$

Learner's Book pages 320–322

Unit 2 Summative assessment

TERM 3, MODULE 2

1 a) photoelectric effect
b) work function
c) photon
d) cut-off wavelength
e) emission
f) line absorption

2 a) False. The photoelectric effect provides strong evidence that light has a **particle** nature.
b) False. Electrons will only be ejected from the surface of a metal if the work function of the metal is **less** than the energy of the photons radiated on the metal.
c) False. If both green light and yellow light can eject electrons from the surface of a certain metal, then **green** light will produce photoelectrons with the larger kinetic energy.
d) True

3 a) C
b) A
c) D

4 a) The statement means that $4{,}32 \times 10^{-19}$ J is needed to remove an electron from the surface of sodium metal.
b) We are given $W_0 = 4{,}32 \times 10^{-19}$ J and are required to find λ.
From $W_0 = hf_0 = \frac{hc}{\lambda}$ we have:
$\lambda = \frac{hc}{W_0} = \frac{6{,}63 \times 10^{-34} \text{ J·s} \times 3{,}0 \times 10^{8} \text{ m.s}^{-1}}{4{,}32 \times 10^{-19} \text{ J}} = 4{,}6 \times 10^{-7} \text{ m}$
c) We are given $\lambda = 306 \text{ nm} = 306 \times 10^{-9} \text{ m}$ and wish to find the maximum kinetic energy.
We have $KE_{max} = \frac{1}{2}mv^2_{max} = hf - W_0 = \frac{hc}{\lambda} - W_0$
$= \frac{6{,}63 \times 10^{-34} \text{ J·s} \times 3{,}0 \times 10^{8} \text{ m.s}^{-1}}{306 \times 10^{-9} \text{ m}} - 4{,}32 \times 10^{-19} \text{ J} = 2{,}18 \times 10^{-19} \text{ J}$

5 a) We can use the maximum speed of the ejected electrons to find the maximum kinetic energy. The mass of an electron is given in the data sheet as $m_{electron} = 9{,}11 \times 10^{-31}$ kg

We use the given wavelength of 623 nm = 623×10^{-9} m and the photoelectric equation to find the work function of the metal:

$W_0 = hf - \frac{1}{2}mv_{max}^2 = \frac{hc}{\lambda} - \frac{1}{2}mv_{max}^2$

$= \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3{,}0 \times 10^{8}\ \text{m.s}^{-1}}{623 \times 10^{-9}\ \text{m}} - 9{,}64 \times 10^{-20}\ \text{J}$

$= 2{,}2 \times 10^{-19}\ \text{J}$

The work function of the metal is: $2{,}2 \times 10^{-19}$ J

b) The cut-off frequency for this metal is: $f_0 = \frac{W_0}{h} = \frac{2{,}2 \times 10^{-19}\ \text{J}}{6{,}63 \times 10^{-34}\ \text{J·s}}$

$= 3{,}35 \times 10^{14}$ Hz

6 a) We are given the cut-off wavelength $\lambda_0 = 350$ nm $= 350 \times 10^{-9}$ m, which we can use to find the work function.

$W_0 = hf_0 = \frac{hc}{\lambda_0}$

$= \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3{,}0 \times 10^{8}\ \text{m.s}^{-1}}{350 \times 10^{-9}\ \text{m}}$

$= 5{,}68 \times 10^{-19}\ \text{J}$

We can now use the work function and the given wavelength $\lambda = 270$ nm $= 270 \times 10^{-9}$ m to find the maximum kinetic energy of the photoelectrons:

$KE_{max} = \frac{1}{2}mv_{max}^2 = hf - W_0 = \frac{hc}{\lambda} - W_0$

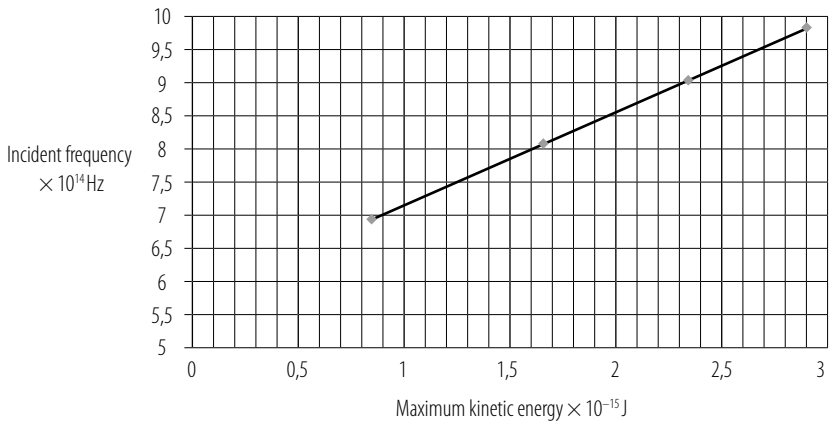
$= \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3{,}0 \times 10^{8}\ \text{m.s}^{-1}}{270 \times 10^{-9}\ \text{m}} - 5{,}68 \times 10^{-19}\ \text{J}$

$= 1{,}69 \times 10^{-19}\ \text{J}$

The maximum kinetic energy of the photoelectrons is: $1{,}69 \times 10^{-19}$ J

b) The wavelength of 360 nm in this case is greater than the cut-off wavelength of 350 nm, and hence there will be no photoelectrons ejected. (If you do the calculation as we did in (a), you will get a negative value for the maximum kinetic energy, which is an impossible value!)

7



a) From the photoelectric equation we get:

$f = \frac{\frac{1}{2}mv^2}{h} - \frac{W_0}{h}$

which is the equation of the graph drawn. The graph is in the form $y = mx + c$

The cut-off frequency occurs at the y-intercept of the graph. This is when $KE_{max} = 0$. When the graph is extrapolated to cut the y-axis, the value is $f = 5{,}5 \times 10^{14}$ Hz. This is the cut-off frequency for sodium.

b) The gradient of the graph is $\frac{1}{h}$

Choosing the points (2,4; 9,0) and (1,0; 7,0) on the graph, we get the gradient:

$\frac{(9-7) \times 10^{14}\ \text{Hz}}{(2{,}4 - 1)} \times 10^{14}\ \text{Hz} = 1{,}4 \times 10^{33}\ \text{s/J}$

Therefore $h = \frac{1}{1{,}4 \times 10^{33}\ \text{s/J}} = 7{,}1 \times 10^{-34}\ \text{J·s}$

c) The approximate work function is obtained from $\frac{W_0}{h} = f_0$
$= 5{,}5 \times 10^{14}\ \text{Hz}$
Using the value of h from (b) we get:

$W_0 = hf = 7{,}1 \times 10^{-34}\ \text{J·s} \times\ 5{,}5 \times 10^{14}\ \text{Hz} = 3{,}9 \times 10^{-19}\ \text{J}$

Compare with the value given in the table of work functions ($4{,}32 \times 10^{-19}$ J).

8 a) X is the cathode (gives off electrons).

b) We are given the cut-off wavelength $\lambda_0 = 592\ \text{nm} = 592 \times 10^{-9}\ \text{m}$, which we can use to find the work function.
$W_0 = hf_0 = \frac{hc}{\lambda_0}$
$= \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3{,}0 \times 10^{8}\ \text{m.s}^{-1}}{592 \times 10^{-9}\ \text{m}}$
$= 3{,}36 \times 10^{-19}\ \text{J}$
The work function of the metal is $3{,}36 \times 10^{-19}$ J. This work function corresponds to that of cesium.

c) At the cut-off wavelength, the ammeter reading is zero. As soon as the wavelength is decreased, there will be a reading on ammeter. The ammeter reading will remain constant for any further decrease in wavelength. Since the wavelength is below the cut-off wavelength, photoelectrons will be emitted and therefore there will be a current in the circuit. Decreasing the wavelength further will increase the maximum kinetic energy of the photoelectrons, but not the number of photoelectrons. Therefore the current will be constant.

d) Since the wavelength is below the cut-off wavelength, there will be a reading on the ammeter. Decreasing the intensity will result in less photons and hence fewer photoelectrons. The reading on the ammeter will gradually decrease.

9 a) Energy is given off because the atom goes from one excited state to a lower excited state.

b) The energy of the photon is given by:
$E = hf = \frac{hc}{\lambda}$
$= \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3{,}0 \times 10^{8}\ \text{m.s}^{-1}}{656 \times 10^{-9}\ \text{m}}$
$= 3{,}03 \times 10^{-19}\ \text{J}$
The energy of the photon is: $3{,}03 \times 10^{-19}$ J

10 a) The difference in energy between the two states is:
$\Delta E = -10\ \text{eV} - (-20\ \text{eV}) = 10\ \text{eV}$
$= 10 \times 1{,}6 \times 10^{-19}\ \text{J}$
$= 16 \times 10^{-19}\ \text{J}$
The energy of the absorbed photon is $1{,}6 \times 10^{-18}$ J

b) The frequency of the photon is absorbed:
$f = \frac{E}{h} = \frac{1{,}6 \times 10^{-18}\ \text{J}}{6{,}63 \times 10^{-34}\ \text{J·s}} = 2{,}4 \times 10^{15}\ \text{Hz}$

11 a) Figure B. In this figure there is a continuous distribution of energy wavelengths, except for the four dips in energy corresponding to the absorption of photons at those wavelengths.

b) Figure A shows that there are wavelengths for only certain values of energy. This means that the energy distribution in an atom is not continuous but discrete, *i.e.* the energy levels are quantised.

MODULE 4: CHEMICAL CHANGE (CONTINUED)

This unit concludes the discussion on chemical change. Electrochemistry deals with the transformation between electrical energy and chemical energy. Some reactions are spontaneous and are used as sources of electrical energy, for example batteries. Other reactions need an input of electrical energy, for example electrolytic cells. This unit contains two experiments recommended for informal assessment:

Activity 11: Find the galvanic cell with the highest potential and

Activity 12: Investigate the electrolysis of water.

They can be assessed in Term 3.

LB p. 325

Activity 11 Recommended experiment for informal assessment

Find the galvanic cell with the highest potential

School laboratories might have a wider range of chemicals available that can be used in combinations to test various electrochemical cell combinations. Use whatever is available. You can also give different groups of learners different combinations of half-cells and compare the results afterwards in a class discussion.

In the combinations below, Cu^{2+} is the strongest oxidising agent and will oxidise both Pb and Zn. The Pb^{2+} / Pb half-cell falls in the middle and Pb^{2+} will oxidise Zn and Pb will be oxidised by Cu^{2+}.

a) Possible investigative question: Which half-cell combination has the highest potential?

b)

Galvanic cell	Cell potential (V)
Zn^{2+}/Zn with Pb^{2+}/Pb	0,63
Zn^{2+}/Zn with Cu^{2+}/Cu	1,10
Pb^{2+}/Pb with Cu^{2+}/Cu	0,47

c) Zinc-lead cell:
$Pb^{2+} + 2e^- \rightarrow Pb$
$Zn \rightarrow Zn^{2+} + 2e^-$
$Pb^{2+} + Zn \rightarrow Pb + Zn^{2+}$

Zinc-copper cell:
$Cu^{2+} + 2e^- \rightarrow Cu$
$Zn \rightarrow Zn^{2+} + 2e^-$
$Cu^{2+} + Zn \rightarrow Cu + Zn^{2+}$

Lead-copper cell:
$Cu^{2+} + 2e^- \rightarrow Cu$
$Pb \rightarrow Pb^{2+} + 2e^-$
$Cu^{2+} + Pb \rightarrow Cu + Pb^{2+}$

d) The combination of half-cells determine the cell potential. The cell potential for the zinc-copper cell is potentially the greatest and the smallest cell potential is for the lead-copper cell.

LB p. 326

Activity 12 Recommended experiment for informal assessment

Investigate the electrolysis of water

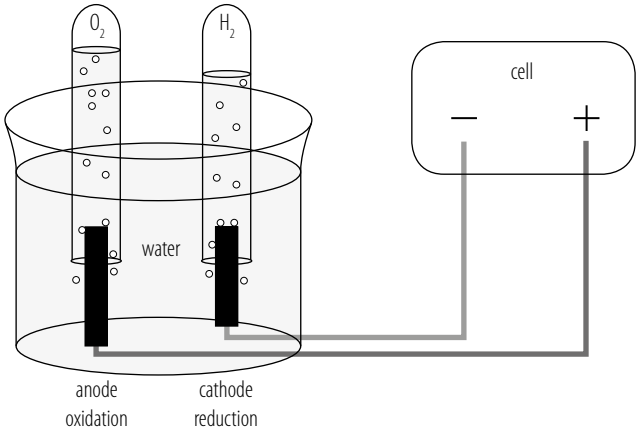
Some school laboratories might have a Hoffmann voltameter, which is much easier to operate than the apparatus illustrated in the diagram. Set the apparatus up beforehand and make sure that the test tubes and electrodes are securely clamped in position to retort stands. Follow the method in the Learner's Book.

Answers to questions

a) An electric current decomposes water to release hydrogen and oxygen gas.

b) Pure water does not conduct an electric current. The ions from the dissolved salt allows the current to flow and decompose the water.

c)



d) Hydrogen gas explodes with a popping sound when a burning splint is held at the test tube mouth. Oxygen gas will set a glowing split alight.

e) Electrolytic cell; energy must be supplied all the time for the reaction to take place – electrical energy → chemical energy

f) $2H_2O(\ell) \rightarrow 2H_2(g) + O_2(g)$
Two moles of water release two moles of hydrogen gas and one mole of oxygen gas. The ratio of gases in the test tubes will be 2H:1O.

g) Distilled water is a non-conductor, but when an ionic compound is added to the water, an electric current is conducted and the water decomposes to form hydrogen gas and oxygen gas. The hydrogen gas is double the volume of the oxygen gas.

LB p. 327

» Activity 13 Experiment

Investigate the reduction of metal ions and halogens

A similar experiment appeared in Grade 11. The reactions and method are straight forward and they are described in the Learner's Book.

Safety: Tetrachloromethane is toxic and prolonged exposure can cause cancer; it is dangerous to the environment. Bromine is carcinogenic and poisonous. Do the experiment in a fume cupboard.

	Mg	**Zn**	**Cu**	**Fe**
$CuSO_4(aq)$	Reaction	Reaction	No reaction	Reaction
$ZnSO_4(aq)$	Reaction	No reaction	No reaction	No reaction
$FeCl_2(aq)$	Reaction	Reaction	No reaction	No reaction
$MgSO_4(aq)$	No reaction	No reaction	No reaction	No reaction

	KCl(*aq*)	**KBr**(*aq*)	**KI**(*aq*)
$Cl_2(aq)$		Reaction – solvent turns yellow	Reaction – solvent turns pink
$Br_2(aq)$	no reaction		Reaction – solvent turns pink

Displacement of metals

Answers to questions

a) Decreasing activity: Mg, Zn, Fe, Cu

b) $Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$
$Mg(s) + ZnSO_4(aq) \rightarrow MgSO_4(aq) + Zn(s)$
$Mg(s) + FeCl_2(aq) \rightarrow MgCl_2(aq) + Fe(s)$
$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
$Zn(s) + FeCl_2(aq) \rightarrow ZnCl_2(aq) + Fe(s)$
$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

Displacements of halogens

Answers to questions

a) $Cl_2(aq) + 2KBr(aq) \rightarrow 2KCl(aq) + Br_2(\ell)$
$Cl_2(aq) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(s)$
$Br_2(aq) + 2KI(aq) \rightarrow 2KBr(aq) + I_2(s)$

b) There are pure covalent bonds between the atoms in Br_2 and I_2 molecules. No dipoles can form and the molecules are non-polar. They will dissolve in non-polar solvents. Bromine colours the solvents reddish-brown to yellow, depending on the concentration. Iodine colours the solvents pink to purple.

Test yourself 9 (LB p. 341)

1

Electrolytic cells	Galvanic/Voltaic cells
Electrical energy → chemical energy	Chemical energy → electrical energy
Reactions not spontaneous	Reactions spontaneous
Uses: Electroplating Refining Extraction of metals	Uses: Cells and batteries

2 a) The platinum electrode is the cathode.

b) $Fe \rightarrow Fe^{3+} + 3e^-$

c) $O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$

d) $2Fe + 3O_2 + 6H^+ \rightarrow 2Fe^{3+} + 3H_2O_2$

e) K^+ increases

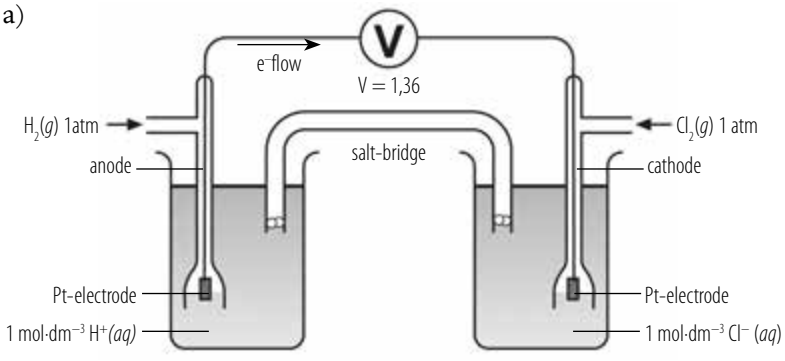
f) Platinum is an inert metal and does not react with the chemicals in the half-cell or their products.

3 a) $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

b) Potassium permanganate is a strong oxidising agent and can easily oxidise oxalic acid to CO_2 and H^+ ions. Oxalic acid is a strong enough reducing agent to oxidise the permanganate ion to Mn^{2+} and H_2O. The cell potential for the reaction is positive:
$E^\circ_{cell} = E^\circ_{OA} - E^\circ_{RA} = 1{,}51 - (-0{,}49) = 2{,}00$ V

c) Oxidation: $H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$
Reduction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
Net ionic equation:
$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$
(Net equation:
$2KMnO_4 + 5\ H_2C_2O_4 + 6HCl \rightarrow 2MnCl_2 + 10CO_2 + 8H_2O + 2KCl$)

4 a)



b) $Pt(s)\,|\,H_2(1\text{ atm})\,|\,H^+(1\text{ mol·dm}^{-3})\,||\,Cl^-(1\text{ mol·dm}^{-3})\,|\,Cl_2(g)\,|\,Pt(s)$

c) The Cl_2/Cl^- half-cell will be the positive pole (cathode).

d) Oxidation half-reaction: $Cr \rightarrow Cr^{3+} + 3e^-$

e) $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 1{,}36 - (-0{,}74) = 2{,}10\text{ V}$

5 a) $Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$

$E^\circ_{cell} = E^\circ_{OA} - E^\circ_{RA} = 0{,}80 - (-0{,}76) = 1{,}56\text{ V}$

b) $Cu(s) + 2Fe^{3+}(aq) \rightarrow Cu^{2+}(aq) + 2Fe^{2+}(aq)$

$E^\circ_{cell} = E^\circ_{OA} - E^\circ_{RA} = 0{,}77 - 0{,}34 = 0{,}43\text{ V}$

6 a) No

b) Yes: $6Br^-(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 3Br_2(\ell) + 2Cr^{3+}(aq) + 7H_2O(\ell)$

c) Yes: $6H^+(aq) + 2Fe(s) \rightarrow 3H_2(g) + 2Fe^{3+}(aq)$

d) No

7 Cu does not dissolve in HCl because the H^+ ion is not a strong enough oxidising agent to oxidise the Cu metal. The cell potential is negative:

$Cu \rightarrow Cu^{2+} + 2e^-$ $\quad E^\circ = 0{,}34\text{ V}$

$2H^+ + 2e^- \rightarrow H_2$ $\quad E^\circ = 0{,}00\text{ V}$

$Cu + 2H^+ \rightarrow Cu^{2+} + H_2$ $\quad E^\circ_{cell} = E^\circ_{OA} - E^\circ_{RA} = 0{,}00 - 0{,}34 = -0{,}34\text{ V}$

Copper dissolves in nitric acid because acidified NO_3^- is a stronger oxidising agent than H^+. The cell potential is positive.

$Cu \rightarrow Cu^{2+} + 2e^-$ $\quad E^\circ = 0{,}34\text{ V}$

$HNO_3 + 3H^+ + 3e^- \rightarrow NO + 2H_2O$ $\quad E^\circ = 0{,}96\text{ V}$

$3Cu + 2HNO_3 + 6H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$

$E^\circ_{cell} = E^\circ_{OA} - E^\circ_{RA} = 0{,}96 - 0{,}34 = 0{,}62\text{ V}$

8 a) The Cu will form the cathode and the Zn the anode.

b) The cell sap contains salicylic acid and salts that will act as the electrolyte.

c) The potatoes have less cell sap than the lemons.

9 a) The cadmium electrode is the anode.

b) $Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$

c) $Cd + 2NiO(OH) + 2H_2O \rightarrow 2Ni(OH)_2 + Cd(OH)_2$

d) $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 0{,}48 - (-0{,}82) = 1{,}30\text{ V}$

e) During recharge the electrons will flow from the cathode to the anode: NiO(OH) to Cd.

Test yourself 10 (LB p. 349)

1 a) Bauxite is the principle ore of aluminium and consists mainly of aluminium oxide and impurities – sand and iron(III) oxide.

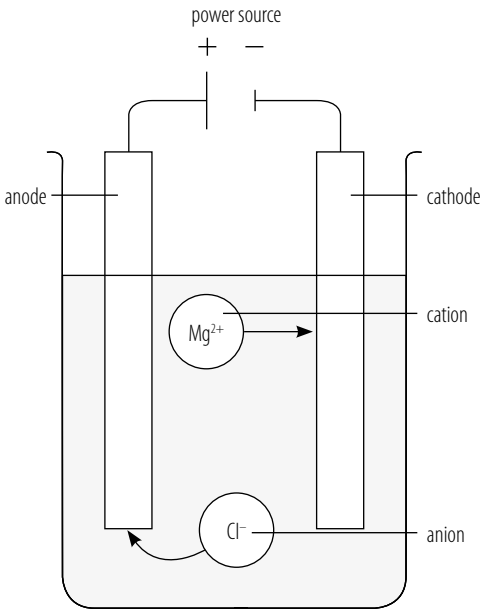
b) Cryolite is added to lower the melting point of aluminium oxide. A lower working temperature lowers the energy requirements of the plant and makes it more economical.

c) Anode: $2O^{2-} \rightarrow O_2 + 4e^-$
Cathode: $Al^{3+} + 3e^- \rightarrow Al$
Net reaction: $2Al_2O_3(s) \rightarrow 4Al(\ell) + 3O_2(g)$

d) The electrolysis reaction is carried out at temperatures of around 1 000 °C and at these temperatures the graphite anodes burn in the oxygen that is released at the anodes.
$C(s) + O_2(g) \rightarrow CO_2(g)$
The anodes therefore have to be replaced regularly.

e) Recycling saves money, energy, time and space.
- Recyclable material, such as aluminium, should not be dumped in a landfill site where it uses space.
- It costs time, energy and money to dispose of garbage and transport it to the landfill site.
- Much less energy is required to remelt aluminium than to produce it from its ore.

2 a)



b) Anode: Oxidation: $2Cl^- \rightarrow Cl_2 + 2e^-$
Cathode: Reduction: $Mg^{2+} + 2e^- \rightarrow Mg$
Net reaction: $Mg^{2+}(aq) + 2Cl^-(aq) \rightarrow Mg(s) + Cl_2(g)$

3 a) Anode: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

b) Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

c) Net reaction: $6H_2O \rightarrow O_2 + 4H^+ + 4OH^- + 2H_2$
$2H_2O(\ell) \rightarrow O_2(g) + 2H_2(g)$

d) The gases form in a ratio of 1 O_2 : 2 H_2.

e) A is the anode, because less gas developed there.

f) In A (anode), H^+ ions form. The solution will be acidic and the indicator will turn yellow. In B (cathode), OH^- ions form. The solution will be basic and the indicator will turn blue.

Activity 14 Investigation

Investigate corrosion

1 $2Fe(s) + O_2(g) + 4H^+(aq) \rightarrow 2Fe^{2+}(aq) + 2H_2O(\ell)$

2 $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 1{,}23 - 0{,}45 = 0{,}78$ V

3 No, it should be less than 1,23 V because the concentration of the H^+ ions in the water droplet is not 1 mol·dm^{-3}. However, experiments show that even at pH 7 the potential for the reduction half-reaction is 0,81 V, which means that the cell potential is positive and the reaction will be spontaneous.

4 The water droplet provides the pathway for the ions to migrate and serves as the salt-bridge.

5 $CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq)$

6 Learners might find this question difficult to answer. Guide them by explaining that through corrosion, iron objects deteriorate, rust away and lose their usefulness. Sustainable development is aimed at reusing and preserving resources for the future.

7
- Painting is an inexpensive and easy way to protect iron and steel. We use it on vehicle bodies, ships, bridges, iron railings and many other structures. When the painted surface is damaged, it must be repainted to maintain its effectiveness.
- Oiling or greasing is used on moving parts that cannot be painted. The oil or grease must be reapplied constantly to be effective.
- A plastic coating can be used to form a protective layer on items such as refrigerators, garden chairs, and so on.
- In electroplating, a protective layer of chromium or tin is applied to steel. Chromium is used on vehicle bumpers and bicycle handlebars. Tin cans, used for preserving food, are made of steel coated on both sides with a very thin layer of tin. Tin is used because it is unreactive and non-toxic.
- In galvanising, steel is covered with a layer of zinc which is a more reactive metal than iron. The protection still works if the zinc layer is badly scratched because the zinc will corrode, and not the steel. Zinc corrodes very slowly. Vehicle bodies are dipped into baths of molten zinc to form a protective layer.
- Sacrificial protection is used on the hulls of ships and oilrigs. Blocks of a reactive metal are attached to the iron surface. Zinc or magnesium blocks are normally used and they will corrode in preference to the iron.

Activity 15 Investigation

Investigate chlorine

1. $HCl + MnO_2$:
Oxidation: $2Cl^- \rightarrow Cl_2 + 2e^-$
Reduction: $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$
Net reaction:
$2Cl^-(aq) + MnO_2(s) + 4H^+(aq) \rightarrow Cl_2(g) + Mn^{2+}(aq) + 2H_2O(\ell)$
$HCl + MnO_4^-$:
Oxidation: $2Cl^- \rightarrow Cl_2 + 2e^-$
Reduction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

Net reaction:
$5Cl^-(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 5Cl_2(g) + 2Mn^{2+}(aq) + 8H_2O(\ell)$

2. The reaction between Cl^- and MnO_2 is not spontaneous. MnO_2 is not a strong enough oxidising agent to oxidise Cl^- to Cl_2. The cell potential is negative:

   $E^\circ_{cell} = E^\circ_{OA} - E^\circ_{RA} = 1{,}21 - 1{,}36 = -0{,}15$ V

   By increasing the concentration of the Cl^- ions, the forward reaction is favoured and the reaction will take place.
3. Chlorine is a bleaching agent and will bleach the colours in a costume which will soon fade. Chlorine might also attack the fabric itself and it might lose its elasticity.
4. Water contains many pathogens that can make us ill and cause diseases, such as typhoid and gastro enteritis. Chlorine oxidises the bacteria and kills them.
5. Learner's own research. Ancient methods were sufficient because the human population was so much smaller and contamination of water sources was not a factor.
6. Learner's own ideas. No upliftment and development can be effective if people have to spend hours collecting water for domestic use. Water-borne diseases cause many people, especially the very young and very old, to become ill. Other family members must care for them and they cannot go to work to earn wages.
7. Hydrogen peroxide can also be used as an oxidising agent, but it is too unstable to use for commercial purposes. It will quickly decompose and there will be no residual H_2O_2 to kill newly introduced pathogens.
8. There are different methods used. Reactions might include the following:
   Lime is added to adjust the pH: acid-base reaction.
   Polymeric coagulant (poly aluminium chloride): precipitates the solids to form a 'floc'.
   Chlorine is added at various stages: redox reactions.
9. Commercial chlorinators have platinum electrodes that electrolyse a brine solution. The products are similar to those formed in the chloralkali process Cl_2, H_2 and NaOH. Swimming pool acid ($HCl(aq)$) must be added to neutralise the NaOH that forms. Learner's own research.

Learner's Book pages 353–357

Unit 4 Summative assessment

TERM 3, MODULE 4

1 a) galvanic cell
   b) electrolytic cell
   c) reduction
   d) oxidation-reduction/redox reactions
   e) reducing agent
   f) oxidation
   g) salt-bridge
   h) standard hydrogen electrode
   i) oxidising agent

2 a) The standard conditions used to measure standard electrode potentials are:
   temperature = 298 K (25 °C)

concentration = 1 mol·dm^{-3}
pressure = 101,3 kPa

b) During electroplating of a steel teaspoon with silver, the teaspoon is the cathode and the electrolyte is a solution of a soluble silver compound.
c) A galvanic cell converts chemical energy to electrical energy.
d) During the industrial preparation of chlorine and sodium hydroxide, electrical energy is converted to chemical energy.
e) In the reaction $CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq)$, $CuSO_4$ is the oxidising agent and Zn is being oxidised.
f) In a cell with notation $Co|Co^{2+}||Ni^{2+}|Ni$, Ni is the cathode, Ni^{2+} ions are reduced and the mass of the Ni electrode increases.
g) The E_{cell} for a $Ni|Ni^{2+}||Ag^{+}|Ag$ cell at standard conditions is 1,05 V.

3 a) B
b) C
c) B
d) D
e) C
f) B
g) A
h) C

4 Matching items:
a) E
b) J
c) G
d) K
e) A
f) F
g) C
h) I
i) H
j) L
k) D
l) B

5 a) Standard conditions: $O_2(g)$ pressure of 1 atm; $Pb^{2+}(aq)$ concentration of 1 mol·dm^{-3}; temperature of 25 °C (298 K)
b) Pb
c) Oxidation: $Pb \rightarrow Pb^{2+} + 2e^-$
d) Reduction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
e) Net reaction: $2Pb(s) + O_2(g) + 4H^+(aq) \rightarrow 2Pb^{2+}(aq) + H_2O(\ell)$
f) $E_{cell} = E^\circ_{OA} - E^\circ_{RA}$
$= 1{,}23 - (-0{,}13)$
$= 1{,}36$ V

6 a) $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$
b) $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$
c) $2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(\ell)$
d) MnO_2 is the catalyst.
e) The oxidising ability of hydrogen peroxide is responsible for its bleaching action.

7 a) H_2SO_4 at standard conditions of 1 mol·dm^{-3} and 25 °C is not a strong enough oxidising agent to oxidise Cu metal. By changing the conditions to concentrated acid and a higher temperature, the equilibrium shifts to the right, the forward reaction is favoured and the normally non-spontaneous reaction can take place.

b) $NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$

c) $Cu(s) + 2NO_3^-(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(\ell)$

8 Zinc is a stronger reducing agent than iron because it has a more negative E° value. Zn will be oxidised in preference to Fe and will therefore protect the Fe from being oxidised.

9 a) temperature: 298 K (25 °C); concentration of electrolyte: 1 mol·dm^{-3}

b) $Mg \rightarrow Mg^{2+} + 2e^-$

c) $Mg(s)\,|\,Mg^{2+}(1\ mol{\cdot}dm^{-3})\,||\,Pb^{2+}(1\ mol{\cdot}dm^{-3})\,|\,Pb(s)$

d) $E_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 0{,}13 - (-2{,}36) = 2{,}23$ V

e) i) Decreases

ii) Increases

The cell reaction is $Mg + Pb^{2+} \rightarrow Mg^{2+} + Pb$. If the $[Mg^{2+}]$ increases, the equilibrium will shift to the left and the forward reaction will decrease. The result is a lower E_{cell}. If the $[Pb^{2+}]$ increases, the forward reaction will be favoured and the reaction will happen faster, with an increase in E_{cell}.

f) Half-cell A to half-cell B. The concentration of cations (Pb^{2+}) decreases in half-cell B and concentration of cations (Mg^{2+}) increases in half-cell A. Cations flow in the salt-bridge to prevent a build-up of cations in half-cell A and anions in half-cell B.

10 a) The process in which electricity is used to bring about a chemical change and the electrical energy is converted to chemical energy.

b) C; The chloride ions are negative and move towards the positive electrode.

c) Fe

d) $2Cl^- \rightarrow Cl_2 + 2e^-$

e) The reduction reaction for Ca^{2+}/Ca has a lower E° value than the reduction reaction for Na^+/Na. Na^+ is the stronger oxidising agent and will react in preference to Ca^{2+}.

f) Na metal is less dense than the liquid NaCl and will float.

g) The Na metal and Cl_2 gas will react violently if they come into contact.

11 a) A liquid or solution that conducts electricity.

b) Brine contains positive Na^+ and negative Cl^- ions that are free to move.

c) Chloride ions; chloride ions are oxidised to form Cl_2.

d) $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

e) Anode; chloride ions are oxidised to Cl_2 – oxidation at the anode

f) Contamination can be prevented by using a membrane or selective ion-exchange diaphragm.

g)
- Chlorine is poisonous and harmful to humans and the environment.
- Leaching of sodium hydroxide into groundwater can carry health risks for humans and the environment.
- Hydrogen gas can cause an explosion.

TERM THREE

MODULE 6: CHEMICAL SYSTEMS

This module on the chemical industry comprises only one unit on the fertiliser industry. You should spend 6 hours teaching time to complete this very short and last section of science for the year. The unit looks at the application of science in industry and covers the important industrial processes, such as the Haber, Ostwald and Contact processes that manufacture inorganic fertilisers to feed a growing population. There are no prescribed activities in this unit.

Test yourself 1 (LB p. 362)

1 Fertilisers are needed because there are not always enough nutrients in the soil for healthy growth of plants.

2 a) Carbon, oxygen and hydrogen
b) Plants obtain C, O and H from the atmosphere and rainwater through their leaves and roots.
c) Nitrogen, phosphorus and potassium
d) The nutrients dissolve in water in the soil and are absorbed by the roots of plants.

3 Nitrogen is used to synthesise amino acids, proteins, enzymes and chlorophyll. N is needed to develop green leaves in leafy crops.
Phosphorus is used to synthesise DNA and RNA, as well as ADP and ATP. DNA and RNA are needed for cell division and growth, and ADP and ATP are used in energy storage and transfer reactions. They provide the energy required by all biological processes.
Potassium acts as a catalyst in many metabolic processes and functions as a regulator of various processes, such as growth. Plants require potassium for protein synthesis and the opening and closing of leaf stomata. Potassium also functions in photosynthesis and activation of some enzymes.

4 Nitrogen was obtained from guano (bird and bat droppings); phosphorus was obtained from bone meal (animal bones treated with sulfuric acid); potassium was obtained from potash and had to be imported (Germany had the monopoly till after World War I).

Test yourself 2 (LB p. 367)

1 a) $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$
b) Fractional distillation is used to produce nitrogen gas from liquid air; hydrogen is obtained as a by-product from coal gasification or by reforming methane (natural gas).
c) Increase the pressure; increase the temperature; add a catalyst; remove the product
d) The ammonia is separated from the reactants by liquefaction, as ammonia has a much higher boiling point than nitrogen and hydrogen. By releasing some pressure, the expansion causes cooling, and ammonia is condensed and removed.

2 a) Step. 1: $4NH_3(g) + \mathbf{5O_2} \rightarrow \mathbf{4NO} + 6H_2O(g)$
Step. 2: $\mathbf{2NO} + O_2(g) \rightarrow \mathbf{2NO_2}$
Step. 3: $\mathbf{4NO_2} + 2H_2O(\ell) \rightarrow 4HNO_3(aq) + \mathbf{NO}$
b) Platinum/rhodium catalyst
c) Oxidation states of N in:
NH_3: 3
NO: + 2
NO_2: + 4
HNO_3: + 5
All the reactions are redox reactions because the oxidation number of N increases every time. N is oxidised in every reaction.

3 a) Sulfur dioxide
b) SO_2 is soluble in water and will form H_2SO_3. The process requires that SO_2 must react with oxygen to form SO_3 in the next step.
c) $2SO_2 + O_2 \rightarrow 2SO_3$ (reversible arrows can also be used)
d) H_2SO_4
e) V_2O_5 (vanadium(V) oxide)
f) The SO_3 vapour that forms is dissolved in 98% sulfuric acid to form oleum, $H_2S_2O_7$. This is to prevent the formation of acid mist that is difficult to precipitate.
$SO_3(g) + H_2SO_4(\ell) \rightarrow H_2S_2O_7(\ell)$
When water is added to the oleum, sulfuric acid is formed.
$H_2S_2O_7(\ell) + H_2O(\ell) \rightarrow H_2SO_4(\ell)$

4 a) Sulfuric acid
b) Calcium sulfate (gypsum) and hydrogen fluoride
c) The phosphoric acid is filtered from the solid gypsum and then concentrated through evaporation.

Test yourself 3 (LB p. 371)

1 a) $NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$
b) There are three primary macronutrients: N, P and K. In a compound fertiliser the N is supplied by NH_4NO_3, the P (and more N) is supplied by $(NH_4)_3PO_4$ and the K is supplied by KCl.

2 a) The primary macronutrients are in a ratio of 2N : 3P : 2K. These nutrients make up 22% of the total bag contents.
b) N: 2 in every 7 parts contain nitrogen
P: 3 in every 7 parts contain phosphorus
K: 2 in every 7 parts contain potassium
These three elements make up 22% of the total mass of the fertiliser.
The percentages of N, P and K are:

$\%N: \frac{2}{7} \times 22 = 6{,}29\%$

$\%P: \frac{3}{7} \times 22 = 9{,}43\%$

$\%K: \frac{2}{7} \times 22 = 6{,}29\%$

c) Learner's own research

3 • Liquid fertilisers can be applied through irrigation systems, with minimum wastage and environmental problems.
• Micronutrients can be homogeneously dispersed for uniform application.
• Pesticides and herbicides can be added to the liquid fertiliser and only one application to a crop field is needed.
• The concentrations of the fertiliser, pesticide and herbicide can be accurately determined and applied uniformly.

Test yourself 4 (LB p. 375)

1 Organic fertilisers:
• are derived from plant remains (compost) and animal excretions (animal manure)
• contain small amounts of plant nutrients, typically less than 1% as nitrogen compounds
• have a composition which is not uniform and is unknown
• improve soil quality
• are slow-releasing.

Inorganic fertilisers:

- are manufactured in chemical processing plants
- contain a high percentage of plant nutrients
- are predetermined and accurately controlled with regard to the percentage of plant nutrients
- are mostly fast-releasing.

Also learner's own opinion.

2 Learner's own opinion.

3 a) Eutrophication is the process in which extra nutrients are added to water, thereby increasing the growth of plants and bacteria, and reducing the oxygen levels.

b) When fertiliser run-off lands up in rivers, streams and dams the nutrient content of the water increases. The algae in the water grow much faster and result in an algal bloom. The algae then die and decompose. The algal bloom and decomposition use up much of the oxygen in the water.

c) A lack of oxygen in the water causes the fish and other water-life to die.

d) Farmers should not spread fertiliser shortly before it rains and should make sure that they do not over-fertilise the land.

LB p. 376

Activity 1 Investigation

Investigate fertilisers

1 a) & b) The learner's list of apparatus and own method must be clearly set out. Results and conclusion must be clear and in full sentences.

c) Learner's own ideas, depending on which part of the country they use as reference. The best suggestion would be to insulate the fertiliser against temperature fluctuation by covering with insulating material such as paper or hay.

2 a) Total grams of fertiliser per litre = 178,01 g

b) NaCl makes up the largest percentage of marine salt.

c) The ratio is 72:45:30. Total = 147
Percentage ration of elements: 49%:31%:20%
Rounded off it gives a ratio of 5:3:2, so the fertiliser number would be 5 3 2.

d) 178,01 g of nutrition in 1 litre or 1000 mg of product (assuming that the solvent is water with an SG of 1).
% nutrition = $\frac{178{,}01}{1\,000} \times 100 = 17{,}801\%$

LB p. 376

Activity 2 Class debate

Evaluate the impact that the use of fertilisers has on humans and the environment

A debate is a formal argument and takes the form of a series of persuasive speeches. It has a clear, formal structure. The debate is controlled by a neutral chairperson (normally the teacher) and all comments by the speakers are directed through the chairperson. There are two teams, one arguing in favour of a proposal or topic and the other against it. Each team has three members. The team members speak in turn as follows.

- Speaker 1 for the proposal introduces the positive arguments, then Speaker 1 against the proposal introduces the negative argument and replies to some of the arguments of Speaker 1.
- Speaker 2 for the proposal introduces further points to support the positive argument. Speaker 2 against the proposal then does the same.
- At this point the debate may be opened to the floor. This means that anyone listening to the debate may make a point either for or against the proposal.
- Speaker 3 for the proposal then sums up the team's main points and tries to address the issues raised by the opposition. Speaker 3 against the topic speaks last and does the same.
- At the end of the debate, all who have listened and participated may vote for or against the proposal.

Possible positive arguments
- The growing of crops on a commercial scale leaves the soil depleted of nutrients. Inorganic fertilisers are necessary to replenish the nutrients in the soil.
- The human population is growing at a rapid rate and more food is needed to feed the people.
- The fertiliser industry employs many people who earn wages.
- Fertilisers that are exported earn foreign capital

Possible negative arguments
- All industrial activities have a negative impact on the environment.
- Industries use non-renewable resources and produce a lot of waste that can pollute the environment
- Fertilisers that are not used with care can pollute the environment and lead to eutrophication and other pollution problems.

LB p. 376

Activity 3 Survey

Investigate water quality

1 Investigation on the causes of pollution of rivers near you: each area in the country will have its own unique set of circumstances regarding pollution. Learners' own opinion.
2 Assess the use of fertilisers: learners' own survey of the relationship between fertiliser use and water pollution in their area.

Learner's Book pages 377–380

Unit 1 Summative assessment

TERM 3, MODULE 6

1 a) fertilisers
b) non-mineral nutrients
c) primary nutrients
d) nitrogen
e) the Ostwald process
f) fractional distillation
g) NPK compound fertilisers
h) double superphosphate

i) organic fertilisers
j) eutrophication

2 a) Fertiliser mixed in a ratio 3:1:5 (38%) contains 4,2% phosphorus.
b) During the catalytic oxidation of ammonia the platinum ensures a high reaction rate.
c) Nitrogen, phosphorus and potassium are the three primary nutrients needed by plants.
d) Phosphorus can be obtained from guano.
e) Ammonia is produced through the Haber process.
f) The catalyst used in the Contact process is vanadium pentoxide (vanadium (V) oxide).
g) Double superphosphate contains only calcium phosphate.
h) An NPK fertiliser contains the elements nitrogen, phosphorus and potassium.
i) Inorganic fertilisers are manufactured from ammonium nitrate, ammonium phosphate and potassium chloride.
j) Leaching of nitrogen (and phosphorus) salts are responsible for eutrophication.

3 a) i) C; H; O
ii) N; P; K
b) NH_4^+; NO_3^-
c) A
d) D
e) A
f) i) C
ii) B
g) C
h) D

4

Manufacturing process	Product
a) Haber process	NH_3
b) Contact process	H_2SO_4
c) Fractional distillation	N_2
d) Acid-base reaction	NH_4NO_3
e) mineral ore + sulfuric acid	H_3PO_4
f) Ostwald process	HNO_3
g) reforming of methane	H_2

5 Plant crops use the nutrients in the soil to grow. When the crops are harvested, the nutrients are removed with the crops. The soil becomes deficient in nutrients and the next crop will not have enough nutrients to grow and develop properly.

6

Major elements (macronutrients)	(a) **Non-mineral** nutrients available from (b) **air** and water	C, (c) **H**, (d) **O**
	Mineral nutrients: (e) **Primary** nutrients	N, (f) **P**, (g) **K**

7 a) C, H, O
b) N, P, K

8 a) $2NO + O_2 \rightarrow 2NO_2$
b) Catalytic oxidation of ammonia
c) HNO_3
d) C: $(NH_4)_2SO_4$
D: NH_4NO_3

e) Nitrogen saturation of soil leads to the washing away of other nutrients needed in the soil.
Washing of topsoil into lakes/dams causes it to become acidic.
Build up of nitrates in rivers (eutrophication) cause algae bloom that depletes oxygen. This causes aquatic life to die.
Build up of nitrates in drinking water can cause death under infants due to haemoglobin deficiency.
Ground water becomes acidic.
Promotes growth of alien plants.

9 a) Haber process
b) Ammonia
c) Ostwald process
d) Platinum/rhodium catalyst
e) $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$
f) H_2O
g) NH_4NO_3
h) Fertiliser and explosive

10 a) i) H_2SO_4
ii) H_3PO_4
iii) HF
b) i) (single) superphosphate
ii) double (triple) superphosphate

11 a) Fractional distillation of liquid air
b) $N_2 + 3H_2 \rightarrow 2NH_3$
c) $2SO_2 + O_2 \rightarrow 2SO_3$
d) $H_2S_2O_7$ oleum/pyrosulfuric acid
e) $(NH_4)_2SO_4$ ammoniumsulfate
f) i) soil cannot replenish nutrients at a fast enough rate to sustain growth; globally a bigger demand for food
ii) increase in oil price; increase in price of raw materials

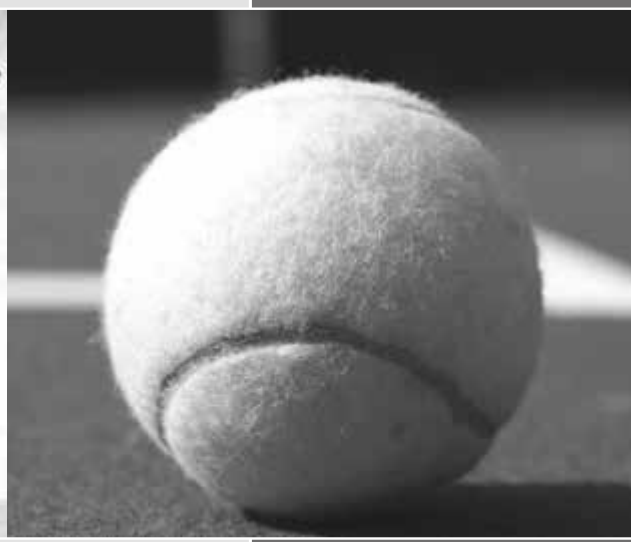
12 a) The NPK ratio gives the proportion/ratio of nitrogen, phosphorus and potassium in a fertiliser.
b) 4:5:8
c) Lower N to prevent too much leaf growth at the cost of fruit growth.
d) Environment: eutrophication, or dead zones
Humans: water poisoning, or blue baby syndrome, or nitrates potentially carcinogenic.

SECTION E

PHOTOCOPIABLE RESOURCES

The Lesson preparation grid, Periodic Table, rubrics and assessment grids on the following pages may be photocopied for use with the Physical Sciences Grade 12 Learner's Book.





Lesson preparation grid

Lesson preparation			
Teacher:	**Grade:**	**School:**	
Time			
Knowledge area			
Knowledge/prior beliefs			
Core knowledge and concepts			
Teacher activities	**Learner activities**	**Resources**	**Assessment methods**

PERIODIC TABLE OF THE ELEMENTS

1												13	14	15	16	17	18
1 H 1,0	2											5 B 10,8	6 C 12,0	7 N 14,0	8 O 16,0	9 F 19,0	2 He 4,0
7 Li 6,9	9 Be 9,0				13 Al 27,0 ← atomic number, symbol, atomic mass												10 Ne 20,2
11 Na 23,0	12 Mg 24,3	3	4	5	6	7	8	9	10	11	12	13 Al 27,0	14 Si 28,1	15 P 31,0	16 S 32,1	17 Cl 35,5	18 Ar 39,9
19 K 39,1	20 Ca 40,1	21 Sc 45,0	22 Ti 47,9	23 V 50,9	24 Cr 52,0	25 Mn 54,9	26 Fe 55,8	27 Co 58,9	28 Ni 58,7	29 Cu 63,5	30 Zn 65,4	31 Ga 69,7	32 Ge 72,6	33 As 74,9	34 Se 79,0	35 Br 79,9	36 Kr 83,8
37 Rb 85,5	38 Sr 87,6	39 Y 88,9	40 Zr 91,2	41 Nb 92,9	42 Mo 96,0	43 Tc (98)	44 Ru 101,1	45 Rh 102,9	46 Pd 106,4	47 Ag 107,9	48 Cd 112,4	49 In 114,8	50 Sn 118,7	51 Sb 121,8	52 Te 127,6	53 I 126,9	54 Xe 131,3
55 Cs 132,9	56 Ba 137,3	57 La 138,9	72 Hf 178,5	73 Ta 180,9	74 W 183,8	75 Re 186,2	76 Os 190,2	77 Ir 192,2	78 Pt 195,1	79 Au 197,0	80 Hg 200,6	81 Tl 204,4	82 Pb 207,2	83 Bi 209,0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Uub (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294)	118 Uuo (294)

lanthanides	58 Ce 140,1	59 Pr 140,9	60 Nd 144,2	61 Pm (145)	62 Sm 150,4	63 Eu 152,0	64 Gd 157,3	65 Tb 158,9	66 Dy 162,5	67 Ho 164,9	68 Er 167,3	69 Tm 168,9	70 Yb 173,0	71 Lu 175,0
actinides	90 Th 232,0	91 Pa 231,0	92 U 238,0	93 Np 237,0	94 Pu (244)	95 Am (234)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (258)	103 Lr (262)

Table of cations

Hydrogen	H^+	Beryllium	Be^{2+}	Aluminium	Al^{3+}	Chromium(VI)	Cr^{6+}
Lithium	Li^+	Magnesium	Mg^{2+}	Chromium(III)	Cr^{3+}	Manganese(VII)	Mn^{7+}
Sodium	Na^+	Calcium	Ca^{2+}	Iron(III)	Fe^{3+}		
Potassium	K^+	Barium	Ba^{2+}	Cobalt(III)	Co^{3+}		
Silver	Ag^+	Tin(II)	Sn^{2+}				
Mercury(I)	Hg^+	Lead(II)	Pb^{2+}				
Copper(I)	Cu^+	Chromium(II)	Cr^{2+}				
Ammonium	NH_4^+	Manganese(II)	Mn^{2+}				
		Iron(II)	Fe^{2+}				
		Cobalt(II)	Co^{2+}				
		Nickel(II)	Ni^{2+}				
		Copper(II)	Cu^{2+}				
		Zinc(II)	Zn^{2+}				

Table of anions

Fluoride	F^-	Oxide	O^{2-}
Chloride	Cl^-	Peroxide	O_2^{2-}
Bromide	Br^-	Carbonate	CO_3^{2-}
Iodide	I^-	Sulfide	S^{2-}
Hydroxide	OH^-	Sulfite	SO_3^{2-}
Nitrite	NO_2^-	Sulfate	SO_4^{2-}
Nitrate	NO_3^-	Thiosulfate	$S_2O_3^{2-}$
Hydrogen carbonate	HCO_3^-	Chromate	CrO_4^{2-}
Hydrogen sulfite	HSO_3^-	Dichromate	$Cr_2O_7^{2-}$
Hydrogen sulfate	HSO_4^-	Manganate	MnO_4^{2-}
Dihydrogen phosphate	$H_2PO_4^-$	Oxalate	$(COO)_2^{2-}$ or $C_2O_4^{2-}$
Hypochlorite	ClO^-	Hydrogen phosphate	HPO_4^{2-}
Chlorate	ClO_3^-	Nitride	N^{3-}
Permanganate	MnO_4^-	Phosphate	PO_4^{3-}
Acetate (ethanoate)	CH_3COO^-	Phosphide	P^{3-}

Solubility table

Soluble compounds		Exceptions
Almost all salts of Na^+, K^+ and NH_4^+		
All salts of Cl^-, Br^- and I^-	⇔	Halides of Ag^+, Ba^{2+} and Pb^{2+}
Compounds containing F^-	⇔	Fluorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+} and Pb^{2+}
Salts of nitrate, NO_3^- chlorate, ClO_3^- perchlorate, ClO_4^- acetate, CH_3COO^-		potassium perchlorate, $KClO_4$
Salts of sulfate, SO_4^{2-}	⇔	Sulfates of Sr^{2+}, Ba^{2+} and Pb^{2+}

Insoluble compounds		Exceptions
All salts of carbonate, CO_3^{2-} phosphate, PO_4^{3-} oxalate, $C_2O_4^{2-}$ chromate, CrO_4^{2-} sulfide, S^{2-} Most metal hydroxides, OH^- Most metal oxides, O^{2-}	⇔	Salts of NH_4^+ and alkali metal cations

Generic checklist for graphs

Assessment Criteria	Rating		
	2	1	Comments
Correct type of graph (bar/histogram/line/pie chart)	Correct type	Not correct type	
Suitable heading describing variables	Complete	Not present or incomplete	
Independent variable on x-axis (horizontal)	Present	Not present	
Suitable scale on x-axis (horizontal)	Correct	Incorrect	
Labelling x-axis (horizontal)	Correct	Incorrect	
Units for independent variable on x-axis (horizontal)	Correct	Incorrect	
Dependent variable on y-axis (vertical)	Present	Not present	
Suitable scale on y-axis (vertical)	Correct	Incorrect	
Labelling y-axis (vertical)	Correct	Incorrect	
Units for independent variable on y-axis (vertical)	Correct	Incorrect	
Plotting points (check any three)	All correct	All incorrect or 1–2 correct	
Neatness (joining points)	Tidy	Untidy	
Size of graph	Large, clear	Small, unclear	

Teacher assessment

GRID A

Summative assessment: Practical work

Class:_____ Date: _____

(Add marks in the appropriate column)

Learner's name	Experiment 1: Chemistry Total marks 20	Experiment 2: Physics Total marks 20	Project Total marks 20	TOTAL 60 marks

GRID **B**

Teacher assessment

Summative assessment: Control tests

Class:______________________________ Date: ______________

(Add marks in the appropriate column)

Learner's name	Control test 1		Control test 2		Total marks out of 20
	Total marks 50	Marks out of 10	Total marks 50	Marks out of 10	

Teacher assessment

GRID C

Summative assessment: Assessment tasks

Class:_____ Date: _____

(Add marks in the appropriate column)

Learner's name	Control tests Total marks 20	Mid-year examination Total marks 20	Practical work Total marks 60	TOTAL 100 marks

SECTION F

DOCUMENTS

This section is for you to file the Curriculum and Assessment Policy Statement (CAPS) for Physical Sciences. You may add any other documents you receive to this section and list them here for easy reference.

Grade 12

Study & Master

Physical Sciences

Study & Master Physical Sciences Grade 12 has been especially developed by an experienced author team for the Curriculum and Assessment Policy Statement (CAPS). This new and easy-to-use course helps learners to master essential content and skills in Physical Sciences.

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- includes case studies that link science to real-life situations and present balanced views on sensitive issues
- includes 'Did you know?' features providing interesting additional information
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- photocopiable templates and resources for the teacher.

After years of working in laboratories **Karin Kelder** taught at a range of schools, tutored mainstream learners and was involved in outreach programmes at disadvantaged schools in the Overberg. She is now a fulltime author. **Derick Govender** is a subject advisor for Physical Sciences in KZN, a national moderator for School Based Assessments and for Marking Standards. **Jagathesan Govender** now lectures in Physics at UKZN after a long career as subject advisor for Physical Sciences as well as an examiner and moderator of provincial matric examination papers.

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