Study & Master

Physical Sciences

CAPS

Teacher's Guide

Grade 11

Karin H. Kelder

Study & Master

Physical Sciences

Grade 11
Teacher's Guide

Karin H. Kelder

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Mexico City

Cambridge University Press
The Water Club, Beach Road, Granger Bay, Cape Town 8005, South Africa

www.cup.co.za

First published 2012

ISBN 978-1-107-38059-*2*

Editor: Leonie Hofmeyr-Juritz
Proofreader: Sanne Paarman
Typesetter: Simon van Gend
Illustrators: Belinda Danzfuss, Claudia Eckard, Imar Krige, Tina Nel, James Whitelaw

Cover image: *Crocothemis erythraea*, commonly known as the scarlet darter dragonfly,
© NP Djoudj/The Bigger Picture

. . . .

. . . .

NOTICE TO TEACHERS

The photocopy masters in this publication may be photocopied or distributed [electronically] free of charge for classroom use within the school or institution which purchases the publication. Worksheets and copies of them remain in the copyright of Cambridge University Press and such copies may not be distributed or used in any way outside the purchasing institution.

Acknowledgements
The publishers and author wish to thank the following individuals for providing section-opener photos: **Bigstock**: satellite Section A(a), water droplet Section A(c), tap dripping Section F(a), tennis ball Section E(c), transmission wires Section F(c); **Gallo Images/Getty Images**: stream of water with balloon Section C(c); **The Bigger Picture**: female scientist Section A(b), diffraction through water droplet Section B(c), person with oscilloscope Section B(b), single slit red band diffraction Section B(a), thermite reaction Section D(a), boy doing experiment Section C(b), girl doing titration experiment Section E(b), steel industry in Spain Section D(b) and F(b); **Karin Kelder**: fern uncurling Section D(c), Mount Kilimanjaro Section E(a), solenoids Section C(a)

If you want to know more about this book or any other Cambridge University Press publication, phone us at +27 21 4127800, fax us at +27 21 419-8418 or send an e-mail to capetown@cambridge.org

Table of contents

Welcome to *Physical Sciences* Grade 11. 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 11 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 three 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 11. 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, environmental justice 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 pollution of the lithosphere and atmosphere (Chemical systems).

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 always found ways to make fire by friction.

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 11 is shown in the 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 11 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	30	10

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	**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. These are indicated in the yellow sections of the Learner's Book and this Teacher's Guide.

Overview of formal assessment and recommended informal experiments

For Grade 11 two prescribed experiments are done as formal assessment per year – there is one physics experiment and one chemistry experiment (one experiment per term for Terms 1 and 2). One project is done per year as formal assessment either in physics or in chemistry or an integrated chemistry/physics project (started in Term 1 and assessed in Term 3). The learners can do any one of the projects described in the Learner's Book, any one of the experiments described as a practical investigation or any other topic of choice as a project. It is recommended that the teacher gives the learners the project topic early in the first term so that learners can start the project. The final assessment of the project is done and recorded in the third term.

There are four prescribed formal practical activities for Grade 11.
The table lists prescribed practical activities for formal assessment as well as recommended practical activities for informal assessment and indicates where they can be found in our Learner's Book.

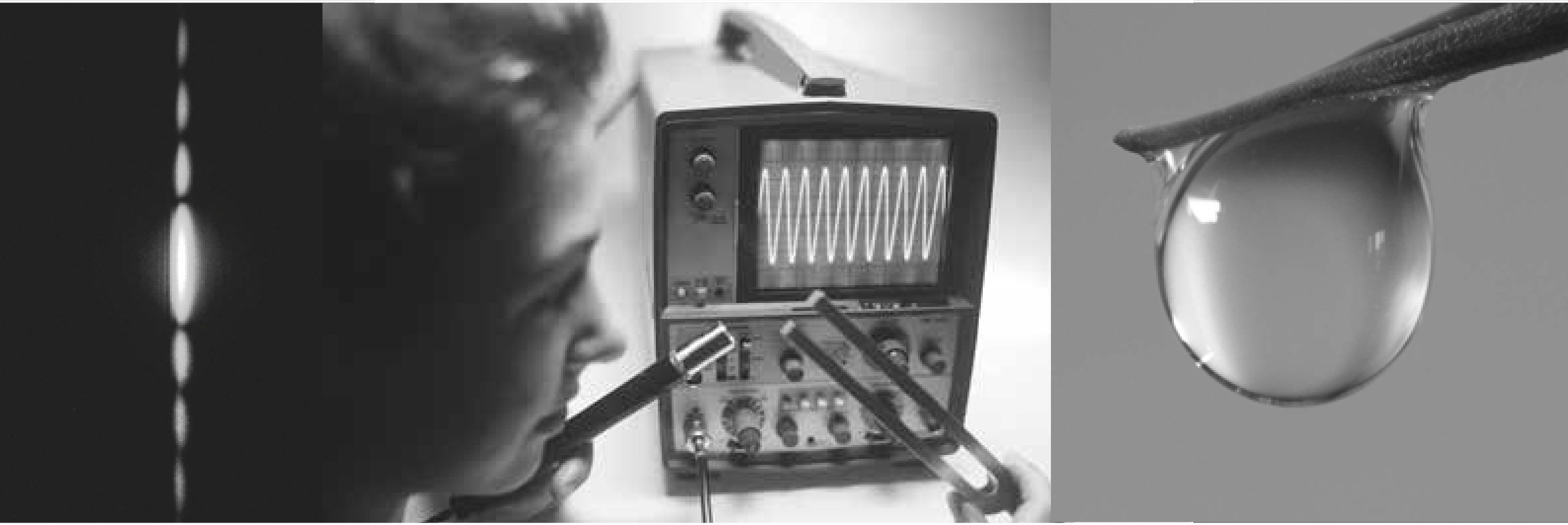
Term	Prescribed practical activities for formal assessment	Recommended practical activities for informal assessment
1	Experiment 1 (Physics): Verify Newton's Second Law (LB page 55–57)	Experiment (Physics): Determine the resultant of three non-linear force vectors (LB page 33–34) OR Practical investigation (Physics): Investigate friction (LB page 47) OR Experiment (Chemistry): Investigate the physical properties of water (LB page128)
2	Activity 3 (Chemistry): Investigate intermolecular forces and their effects (LB page 118–121)	Experiment (Physics): Determine the critical angle of a rectangular glass block (LB page 148) OR Experiment (Chemistry): Verify Boyle's Law (LB page 162–163) OR Experiment (Chemistry): Determine the mass of PbO_2 prepared from $Pb(NO_3)_2$ (LB page 195–196)
3	Project: Chemistry: Investigate endothermic and exothermic reactions (LB page 252–254) OR Physics: Verify Snell's Law (LB page 145)	Experiment (Physics): Determine which components obey Ohm's Law (LB page 230–231) OR Experiment (Chemistry): Investigate indicators (LB page 269–270)
4		Experiment (Chemistry): Investigate redox reactions (LB page 283–287)

Weighting of topics (40 week programme)

Mechanics	16,87%
Waves, sound and light	8,13%
Electricity and magnetism	12,50%
Matter and materials	15,00%
Chemical change	17,50%
Chemical systems	5,00%
Total teaching time (Theory and practical work)	75,00%
Total time for examinations and control tests	25,00%

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. Examinations papers and control tests in the Physical Sciences in Grade 11 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 for Terms 1, 2 and 3 can be found at the end of this section.

Practical investigations and experiments

Focus practical investigations and experiments on the practical aspects and the process skills required for scientific inquiry and problem-solving. Design assessment activities so that learners are assessed on their use of scientific inquiry skills such as planning, observing and gathering information, comprehending, synthesising, generalising, hypothesising and communicating results and conclusions. Practical investigations should assess performance at different cognitive levels and a focus on process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts.

The difference between a practical investigation and an experiment is that an experiment is conducted to verify or test a known theory whereas an investigation is an experiment that is conducted to test a hypothesis – that is, the result or outcome is not known beforehand.

For example: Verifying Newton's Second Law is a prescribed experiment for formal assessment on page 55 of the Learner's Book. The propagation of light through a glass block can be regarded as a practical investigation (Learner's Book page 141).

Projects

A project is an integrated assessment task that focuses on process skills, critical thinking and scientific reasoning, as well as strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts. This requires a learner to follow the scientific method either to produce a poster, a device or a model, or to conduct a practical investigation.

A project will entail only one of the following:

- making a scientific poster
- construction of a device – for example, an electric motor
- building a physical model in order to solve a challenge you have identified using concepts in the FET Physical Sciences curriculum – for example, the atomic model
- practical investigation.

Note: The assessment tools used, specifying the assessment criteria for each task, will be dictated by the nature of the task and the focus of the assessment, and could be one or a combination of rubrics, checklists, observation schedules and memoranda. Photocopiable generic rubrics, checklists and assessment sheets can be found on pages E6 to E17 of this Teacher's Guide.

Requirements for Grade 11 practical work

In Grade 11 learners will do two prescribed experiments for formal assessment (one physics and one chemistry experiment) and one project on either physics or chemistry. This gives a total of three formal assessments in practical work in Physical Sciences.

It is recommended that learners do four experiments for informal assessment (two physics and two chemistry experiments). This gives a total of four informal assessments in practical work in Physical Sciences.

Practical work	Physics	Chemistry
Prescribed experiments (formal assessment)	1	1
Project (formal assessment)	1 in either physics or chemistry	
Experiments (informal assessment)	2	2
Total	7 practical activities	

The forms of assessment that the teacher uses should be appropriate for the age of the learners and their developmental level. The design of these tasks should cover the content of the subject and include a variety of tasks designed to achieve the objectives of the subject.

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.

Rubrics and checklists in the physical sciences

The generic rubrics and checklists are in Section E: Photocopiable resources. Modify them for your needs and use them as a guideline to help you develop rubrics specifically for your activities and projects.

Programme of Formal Assessment

The Programme of Formal Assessment is designed to spread formal assessment tasks in all subjects in a school throughout a term and for the whole year. In addition to daily assessment (informal assessment), teachers should develop a year-long formal Programme of Assessment for Grade 11. The learner's performance in this Programme of Formal Assessment will be used for promotion purposes to Grade 12. Assessment is school-based, or internal, for Grade 11. The marks achieved in each of the assessment tasks that make up the Programme of Formal Assessment must be reported to parents. The table illustrates an assessment plan and weighting of tasks in the Programme of Formal Assessment for Physical Sciences Grade 11.

Programme of Formal Assessment for Grade 11						
Assessment tasks (25%)						End-of-year assessment (75%)
Term 1		Term 2		Term 3		Term 4
Type	Marks	Type	Marks	Type	Marks	Final exam (2 × 150 marks)
Experiment	20	Experiment	20	Project. Any one of: poster; construction of device; building a model; practical investigation	20	
Control test	10	Mid-year exam	20	Control test	10	
Total: 30 marks		Total: 40 marks		Total: 30 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

End-of-year examination

The end-of-year examination papers for Grade 11 will be internally set, marked and moderated, unless otherwise instructed by provincial Departments of Education. The internally set, marked and moderated examination will consist of two papers. The table below shows the weighting of questions across cognitive levels and the specification and suggested weighting of the content for Grade 11 end-of-year examinations across 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	68	150	3	15%	35%	40%	10%
	Waves, sound and light	32						
	Electricity and magnetism	50						
Paper 2: Chemistry focus	Chemical systems	20	150	3	15%	40%	35%	10%
	Chemical change	70						
	Matter and materials	60						

Below is a list of selected content, outlined for Grades 10 and 11 in the CAPS document, that is also examinable in the Grade 12 final examination. Draw the learners' attention to this fact when teaching the Grade 11 topics that appear in the list below.

Selected examinable Grades 10 and 11 topics	
Physics from Grade 11	**Chemistry from Grades 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)

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.

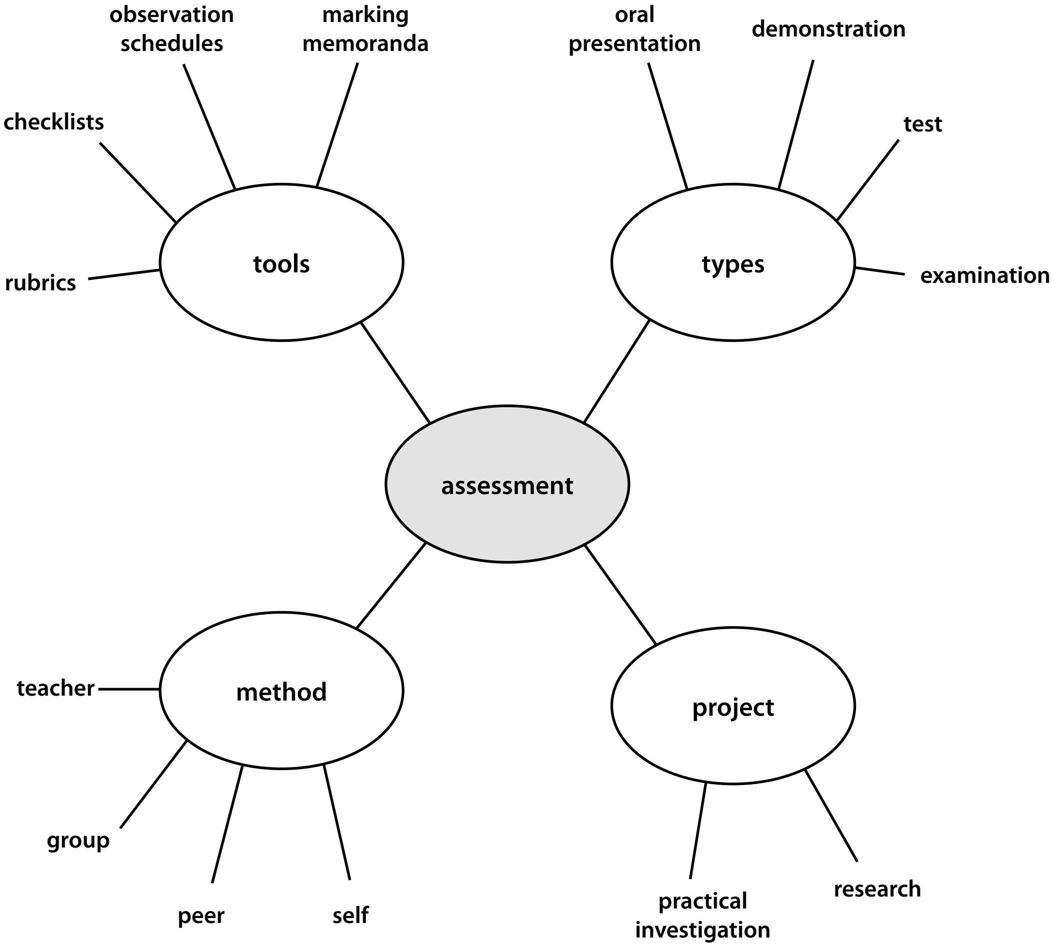
Physical Sciences assessment taxonomy

The table on the next page 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	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

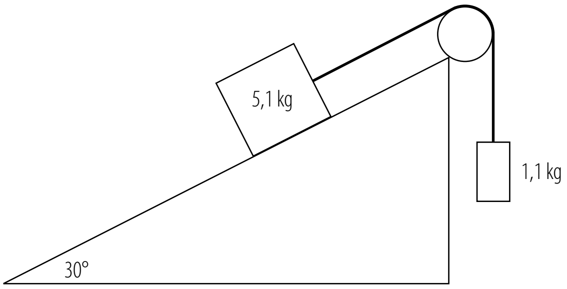
Description of cognitive	Level	Explanation	Skills demonstrated	Action verbs
Comprehension	2	A number of connections may be made but the meta-connections are missed, as is their significance for the whole. The learner has first level understanding, recalls and understands information and describes meaning.	• 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

Summary of assessment



Module 1: Mechanics Units 1–2: 30 marks
Module 2: Matter and materials Units 1–2: 20 marks

1 A 5,1 kg block rests on a 30° incline and is kept in equilibrium by a 1,1 kg mass suspended over a pulley, as shown in the diagram.



a) Calculate the magnitude of the weight of the 1,1 kg block. (3)
b) Determine the magnitude of the component of the weight of the 5,1 kg block that works parallel to the incline. (3)
c) Draw a labelled free-body diagram of the forces that act parallel to the incline on the 5,1 kg block. (3)
d) Calculate the direction and magnitude of the frictional force acting on the 5,1 kg block. (3)
e) If the calculated frictional force is the maximum static frictional force, calculate the coefficient of static friction. (5)
f) Do you expect the coefficient of kinetic friction to be smaller or larger than you answer in (e)? (1)

[18]

2 Assume that a car is travelling at 33 $m \cdot s^{-1}$ and the driver is strapped in with a seat belt. The car hits a tree and the front end crumples by 1,5 m (so that the rest of the car and the driver move a distance of 1,5 m before stopping).
a) Why should a person always wear a seat belt while travelling in a car? Explain your answer by making use of principles of physics. (4)
b) Draw a force diagram to show all the horizontal forces acting on the driver during the collision. (2)
c) If the mass of the driver is 70 kg, calculate the force exerted by the seat belt during the collision. (6)

[12]

3 Consider a water molecule.
a) Draw Lewis diagrams to show how a water molecule forms from its atoms. (3)
b) A water molecule can react with a hydrogen ion to form an oxonium or hydronium ion.
   i) Give the Lewis structure of the oxonium ion. (2)
   ii) Name this type of bond. (1)
c) Use the VSEPR theory and predict the shape of the water molecule. Explain your choice. (3)

d) Both the C=O bond in CO_2 and the H–O bond in H_2O are polar. Draw a diagram of these two molecules to show their polarity. (4)

e) Water has a boiling point of 100 °C and hydrogen sulfide has a boiling point of –60 °C. Explain the difference. (4)

f) The density of water reaches a maximum value at 4 °C. Discuss the importance of this phenomenon. (3)

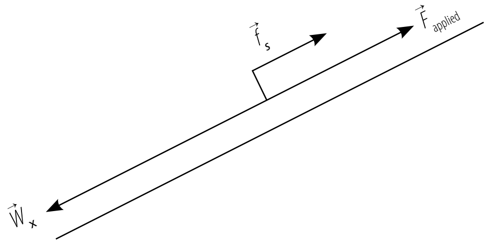
[20]

Total: 50

1 a) $W = mg = 1{,}1\text{ kg} \times 9{,}8\text{ m·s}^{-2} = 11\text{ N}$ (3)

b) $W_x = mg \sin 30° = 5{,}1\text{ kg} \times 9{,}8\text{ m·s}^{-2} \times \sin 30° = 25\text{ N}$ (3)

c) (3)



d) The frictional force keeps the system in equilibrium and is equal to F_{net}, but opposite in direction. Take up the slope as positive:

$F_{\text{net}} = F_{\text{up the slope}} + F_{\text{down the slope}}$

$= +11\text{ N} + (-25\text{ N}) = -14\text{ N}$

The frictional force = 14 N up the slope (3)

e) First calculate the normal force on the 5,1 kg block:

$N = mg \cos 30° = 43\text{ N}$

$f_s^{\max} = \mu_s N$

$\therefore \mu_s = \frac{14\text{ N}}{43\text{ N}} = 0{,}33$ (5)

f) Smaller (1)

[18]

2 Take the original direction in which the car is travelling as positive.

a) When the car is moving, the passengers are travelling at the same speed as the car. During a sudden change of speed or if the car stops suddenly, the passengers' inertia will cause them to continue to move forward at their initial speed, according to Newton I. They could collide with the windscreen or steering wheel and injure themselves. The seat belt holds them back in position in their seats so that this does not happen. (4)

b) force of seat belt on driver $\longleftarrow\!\bullet$ (2)

c) First calculate a: $v_f^2 = v_i^2 + 2a\Delta x \Rightarrow a = \frac{v_f^2 - v_i^2}{2\Delta x}$

$a = \frac{(0\text{ m·s}^{-1})^2 - (33\text{ m·s}^{-1})^2}{2 \times 1{,}5\text{ m}} = -363\text{ m·s}^{-2}$

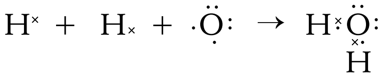
$\therefore a = 363\text{ m·s}^{-2}$ away from the tree

$F_{\text{net}} = ma = 70\text{ kg} \times 363\text{ m·s}^{-2} = 25\ 410\text{ N}$

$\therefore \vec{F}_{\text{net}} = 25\ 410$ or $2{,}5 \times 10^4$ N away from the tree (6)

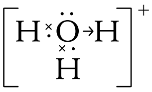
[12]

3 a) (3)



$$H^{\times} + H_{\times} + \cdot\ddot{\underset{\cdot}{O}}\!: \rightarrow H\overset{\times}{\cdot}\ddot{\underset{\times\cdot}{O}}\!:\ \underset{H}{}$$

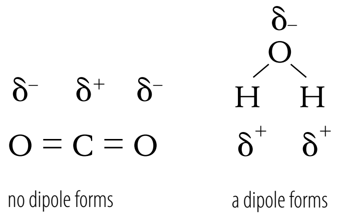
b) i) (2)



$$\left[H\overset{\times}{\cdot}\ddot{\underset{\times\cdot}{O}}\!\rightarrow\! H \atop H\right]^{+}$$

ii) coordinate covalent bond/dative covalent bond (1)

c) angular; molecular class AX_4: tetrahedron; two lone pairs occupy two corners of the tetrahedral shape (3) d)



(4)

e) strong hydrogen bonds between the H_2O molecules; weaker dipole–dipole forces (van der Waals forces) between H_2S molecules (4)

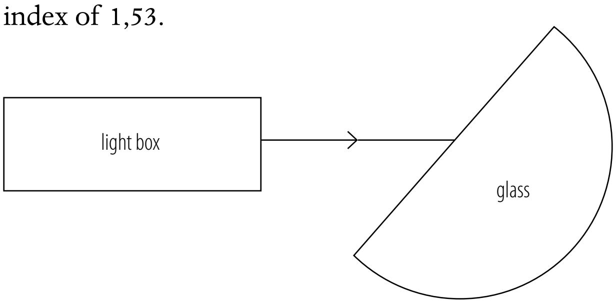
f) moderate temperature on the Earth; sea life survives under ice; ice less dense than water and floats (3)

[20]

Total: 50

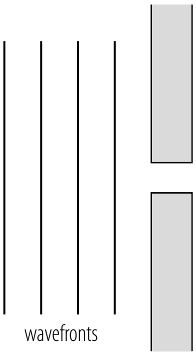
Module 3: Waves, sound and light Units 1–2: 20 marks
Module 2: Matter and materials Unit 3: 12 marks
Module 4: Chemical change Unit 1: 18 marks

1 A learner does an experiment to verify Snell's Law. She uses the apparatus as indicated in the diagram. The glass has a refractive index of 1,53.



a) Redraw the diagram in your book and complete the path of the light beam through the block. Indicate the angle of incidence, normal and angle of refraction. (4)
b) By using Snell's Law, determine the angle of refraction she will measure if the angle of incidence is 40°. (3)
c) She now wants to determine the critical angle of the glass. Draw a diagram to show how she would arrange the apparatus to measure the critical angle. Label the critical angle in your diagram. (3)
d) Calculate the theoretical critical angle of this type of glass to air. (3)
e) Name the phenomenon that the learner would notice if she were to increase the angle of incidence any further. (2)
[15]

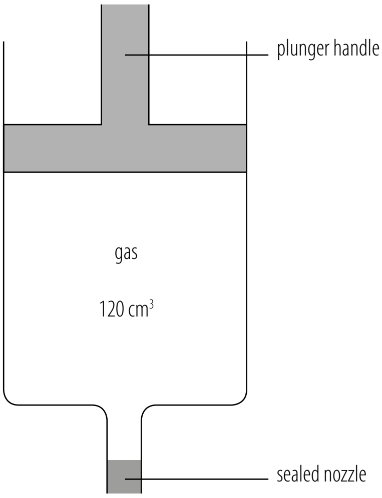
2 A series of wavefronts is passed through an aperture, as indicated in the diagram.



a) Define diffraction. (2)
b) Draw the diffraction pattern that can be seen on the other side of the aperture. (3)
[5]

3 The diagram shows a gas syringe with a total volume of 150 cm^3. The plunger handle of the syringe is free to move. 120 cm^3 of nitrogen gas is trapped in the syringe at atmospheric pressure

and 27 °C. The nozzle tip is sealed. The syringe is then slowly immersed in a bath of hot water at 77 °C.



a) The plunger handle is held in place at its original position. Will the gas pressure be less than, greater than or equal to atmospheric pressure at 77 °C? Explain your answer. (3)
b) Calculate the change in volume of the nitrogen gas in the syringe if the plunger handle is allowed to move. (5)
c) Calculate the number of moles of nitrogen gas in the syringe. (4)

[12]

4 A standard solution of oxalic acid [$(COOH)_2 \cdot 2H_2O$] was prepared by dissolving 3,15 g of the solid acid in 250 cm³ of distilled water. The acid was titrated against an impure solution of sodium hydroxide (NaOH). The impure solution of NaOH was prepared by dissolving 2,00 g of the impure mixture in 250 cm³ of distilled water. (Assume the impurities did not react.)

In the titration, 25,0 cm³ of the impure sodium hydroxide was neutralised by 20,0 cm³ of the acid solution. The balanced reaction equation is:

$$(COOH)_2 + 2NaOH \rightarrow (NaCOO)_2 + 2H_2O$$

a) Calculate the concentration of the oxalic acid solution. (4)
b) Calculate the concentration of the impure sodium hydroxide solution. (5)
c) Calculate the mass of the impurities contained in the 2,0 g of the impure sodium hydroxide. (5)

[14]

5 Butane burns in a lighter to produce carbon dioxide and water vapour according to the balanced equation:

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

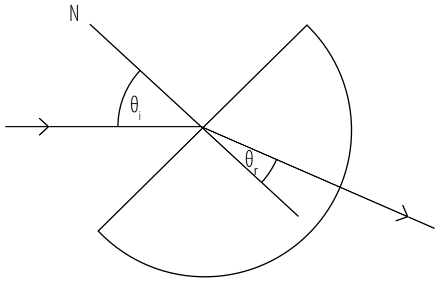
Calculate the volume of gas released in (m³) during the reaction if 2 moles of butane burns at standard temperature and pressure.

(4)

[4]

Total: 50

1 a)



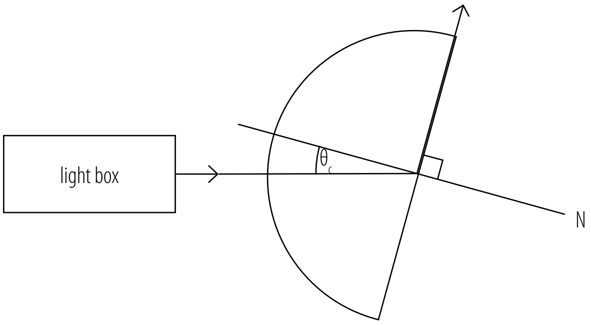
(4)

b) $n_1 \sin \theta_1 = n_2 \sin \theta_2 \Rightarrow \sin \theta_2 = \frac{n_1}{n_2} \sin \theta_1$

$\sin \theta_2 = \frac{1,00}{1,53} \times \sin 40° = 0,42$

$\theta_2 = 24,8°$ (3)

c)



(3)

d) $\sin \theta_c = \frac{n_{\text{air}}}{n_{\text{glass}}} \sin 90° = \frac{1,00}{1,53} \times 1,00 = 0,65$

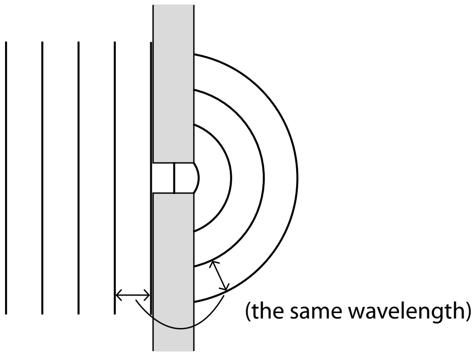
$\theta_c = 40,8°$ (3)

e) Total internal reflection (2)

[15]

2 a) Diffraction is the ability of wavefronts to spread out when they pass through an aperture and curl behind the obstruction. (2)

b)



(3)

[5]

3 a) The pressure will increase if the plunger of the syringe is prevented from moving out.

$PV = nRT \Rightarrow P = kT$ if V and n are constant. If T increases, P will also increase. (3)

(If the plunger is allowed to move out, it will continue doing so until the pressure in the syringe equals the external atmospheric pressure.)

b) $P_1 = P_2$

$V_1 = 120 \text{ cm}^3$; $T_1 = 273 + 27 = 300 \text{ K}$

$V_2 = ?$; $T_2 = 273 + 77 = 350 \text{ K}$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow V_2 = \frac{V_1T_2}{T_1}$$

$$V_2 = \frac{120 \text{ cm}^3 \times 350 \text{ K}}{300 \text{ K}} = 140 \text{ cm}^3$$

Change in volume = $140 \text{ cm}^3 - 120 \text{ cm}^3 = 20 \text{ cm}^3$ increase (5)

c) $PV = nRT \Rightarrow n = \frac{PV}{RT}$

$$n = \frac{101{,}3 \times 10^3 \text{ Pa} \times 120 \times 10^{-6} \text{ m}^3}{8{,}31 \text{ J·K}^{-1}\text{·mol}^{-1} \times 300 \text{ K}} = 4{,}88 \times 10^{-3} \text{ mol}$$ (4)

[12]

4 a) $c = \frac{m}{MV} = \frac{3{,}15 \text{ g}}{126{,}0 \text{ g·mol}^{-1} \times 0{,}250 \text{ dm}^3} = 0{,}100 \text{ mol·dm}^{-3}$ (4)

b) $\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$

$$\therefore \frac{1}{2} = \frac{0{,}100 \text{ mol·dm}^{-3} \times 20 \text{ cm}^3}{c_b \times 25{,}0 \text{ cm}^3}$$

$\therefore c_b = 0{,}16 \text{ mol·dm}^{-3}$ (5)

c) mass NaOH neutralised: $m = cVM$

$= 0{,}16 \text{ mol·dm}^{-3} \times 0{,}250 \text{ dm}^3 \times 40{,}0 \text{ g·mol}^{-1}$

$= 1{,}6$ g NaOH

mass of impurities: $2{,}00 - 1{,}60 = 0{,}40$ g (5)

[14]

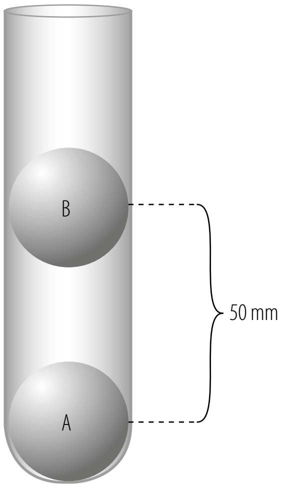
5 18 mol gas at STP: $18 \times 22{,}4 \text{ dm}^3 = 403{,}2 \text{ dm}^3 = 0{,}403 \text{ m}^3$ (4)

[4]

Total: 50

Module 5: Electricity and magnetism Units 1–3: 33 marks
Module 4: Chemical change Units 2–3: 17 marks

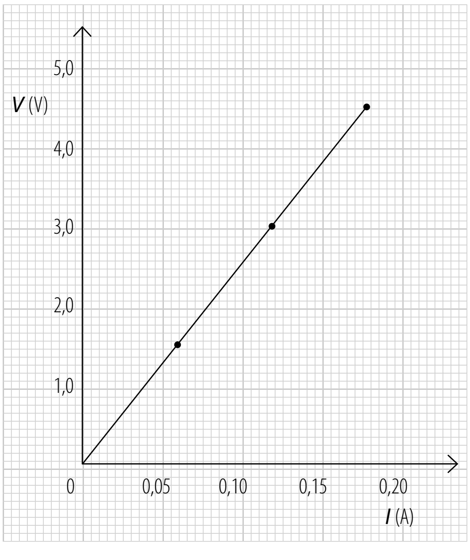
1 Two identical polystyrene spheres, A and B, each covered with a thin layer of graphite, have masses of $5,00 \times 10^{-6}$ kg each and carry identical positive static charges. They are placed in a narrow vertical glass test tube as illustrated, with sphere B remaining suspended 50,0 mm above sphere A.



a) Draw a diagram of the electric field between A and B. (3)
b) Calculate the magnitude of the charge on each sphere. (5)
b) If the charge on the spheres gradually leaked away, what would happen to sphere B during the process? Explain your answer. (2)
[10]

2 Consider the graph below and then answer the questions.

Graph of potential difference against current



a) Choose the most likely component that was used to obtain these results: light bulb, diode, resistor. Explain your answer by referring to the correct physics law. (4)

b) Calculate the resistance of the component. (4)

[8]

3 You eat toast every morning.

a) How many kWh of energy does a 550 W toaster use in the morning if it is in operation for a total of 10 min? (3)

b) At a cost of 80c/kWh, how much would this add to your monthly electricity bill if you made toast five mornings per week? Assume that there are four full weeks in the month. (2)

[5]

4 A solenoid with 350 loops and a cross-sectional area of 5,00 cm is placed perpendicularly in a magnetic field of 1,75 T. It is pulled from the magnetic field in 0,500 s.

a) How much flux passes through the solenoid? (3)

You can use Faraday's Law to calculate the induced emf in the coil.

b) State Faraday's Law. (3)

c) What is the emf induced in the coil? (4)

[10]

5 When iron and sulfur react, heat is given off during the reaction.

a) Is this an exothermic or endothermic reaction? (1)

b) Will the value for enthalpy change be zero, greater than zero or smaller than zero? (1)

The reaction is not spontaneous and the mixture must first be heated before the reaction will commence.

c) Draw a fully labelled energy profile of the reaction. Include all the stages, from when the iron and sulfur are first mixed. (5)

[7]

6 Ammonia reacts with water in an acid base reaction.

a) Write a balanced equation for the reaction. (2)

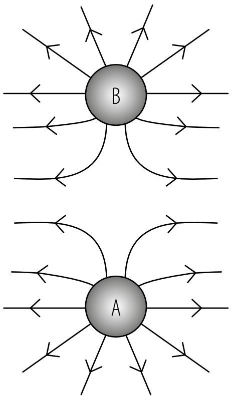
b) Will the resultant solution be acidic or basic? Give a reason for your answer. (2)

c) Identify the conjugate acid/base pairs in the reaction. (4)

d) Which substance acts as an ampholyte? Give a reason for your answer. (2)

[10]

1 a)



(3)

b) For B to remain suspended the forces on it must be in equilibrium.

$F = W \Rightarrow mg = k\frac{Q^2}{r^2}$

$\therefore\ 5,00 \times 10^{-6}\ \text{kg} \times 9,80\ \text{m·s}^{-2} = \frac{9,00 \times 10^{9}\ \text{N·m}^2\text{·C}^{-2} \times Q^2}{(0,0500\ \text{m})^2}$

$\therefore\ Q = 3,69 \times 10^{-9}\ \text{C}$ (5)

c) B will get closer to A (lower in the test tube) because force F decreases, which results in a downward resultant force. This will cause a downward acceleration. (2)

[10]

2 a) A resistor. The voltage is directly proportional to the current and the graph shows a straight line through the origin. This is an indication of a component that obeys Ohm's Law. A light bulb and a diode are non-ohmic and will not show a direct proportionality. (4)

b) $R = \frac{V}{I} = \frac{1,5\ \text{V}}{0,06\ \text{A}} = 25\ \Omega$ (4)

[8]

3 a) $550\ \text{W} = 0,550\ \text{kW} \times \frac{10}{60}\ \text{h} = 0,92\ \text{kWh}$ (3)

b) Cost for 1 morning: 0,92 kWh × 80c = 73c

Cost for 20 mornings: 0,73 × 20 = R14.67 (2)

[5]

4 a) $\Phi = B \times A = 1,75\ \text{T} \times 5,00 \times 10^{-4}\ \text{m} = 8,75 \times 10^{-4}\ \text{Wb}$ (3)

b) The induced emf in any closed circuit is equal to the rate of change of the magnetic flux through the circuit. (3)

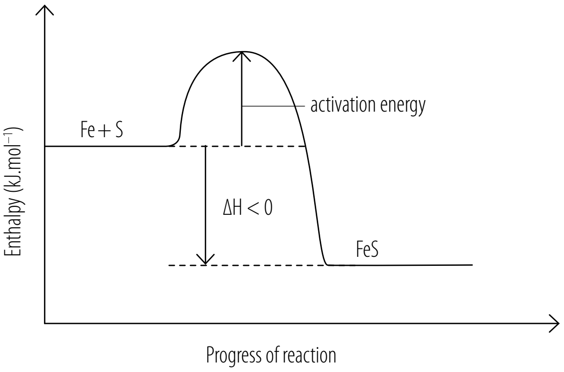
c) $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -350\ \frac{0\ \text{Wb} - 8,75 \times 10^{-4}\ \text{Wb})}{0,500\ \text{s}} = 0,613\ \text{V}$ (4)

[10]

5 a) Exothermic (1)

b) ΔH < 0 (1)

c)



(5)

[7]

6 a) $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ (2)

b) Basic – OH^- ions are formed (2)

c) Base: NH_3; Conjugate acid: NH_4^+
Acid: H_2O; Conjugate base: OH^- (4)

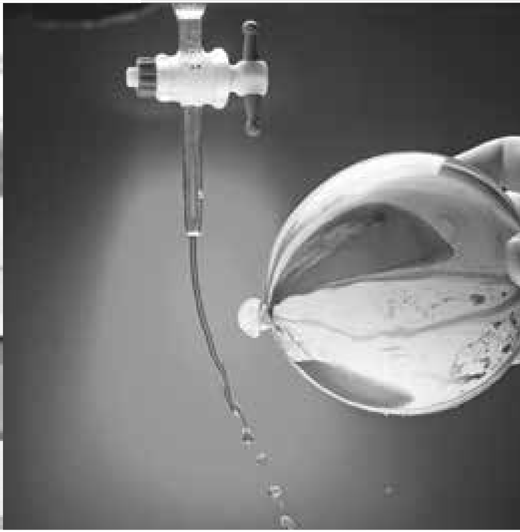
d) H_2O: It can act as an acid and donate an H^+ to form OH^-; it can act as a base and accept an H^+ to form H_3O^+ (2)

[10]

Total: 50

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 Teacher's File.

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 form 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. 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%	Physics 1. Optical phenomena and properties of materials
		11,50%	Chemistry 2. Organic chemistry 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

Term 1						
Module 1: Mechanics						
Hours	**Units**	**Topics**	**LB page**	**Content, concepts and skills**	**Planned date**	**Completion date**
2	Unit 1: Vectors in two dimensions	Resultant of perpendicular vectors	24	• Draw a sketch of the vectors (parallel and perpendicular) on the Cartesian plane. • Add co-linear vectors along the parallel and perpendicular direction to obtain the net parallel component ($\vec{R}_x$) and the net perpendicular component ($\vec{R}_y$). • Sketch $\vec{R}_x$ and $\vec{R}_y$. • Sketch the resultant ($\vec{R}$) using either the tail-to-head or tail-to-tail method. • Determine the magnitude of the resultant using the Theorem of Pythagoras. • Find the resultant vector graphically using the tail-to-head method as well as by calculation (by component method) for a maximum of four force vectors in both 1D and 2D. • Understand what a closed vector diagram is. • Determine the direction of the resultant using simple trigonometric ratios.		
2		Resolution of a vector into its parallel and perpendicular components	34	• Draw a sketch of the vector on the Cartesian plane showing its magnitude and the angle (q) between the vector and the *x*-axis. • Use $\vec{R}_x = \vec{R}\cos\theta$ for the resultant *x*-component. • Use $\vec{R}_y = \vec{R}\sin\theta$ for the resultant *y*-component.		
5	Unit 2: Newton's Laws and application of Newton's Laws	Different kinds of forces: weight, normal force, frictional force, applied (push, pull), tension (strings or cables)	39	• Define normal force, *N*, as the force exerted by a surface on an object in contact with it. • Know that the normal force acts perpendicular to the surface irrespective of whether the plane is horizontal or inclined. • Define frictional force, *f*, as the force that opposes the motion of an object and acts parallel to the surface the object it is contact with. • Distinguish between static and kinetic frictional forces. • Explain what is meant by the maximum static friction, f_s^{max}. • Calculate the value of the maximum static frictional force for objects at rest on a horizontal and inclined planes using $f_s^{max} = \mu_s N$. • Know that static friction $f_s < \mu_s N$. • Calculate the value of the frictional force for a moving object on horizontal and inclined planes using $f_k = \mu_k N$.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
3		Force diagrams, free-body diagrams	44	• Know that a force diagram is a picture of the object(s) of interest with all the force acting on it (them) drawn in as arrows. • Know that in a free-body diagram, the object of interest is drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot. • Resolve two-dimensional forces (such as the weight of an object with respect to the inclined plane) into its parallel (*x*) and perpendicular (*y*) components. • The resultant or net force in the *x*-direction is a vector sum of all the components in the *x*-direction. • The resultant or net force in the *y*-direction is a vector sum of all the components in the *y*-direction.		
11		Newton's First, Second and Third Laws	49	• State Newton's First Law: *An object continues in a state of rest or uniform (moving with constant) velocity unless it is acted upon by an unbalanced (net or resultant) force.* • Discuss why it is important to wear seatbelts, using Newton's First Law. • State Newton's Second Law: *When a net force,* $\vec{F}_{net}$*, is applied to an object of mass, m, it is accelerated in the direction of the net force. The acceleration,* $\vec{a}$*, is directly proportional to the net force and inversely proportional to the mass:* $\vec{F}_{net} = m\vec{a}$. • Draw force diagrams for objects that are in equilibrium (at rest or moving with constant velocity) and accelerating (non-equilibrium). • Draw free-body diagrams for objects that are in equilibrium (at rest or moving with constant velocity) and accelerating (non-equilibrium). • Apply Newton's laws to a variety of equilibrium and non-equilibrium problems, including a single object moving on a horizontal/ inclined plane (frictionless and rough), vertical motion (lifts, rockets, etc.) and also two-body systems such as two masses joined by a light (negligible mass) string. • Understand apparent weight. • State Newton's Third Law: *When object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A.* • Identify action-reaction pairs, e.g. donkey pulling a cart, a book on a table. • List the properties of action-reaction pairs.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
4		Newton's Law of Universal Gravitation	67	• State Newton's Law of Universal Gravitation. • Use the equation for Newton's Law of Universal Gravitation to calculate the force two masses exert on each other: $F = G \frac{m_1 m_2}{d^2}$ • Describe weight as the gravitational force the Earth exerts on any object on or near its surface. • Calculate the acceleration due to gravity on Earth using the equation: $g_{\text{Earth}} = G \frac{M_{\text{Earth}}}{d^2_{\text{Earth}}}$ N.B. This formula can be used to calculate g on any planet using the appropriate planetary data. • Calculate weight using the expression $W = mg$, where g is the acceleration due to gravity. Near the Earth the value is approximately 9,8 $m \cdot s^{-2}$. • Calculate the weight of an object on other planets with different values of gravitational acceleration. • Distinguish between mass and weight. Know that the unit of weight is the newton (N), and that of mass is the kilogram (kg). • Understand weightlessness.		
Module 2: Matter and materials						
2	Unit 1: Atomic combinations: molecular structure	Chemical bonds	89	• Recall the role of models in science and describe the explanations of chemical bonding in this course as an application of a model. • Deduce the number of valence electrons in an atom of an element. • Represent atoms using Lewis diagrams. • Explain, referring to diagrams showing electrostatic forces between protons and electrons, and in terms of energy considerations, why – two H atoms form an H_2 molecule, but – He does not form He_2. • Draw a Lewis diagram for the hydrogen molecule. • Describe a covalent chemical bond as a shared pair of electrons. • Describe and apply simple rules to deduce bond formation, namely – different atoms, each with an unpaired valence electron, can share these electrons to form a chemical bond – different atoms with paired valence electrons, called lone pairs of electrons, cannot share these four electrons and cannot form a chemical bond		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				– different atoms with unpaired valence electrons can share these electrons and form a chemical bond for each electron pair shared (multiple bond formation) – atoms with an incomplete complement of electrons in their valence shell can share a lone pair of electrons from another atom to form a co-ordinate covalent or dative covalent bond (for example, NH_4^+, H_3O^+). • Draw Lewis diagrams, given the formula and using electron configurations, for – simple molecules (for example, F_2, H_2O, NH_3, HF, OF_2 and HOCl) – molecules with multiple bonds (for example, N_2, O_2 and HCN).		
2		Molecular shape as predicted using the Valence Shell Electron Pair Repulsion (VSEPR) theory	96	• State the major principles used in the VSEPR. • The five ideal molecular shapes according to the VSEPR model. (Ideal shapes are found when there are no lone pairs on the central atom, only bonding pairs.) A is always the central atom and X are the terminal atoms – linear shape AX_2 (for example, CO_2 and $BeCl_2$) – trigonal planar shape AX_3 (for example, BF_3) – tetrahedral shape AX_4 (for example, CH_4) – trigonal bipyramidal shape AX_5 (for example, PCl_5) – octahedral shape AX_6 (for example, SF_6). • Molecules with lone pairs on the central atom cannot have one of the ideal shapes (e.g. water molecule). • Deduce the shape of – molecules like CH_4, NH_3, BeF_2 and BF_3 – molecules with more than four bonds like PCl_5 and SF_6 – molecules with multiple bonds like CO_2, SO_2 and C_2H_2 from their Lewis diagrams using the VSEPR theory.		
1		Electronegativity of atoms to explain the polarity of bonds	101	• Explain the concepts – electronegativity – non-polar bonds with examples (for example, H-H) – polar bonds with examples (for example, H-Cl). • Show polarity of bonds using partial charges: δ^+H-Clδ^- . • Compare the polarity of chemical bonds using a table of electronegativities. • With an electronegativity difference $\Delta EN > 2,1$, electron transfer will take place and the bond will be ionic.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• With an electronegativity difference ΔEN > 1, the bond will be covalent and polar. • With an electronegativity difference ΔEN < 1, the bond will be covalent and very weakly polar. • With an electronegativity difference ΔEN = 0 the bond will be covalent and non-polar. • Show how polar bonds do not always lead to polar molecules.		
1		Bond energy and length	105	• Give a definition of bond energy. • Give a definition of bond length. • Explain what is the relationship between bond energy and bond length. • Explain the relationship between the strength of a bond between two chemically bonded atoms and − the length of the bond between them − the size of the bonded atoms − the number of bonds (single, double, triple) between the atoms.		
6	Unit 2: Intermolecular forces	Intermolecular and interatomic forces (chemical bonds); Physical state and density explained in terms of these forces; Particle kinetic energy and temperature	107	• Name and explain the different intermolecular forces: (i) ion–dipole forces (ii) ion–induced dipole forces (iii) dipole–dipole forces (iv) dipole–induced dipole forces (v) induced dipole forces with hydrogen bonds as a special case of dipole–dipole forces. The last three forces (involving dipoles) are also called Van der Waals forces. • Explain hydrogen bonds (dipole–dipole). • Revise the concept of a covalent molecule. • Describe the difference between intermolecular and interatomic forces, using a diagram of a group of small molecules, and in words. • Represent a common substance made of small molecules like water, using diagrams of the molecules, to show microscopic representations of ice $H_2O(s)$, water liquid $H_2O(\ell)$ and water vapour $H_2O(g)$. • Illustrate the proposition that intermolecular forces increase with increasing molecular size with examples (for example, He, O_2, C_8H_{18} (petrol), $C_{23}H_{48}$ (wax). (Only for Van der Waals forces.) • Explain density of material in terms of the number of molecules in a unit volume (e.g. compare gases, liquids and solids).		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Explain the relationship between the strength of intermolecular forces and the melting points and boiling points of substances composed of small molecules. • Contrast the melting points of substances composed of small molecules with those of large molecules where bonds must be broken for substances to melt. • Describe thermal expansion of a substance and how it is related to the motion of molecules in a substance composed of small molecules (for instance, alcohol in a thermometer). • Explain the differences between thermal conductivity in non-metals and metals.		
4		The chemistry of water	122	• Describe the shape of the water molecule and its polar nature. • Water's unique features are due to the hydrogen bonding in solid, liquid and gaseous water. • Indicate the number of H_2O molecules in 1 litre of water. • The hydrogen bonds require a lot of energy to break; therefore water can absorb a lot of energy before the water temperature rises. • The hydrogen bonds formed by the water molecules enable water to absorb heat from the sun. The sea acts as reservoir of heat and is able to ensure the Earth has a moderate climate. • Explain that, because of its polar nature and consequent hydrogen bonding, there are strong forces of attraction between water molecules that cause a high heat of vaporisation (water needs a lot of energy before it will evaporate), and an unusually higher than expected boiling point when compared to other hydrides. • A decrease in density when water freezes helps it moderate the temperature of the Earth and its climate. • The density of ice is less than the density of liquid and ice floats on water, forming an insulating layer between water and the atmosphere, keeping the water from freezing, and preserving aquatic life (water is the only liquid which freezes from the top down).		
Term 2						
Module 3: Waves, sound and light						
3	Unit 1: Geometrical optics	Refraction	137	• Revision: Explain reflection. • Revision: State the Law of Reflection. • Define the speed of light as being constant when passing through a given medium and having a maximum value of $c = 3 \times 10^8$ m·s^{-1} in a vacuum. • Define refraction. • Define refractive index as $n = \frac{c}{v}$.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Define optical density. • Know that the refractive index is related to the optical density. • Explain that refraction is a change of wave speed in different media, while the frequency remains constant. • Define the Normal. • Define angle of incidence. • Define angle of refraction. • Sketch ray diagrams to show the path of a light ray through different media.		
4		Snell's Law	144	• State the relationship between the angles of incidence and refraction and the refractive indices of the media when light passes from one medium into another (Snell's Law). $n_1 \sin \theta_1 = n_2 \sin \theta_2$ • Apply Snell's Law to problems involving light rays passing from one medium into another. • Draw ray diagrams showing the path of light when it travels from a medium with higher refractive index to one of lower refractive index, and vice versa.		
3		Critical angles and total internal reflection	147	• Explain the concept of critical angle. • List the conditions required for total internal reflection. • Use Snell's Law to calculate the critical angle at the surface between a given pair of media. • Explain the use of optical fibres in endoscopes and telecommunications.		
3	Unit 2: 2D and 3D Wavefronts	Diffraction	151	• Define a wavefront as an imaginary line that connects waves that are in phase (e.g. all at the crest of their cycle). • State Huygen's Principle. • Define diffraction as the ability of a wave to spread out in wavefronts as they pass through a small aperture or around a sharp edge. • Apply Huygen's Principle to explain diffraction qualitatively. Light and dark areas can be described in terms of constructive and destructive interference of secondary wavelets. • Sketch the diffraction pattern for a single slit. • Understand that the degree of diffraction $\propto \frac{\lambda}{w}$, where w = slit width. • Understand that diffraction of light demonstrates the wave nature of light.		

Module 2: Matter and materials

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
1	Unit 3: Ideal gases and thermal properties	Motion of particles; Kinetic theory of gases	160	• Describe the motion of individual molecules, that is – collisions with each other and the walls of the container – molecules in a sample of gas move at different speeds. • Explain the idea of 'average speeds' in the context of molecules of a gas. • Describe an ideal gas in terms of the motion of molecules. • Explain how a real gas differs from an ideal gas. • State the conditions under which a real gas approaches ideal gas behaviour. • Use the kinetic theory to explain the gas laws.		
6		Ideal gas law	162	• Describe the relationship between volume and pressure for a fixed amount of a gas at constant temperature (Boyle's Law). • Describe the relationship between volume and temperature for a fixed amount of a gas at constant pressure (Charles' Law). • Describe the relationship between pressure and temperature for a fixed amount of a gas at constant temperature (Gay-Lussac). – practically using an example – by interpreting a typical table of results – using graphs (introducing the Kelvin scale of temperature where appropriate) – using symbols ($\propto$ and $\frac{1}{\propto}$) and the words 'directly proportional' and 'inversely proportional' as applicable – writing a relevant equation. • Combine the three gas laws into the ideal gas law, $PV = nRT$. • Use the gas laws to solve problems, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$. • Give the conditions under which the ideal gas law does not apply to a real gas, and explain why. • Convert Celsius to Kelvin for use in the ideal gas law.		
1		Temperature and heating, pressure	176	• Explain the temperature of a gas in terms of the average kinetic energy of the molecules of the gas. • Explain the pressure exerted by a gas in terms of the collision of the molecules with the walls of the container.		

Module 4: Chemical change						
Hours	**Units**	**Topics**	**LB page**	**Content, concepts and skills**	**Planned date**	**Completion date**
3	Unit 1: Quantitative aspects of chemical change	Molar volume of gases; concentration of solutions	182	• 1 mole of a gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa). • Interpret balanced reaction equations in terms of volume relationships for gases under the same conditions of temperature and pressure (volume of gases is directly proportional to the number of particles of the gases). • Calculate molar concentration of a solution.		
6		More complex stoichiometric calculations	189	• Perform stoichiometric calculations using balanced equations that may include limiting reagents. • Do stoichiometric calculations to determine the percentage yield of a chemical reaction. • Do calculations to determine empirical formula and molecular formula of compounds (revise empirical formula calculations done in Grade 10). • Determine the percentage $CaCO_3$ in an impure sample of sea shells (purity or percentage composition).		
3		Volume relationships in gaseous reactions	197	• Do stoichiometric calculations with explosions as reactions during which a great many molecules are produced in the gas phase so that there is a massive increase in volume – for instance, ammonium nitrate in mining or petrol in a car cylinder. $2NH_4NO_3 \rightarrow 2N_2(g) + 4H_2O(g) + O_2(g)$ $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ Give the reactions and use in stoichiometric calculations. • Do as application the functioning of airbags. Sodium azide reaction: $2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$ Reaction must be given when used in calculations.		
Term 3						
Module 5: Electricity and magnetism						
3	Unit 1: Electrostatics	Coulomb's Law	206	• State Coulomb's Law, which can be represented mathematically as $F = \frac{kQ_1Q_2}{r^2}$ • Solve problems using Coulomb's Law to calculate the force exerted on a charge by one or more charges in one dimension (1D) and two dimensions (2D).		
3		Electric field	209	• Describe an electric field as a region in space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge (+1 C) would move if placed at that point. • Draw electric field lines for various configurations of charges.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Define the magnitude of the electric field at a point as the force per unit charge: $\vec{E} = \frac{\vec{F}}{q}$; $\vec{E}$ and $\vec{F}$ are vectors • Deduce that the force acting on a charge in an electric field is $\vec{F} = q\vec{E}$. • Calculate the electric field at a point due to a number of point charges, using the equation: $\vec{E} = \frac{kQ}{r^2}$ to determine the contribution to the field due to each charge.		
3	Unit 2: Electro-magnetism	Magnetic field associated with current carrying wires	215	• Provide evidence for the existence of a magnetic field (B) near a current-carrying wire. • Use the Right Hand Rule to determine the magnetic field (B) associated with: (i) a straight-current-carrying wire; (ii) a current-carrying loop (single) of wire and (iii) a solenoid. • Draw the magnetic field lines around (i) a straight current-carrying wire, (ii) a current-carrying loop (single) of wire and (iii) a solenoid. • Discuss qualitatively the environmental impact of overhead electrical cables.		
3		Faraday's Law	219	• State Faraday's Law. • Use words and pictures to describe what happens when a bar magnet is pushed into or pulled out of a solenoid connected to a galvanometer. • Use the Right Hand Rule to determine the direction of the induced current in a solenoid when the north or south pole of a magnet is inserted or pulled out. • Know that for a loop of area A in the presence of a uniform magnetic field B, the magnetic flux (Φ) passing through the loop is defined as: $\Phi = BA \cos \theta$, where θ is the angle between the magnetic field B and the normal to the loop of area A. • Know that the induced current flows in a direction so as to set up a magnetic field to oppose the change in magnetic flux. • Calculate the induced emf and induced current for situations involving a changing magnetic field using the equation for Faraday's Law: $\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$, where $\Phi = BA \cos \theta$ is the magnetic flux.		
4	Unit 3: Electric circuits	Ohm's Law	227	• Determine the relationship between current, voltage and resistance at constant temperature using a simple circuit. • State the difference between ohmic and non-ohmic conductors, and give an example of each. • Solve problems using the mathematical expression of Ohm's Law, $R = \frac{V}{I}$, for series and parallel circuits.		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
4		Power, Energy	236	• Define power as the rate at which electrical energy is converted in an electric circuit and is measured in watts (W). • Know that electrical power dissipated in a device is equal to the product of the potential difference across the device and current flowing through it, i.e. $P = VI$. • Know that power can also be given by $P = I^2R$ or $P = \frac{V^2}{R}$ • Solve circuit problems involving the concept of power. • Know that the electrical energy is given by $E = Pt$ and is measured in joules (J). • Solve problems involving the concept of electrical energy. • Know that the kilowatt-hour (kWh) refers to the use of 1 kilowatt of electricity for l hour. • Calculate the cost of electricity usage, given the power specifications of the appliances used as well as the duration, if the cost of 1 kWh is given.		
Module 4: Chemical change						
2	Unit 2: Energy and chemical change	Energy changes in reactions related to bond energy changes	249	• Explain the concept of enthalpy and its relationship to heat of reaction. • Define exothermic and endothermic reactions. • Identify that bond breaking requires energy (endothermic) and that bond formation releases energy (exothermic). • Classify (with reason) the following reactions as exothermic or endothermic: respiration; photosynthesis; combustion of fuels.		
1		Exothermic and endothermic reactions	254	• State that $\Delta H > 0$ for endothermic reactions. • State that $\Delta H < 0$ for exothermic reactions. • Draw free-hand graphs of endothermic reactions and exothermic reactions (without activation energy).		
1		Activation energy	257	• Define activation energy. • Explain a reaction process in terms of energy change and relate this change to bond breaking and formation and to activated complex. • Draw free-hand graphs of endothermic reactions and exothermic reactions (with activation energy).		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
6	Unit 3: Types of reaction	Acid-base	260	• Use the acid-base theories of Arrhenius, Brønsted and Lowry to define acids and bases. • Define an acid as an H^+ donor and a base as an H^+ acceptor in a reaction. • Identify conjugate acid-base pairs. • Define an ampholyte. • List common acids (including hydrochloric acid, nitric acid, sulfuric acid and acetic acid) and common bases (including sodium carbonate, sodium hydrogen carbonate and sodium hydroxide) by name and formula. • Write the overall equation for simple acid- base hydroxide, acid- metal oxide and acid- metal carbonate reactions and relate these to what happens at the macroscopic level. • What is an indicator? Look at some natural indicators. • Use acid-base reactions to produce and isolate salts (for instance, Na_2SO_4, $CuSO_4$ and $CaCO_3$).		
Term 4						
Module 4: Chemical change						
5	Unit 3: Types of reaction	Redox reactions	277	• Determine the oxidation number from a chemical formula and electronegativities. • Identify a reduction-oxidation reaction and apply the correct terminology to describe all the processes. • Describe oxidation-reduction reactions as involving electron transfer. • Describe oxidation-reduction reactions as always involving changes in oxidation number. • Balance redox reactions by using oxidation numbers via the ion-electron method.		
1		Oxidation number of atoms in molecules to explain their relative 'richness' in electrons.	282	• Explain the meaning of oxidation number. • Assign oxidation numbers to atoms in various molecules such as H_2O, CH_4, CO_2, H_2O_2 and HOCl by using oxidation number guidelines or rules. • Use rules of oxidation to assign oxidation numbers to atoms in a variety of molecules and ions.		
Module 6: Chemical systems						
8	Exploiting the lithosphere or Earth's crust	Mining and mineral processing	292	• Give a brief history of humankind across the ages: – linking their technology and the materials they have used to their tools and their weapons – referring to evidence of these activities in South Africa – describe the Earth's crust as a source of the materials man uses • what is available? (The abundance of the elements on the Earth).		

Hours	Units	Topics	LB page	Content, concepts and skills	Planned date	Completion date
				• Where is it found? (The uneven distribution of elements across the atmosphere, the hydrosphere, the biosphere and the lithosphere). • How is it found? (Seldom as elements, inevitably as minerals.) • How are the precious materials recovered? (The need to mine and process the minerals and separating them from their surroundings and processing them to recover the metals or other precious material – use terms like resources, reserves, ore, ore body). • Describe the recovery of gold referring to – why it is worth mining? – the location of the major mining activity in South Africa? – the major steps in the process: deep level underground mining - separation of the ore from other rock – the need to crush the ore bearing rock – separating the finely divided gold metal in the ore by dissolving in a sodium cyanide/ oxygen mixture (oxidation) – simple reaction equation – the recovery of the gold by precipitation (Zn) (reduction) – simple reaction equation (this method is outdated; mines use activated carbon), smelting • Discuss old mining methods and the impact on the environment of such methods, for instance, methods used at Mapungubwe. • Give the major steps in the process of mining if you have chosen one of the other mining activities. • Describe the environmental impact of (1) mining operations and (2) mineral recovery plants. • Describe the consequences of the current large scale burning of fossil fuels, and why many scientists and climatologists are predicting global warming.		

Example of lesson preparation

Lesson preparation			
Teacher:	**Grade:** 11	**School:** A. Nother Secondary School	
Time	4 hours/5 lessons		
Knowledge area	Vectors in two dimensions		
Knowledge/prior beliefs	From Grade 10: vectors and scalars; indicating vectors; properties of vectors; vector addition		
Core knowledge and concepts	Resultant of perpendicular vectors; resolution of a vector into its parallel and perpendicular components		
Teacher activities	**Learner activities**	**Resources**	**Assessment methods**
• Revise properties of vectors and scalars. Learners to do Test Yourself 1. • Draw vectors (R_x and R_y) on blackboard and show vector addition along parallel and perpendicular directions. • Show how vectors are indicated on a Cartesian plane and how to determine the resultant (*R*) graphically using head-to-tail and tail-to-tail methods. Use Pythagoras to determine magnitude of resultant and trigonometric functions to calculate direction. Learners do Test Yourself 2. • Use graphical method to determine resultant. Learners do Test Yourself 3. • Use force triangle for three forces in equilibrium. Learners do Test Yourself 4 • Resolve vector into perpendicular and parallel components; use trigonometric functions. Learners to do Test Yourself 5 and 6 • Prepare apparatus for Activity 1 in Learner's Book, page 33: Determine the resultant of three non-linear force vectors.	• Do Test Yourself 1 on page 24. • Practice tail-to-head and tail-to-tail methods by doing Test Yourself 2 on page 26. • Work through examples of graphical determination of resultant on pages 28-31 and do Test Yourself 3 on page 31. • Work through diagram on page 32 and do Test Yourself 4 on page 32. • Work through examples on pages 35 and 36 and do Test Yourself 5 and 6 on pages 35 and 37. • Perform Activity 1: Experiment on pages 33-34 of Learner's Book and present your results and answers to questions in a report.	• Mathematical sets (accurate ruler, protractor and compass), sharp pencil and eraser for scale diagrams • Scientific calculator to calculate trigonometric functions. • Force board apparatus for Activity 1 in Learner's Book page 33.	• Informal baseline assessment of prior knowledge • Peer assessment of homework task • Teacher assessment of recommended experiment for informal assessment

Updating your knowledge

As a professional educator, you should constantly update your knowledge on your subject. The aim of this section is NOT to provide a complete list of all the available resources for South African teachers in the Physical Sciences. This is an impossible task, so we will give you ideas and contacts to make it easy for you to locate resources in your own area. 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

Find out about 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. There are many different types of museums in South Africa. Find the correct one 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. C20)

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, P O 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

List of activities

Module	Unit	Activity	Page
Term 1			
Module 1: Mechanics	Unit 1: Vectors in two dimensions	Test yourself 1	D6
		Test yourself 2	D6
		Test yourself 3	D6
		Test yourself 4	D7
		1 Recommended experiment for informal assessment: Determine the resultant of three non-linear force vectors	D8
		Test yourself 5	D8
		Test yourself 6	D9
	Unit 2: Newton's laws and application of Newton's laws	Test yourself 7	D11
		2 Recommended investigation for informal assessment: Investigate friction	D11
		Test yourself 8	D13
		3 Prescribed experiment for formal assessment: Verify Newton's Second Law	D13
		Test yourself 9	D17
		Test yourself 10	D18
		Test yourself 11	D19
		Test yourself 12	D19
		4 Experiment: Verify the value for *g*	D20
		Test yourself 13	D21
		5 Extension activity: Investigate circular motion and satellites	D21
		6 Extension activity: Evaluate the relevance of Einstein for school learners	D22
		Summative assessment	D23
Module 2: Matter and materials	Unit 1: Atomic combinations: molecular structure	Test yourself 1	D29
		Test yourself 2	D29
		1 Practical activity: Build molecular shapes	D30
		Test yourself 3	D30
		2 Practical activity: Determine bond and molecular polarity from molecular shapes	D31
		Test yourself 4	D32
		Test yourself 5	D33
	Unit 2: Intermolecular forces	Test yourself 6	D34
		Test yourself 7	D34
		Test yourself 8	D35
		3 Prescribed experiment for formal assessment: Investigate intermolecular forces and their effects	D35
		4 Research project: Consider the effect of intermolecular forces on liquids	D38
		Test yourself 9	D40
		5 Practical activity: Investigate the properties of water	D40
		6 Research project: Investigate traditional cooling apparatus	D41
		Test yourself 10	D41
		7 Recommended experiment for informal assessment: Investigate the physical properties of water	D42
		8 Extension activity: Consider the importance of water	D43
		Summative assessment	D43

Module	Unit	Activity	Page
Term 2			
Module 3: Waves, sound and light	Unit 1: Geometrical optics	Test yourself 1	D49
		Test yourself 2	D49
		Test yourself 3	D49
		1 Practical investigation: Investigate refraction	D50
		2 Prescribed project for formal assessment: Verifying Snell's Law	D51
		Test yourself 4	D52
		3 Recommended experiment for informal assessment: Determine the critical angle of a rectangular glass block	D53
		Test yourself 5	D54
	Unit 2: 2D and 3D wavefronts	Test yourself 6	D55
		Test yourself 7	D55
		4 Experiment: Demonstrate diffraction of light	D55
		Test yourself 8	D56
		Summative assessment	D56
Module 2: Matter and materials (continued)	Unit 3: Ideal gases and thermal properties	9 Recommended experiment for informal assessment: Verify Boyle's Law	D58
		10 Experiment: Verify Charles' Law	D60
		11 Experiment: Verify Gay-Lussac's Law	D61
		12 Practical investigation: Investigate pressure-temperature relationships in a gas	D62
		13 Research discussion: Explain the interdependence of gas temperature, pressure and volume	D63
		14 Application exercises: Apply the ideal gas equation	D63
		Summative assessment	D65
Module 4: Chemical change	Unit 1: Quantitative aspects of chemical change	1 Revision exercises: Calculations using the mole concept	D69
		2 Experiment: Make a standard solution	D69
		3 Application exercises: Use concentration formulae	D69
		Test yourself 1	D70
		4 Recommended experiment for informal assessment: Determine the mass of PbO_2 prepared from $Pb(NO_3)_2$	D71
		Test yourself 2	D72
		Test yourself 3	D73
		Summative assessment	D74
Term 3			
Module 5: Electricity and magnetism	Unit 1: Electrostatics	Test yourself 1	D77
		Test yourself 2	D77
	Unit 2: Electro-magnetism	1 Practical project: Make an electromagnet	D79
		2 Practical investigation: Investigate the induction of an electric current	D79
		Test yourself 3	D80
		Test yourself 4	D80
	Unit 3: Electric circuits	3 Recommended experiment for informal assessment: Determine which components obey Ohm's Law	D80
		4 Application exercises: Apply Ohm's Law	D83
		5 Teacher demonstration: Compare the brightness of bulbs	D83
		Test yourself 5	D84
		Test yourself 6	D85
		Summative assessment	D85

Module	Unit	Activity	Page
Module 4: Chemical change (continued)	Unit 2: Energy and chemical change	5 Prescribed project for formal assessment: Investigate endothermic and exothermic reactions	D89
		6 Application exercises: Determine the energy changes in the preparation of ammonia	D91
		Test yourself 4	D92
		7 Teacher demonstration: Investigate the concept of activation energy	D92
		8 Application exercises: Consider the energies in decomposition and synthesis reactions	D92
	Unit 3: Types of reaction	Test yourself 5	D93
		Test yourself 6	D93
		Test yourself 7	D93
		9 Experiment: Neutralise sodium hydroxide with oxalic acid through titration	D94
		10 Recommended experiment for informal assessment: Investigate indicators	D94
		11 Experiment: Prepare sodium chloride	D95
		12 Research project: Investigate the use of limestone in toilets	D96
		13 Extension activity: Consider the causes of tooth decay	D96
		Summative assessment	D97
Term 4			
Module 4: Chemical change (continued)	Unit 3: Types of reaction (continued)	Test yourself 8	D99
		14 Recommended experiment for informal assessment: Investigate redox reactions	D99
		15 Extension activity: Investigate redox reactions in everyday life	D104
		Summative assessment	D106
Module 6: Chemical systems	Unit 1: Exploiting the lithosphere	1 Revision exercise: Recognise systems	D108
		2 Experiment: Investigate the corrosion of iron	D108
		3 Research project: Describe the extraction of metals	D109
		4 Practical investigation: Investigate calcium carbonate	D111
		5 Experiment: Investigate oxy-cleaners	D112
		6 Application exercises: Consider gold	D113
		7 Class debate: Debate the effects of the mining industry in South Africa	D114
		8 Practical investigation: Investigate the mining industry	D115
		Summative assessment	D117

MODULE 1: MECHANICS

Background information for Module 1

The module starts with a continuation of vectors that were introduced in Grade 10. Emphasis is on components of vectors, and the basics of components are applied in Unit 2 in solving questions relating to inclined planes.

The study of mechanics in Unit 2 revolves around dynamics, including Newton's laws. Apart from the theory and application of the laws, there are a number of experiments, case studies and application exercises included in the Learner's Book. Examples with step-by-step solutions are included to show learners how to solve problems.

In many calculations in this module learners will have to use equations of motion in conjunction with the equation for Newton's Second Law. Equations of motion also form part of the Grade 10 mechanics curriculum. The equations of motion can be found in the information section of the Learner's Book. Perform a baseline assessment activity on basic calculations that use equations of motion to make sure that your learners have mastered the use and manipulation of these equations before attempting the calculations in this module.

Mechanics makes up 16,87% of the Physical Sciences curriculum for Grade 11, so you should spend the first 27 hours of the year's science classes on this module. The content is divided into a short 4 hour unit on vectors, followed by a long 23 hour unit on Newton's laws. There are two recommended activities for informal assessment and one prescribed activity for formal assessment, to verify Newton's Second Law. The marks for this activity will count towards the term marks for the first term.

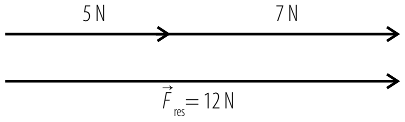
Test yourself 1 (LB p. 24)

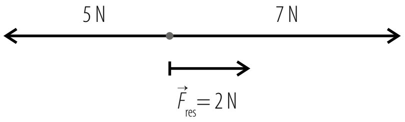
1 a) The minimum resultant is when the two vectors act in same directions.

b) The maximum resultant is when the two vectors act in the opposite direction.

c) Maximum resultant = 5 N + 7 N = 12 N

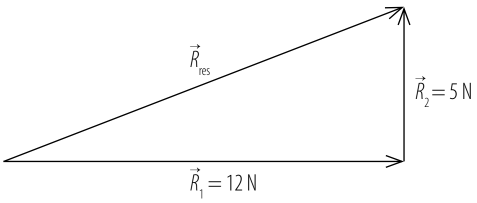
Minimum resultant = 7 N + (–5 N) = 2 N



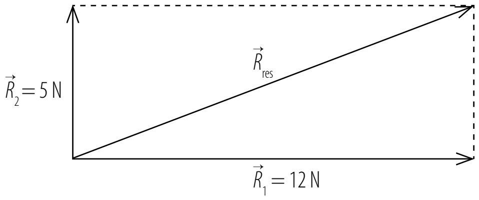


Test yourself 2 (LB p. 26)

Tail-to-head method



Tail-to-tail method



Pythagoras:

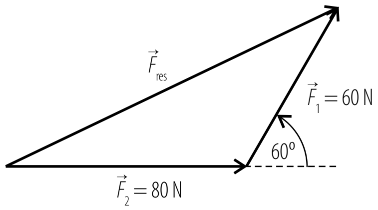
$$c^2 = a^2 + b^2$$

$$= 5^2 + 12^2$$

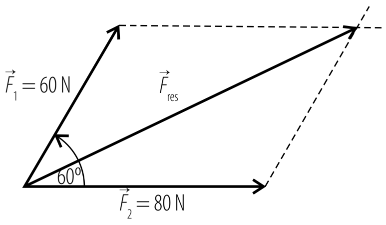
$$\therefore \quad c = 13 \text{ N}$$

Test yourself 3 (LB p. 31)

1 a)

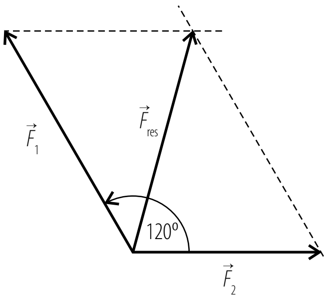


b)

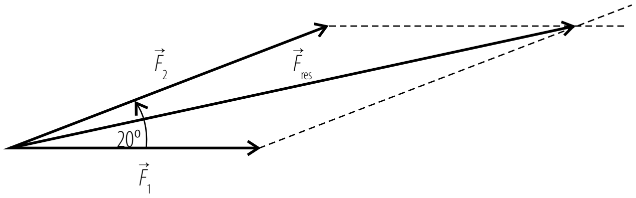


F_{res} = 122 N 25°

2 a)



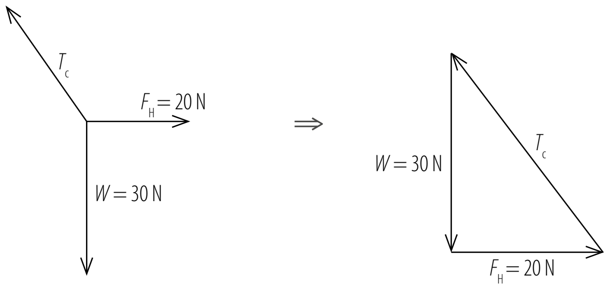
b)



In a) the resultant force is smaller than in b). If the angle between the two forces is increased, the resultant force decreases. The largest resultant force is found when the two forces work in the same direction and the smallest resultant force happens when the two forces work in opposite directions.

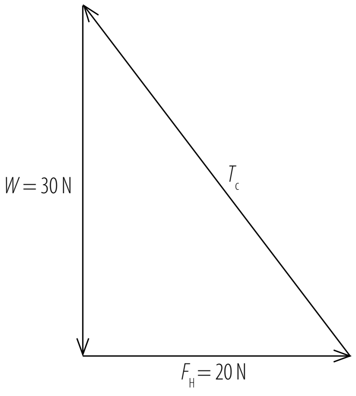
You can also explain to learners how the magnitude of the parallel components changes as the angle between the two forces changes: At an angle of 120°, the parallel components of the forces are in opposite directions. The resultant force will be small, because you subtract their magnitudes. (One force will have a positive direction and the other a negative direction.) When the angle between the two forces decreases to 20°, the parallel components are in the same direction and the resultant force is larger.

Test yourself 4 (LB p. 32)



W = weight of potplant
T_c = tension in the cable
F_H = horizontal force

Construction:



Calculation:

$$T_c^2 = 30^2 + 20^2$$
$$\therefore T_c = 36 \text{ N}$$

LB p. 33 »

Activity 1 Recommended experiment for informal assessment

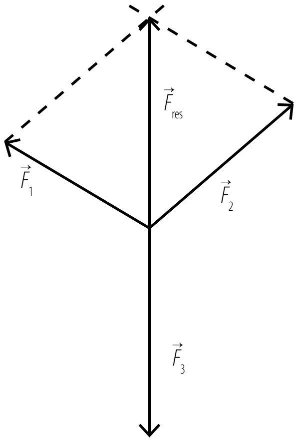
G

Determine the resultant of three non-linear force vectors

Precautions:

- The force board must be vertical.
- The string must be thin, light and non-elastic.
- The pulleys must run freely without friction and in the same plane.
- The mass pieces must not touch the force board.
- Use a plane mirror to mark the position of the strings to eliminate the error of parallax.

The resultant of $\vec{F}_1$ and $\vec{F}_2$, $\vec{F}_{res}$, is shown in the diagram; $\vec{F}_{res}$ should be the same magnitude as $\vec{F}_3$, but opposite in direction.



1. When three forces are in equilibrium, the system is stationary. Then the resultant will be zero.
2. $\vec{F}_3$ is the equilibrant of forces $\vec{F}_1$ and $\vec{F}_2$, because it keeps the other two force in equilibrium. The equilibrant is equal to the resultant of any two forces, but in opposite direction.
3. The equilibrant of forces $\vec{F}_1$and $\vec{F}_3$ is $\vec{F}_2$.
4. The resultant should be zero.

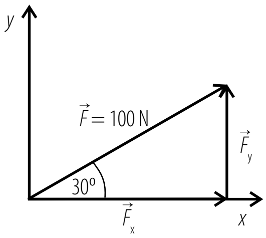
Conclusion: The resultant should be zero.

Checklist of teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Stays focused on experiment			
Understands experimental method			
Follows method in orderly manner			
Uses time efficiently			
Uses equipment correctly			
Helpful/ valuable member of group			
Answers simple questions during experiment			
Records results correctly			
Draws scale diagram correctly			

Test yourself 5 (LB p. 35)

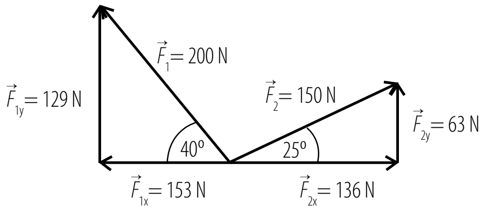
1 a)



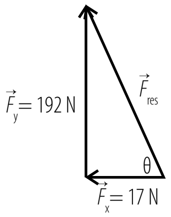
b) $F_x = 100 \text{ N} \cos 30° = 87 \text{ N}$
$F_y = 100 \text{ N} \sin 30° = 50 \text{ N}$

Test yourself 6 (LB p. 37)

1

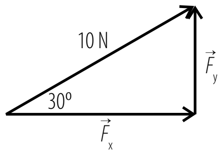


Resolve F_1: F_{1x} = 200 N cos 40° = 153 N
F_{1y} = 200 N sin 40° = 153 N
Resolve F_2: F_{2x} = 150 N cos 25° = 136 N
F_{2y} = 150 N sin 25° = 63 N
$\vec{F}_x = \vec{F}_{1x} + \vec{F}_{2x}$ = 153 N + (–136 N) = 17 N left/west
$\vec{F}_y = \vec{F}_{1y} + \vec{F}_{2y}$ = 129 N + 63 N = 192 N up/north

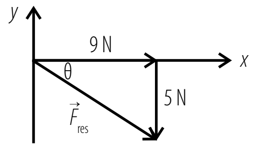


$F_{res} = \sqrt{(17\text{ N})^2 + (192\text{ N})^2}$ = 193 N
Direction: tan θ = $\frac{192}{17\text{ N}}$ = 11
∴ θ = 85°
Resultant = 193 N 5° west of north/ north 5° west/ 355°

2 Resolve the 10 N force at the 30° angle into its components.

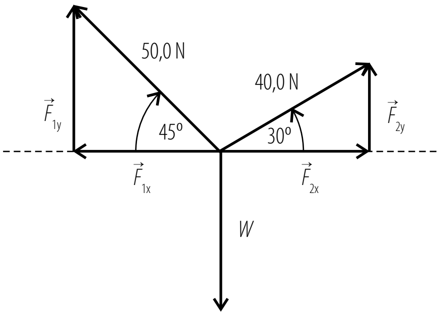


F_x = 10 N cos 30° = 9 N
F_y = 10 N sin 30° = 5 N
Add all the horizontal components: 10 N + (–10 N) + 9 N = 9 N
Add all the vertical components: 5 N + (–10 N) = –5 N



Calculate the magnitude of the resultant: $F_{res} = \sqrt{(9\text{ N})^2 + (5\text{ N})^2}$ = 10 N
Calculate direction of resultant: tan θ = $\frac{5\text{ N}}{9\text{ N}}$ = 0,6
∴ θ = 29°
$\vec{F}_{res}$ = 10 N direction 119° or 29° south of east

3 a)

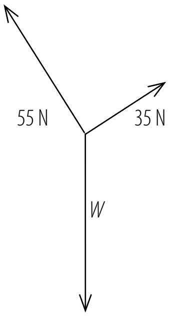


b) $F_{1y} = 50,0 \sin 45° = 35,4$ N
$F_{2y} = 40,0 \sin 30° = 20,0$ N

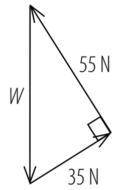
c) $W = 35,4$ N + 20,0 N = 55,4 N vertically down

d) Equilibrant of force W

4 a)



b)

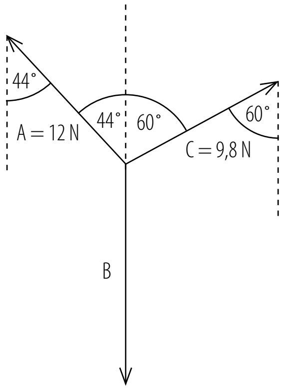


c) weight = $\sqrt{(35 \text{ N})^2 + (55 \text{ N})^2} = 65$ N

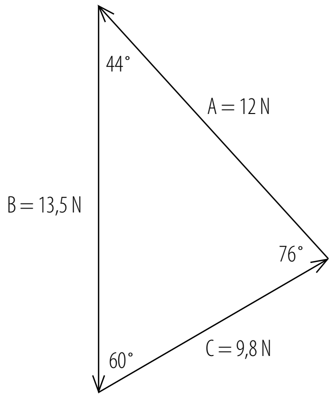
5 a) The system is not moving, so there is no resultant. The system must therefore be in equilibrium.

b) Force C is the equilibrant of forces A and B, because C keeps A and B in equilibrium.

c)



d)



Teacher demonstration

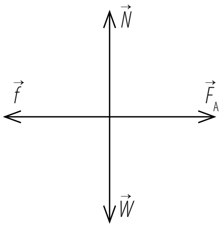
Demonstrate the difference between static and dynamic friction

Cut a rubber band so that you have a long string of rubber. Tie one end to a shoe and place it on a long table or the floor. Pull gently on the other end of the rubber band and increase your pulling force until the shoe begins to move. Use a ruler to measure how long the rubber band stretches before the shoe begins to move. This measurement is an indication of the maximum static friction.

As the shoe starts to move, measure how far the rubber band stretches as you keep the shoe moving. This is an indication of the kinetic friction of the shoe. You should find that the rubber band has not stretched as far as it did when the shoe was stationary, just before movement started.

Pour water on the floor/table and pull the shoe across the floor/table. Show that the extension of the rubber band changes as the surfaces change.

Test yourself 7 (LB p. 44)



The box does not move vertically, so $N = W = 100$ N

a) If there is no applied force, there is no movement and the friction is zero: $f = 0$

b) The static frictional force opposes the applied force.

$f_s^{max} = \mu_s N$

$= 0{,}40 \times 100$ N

$= 40$ N

The applied force of 20 N is not enough to overcome the friction and the box will not move.

c) The applied force balances the frictional force exactly and there is no additional force to move the box, so the box will not move.

d) A 60 N force will overcome the friction and the box will move forward. The kinetic friction is:

$f_k = \mu_k N$

$= 0{,}30 \times 100$ N

$= 30$ N

30 N of the applied force is used to overcome the kinetic friction.

LB p. 47 »

Activity 2 Recommended investigation for informal assessment

G

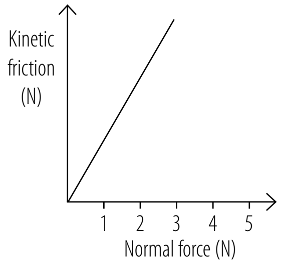
Investigate friction

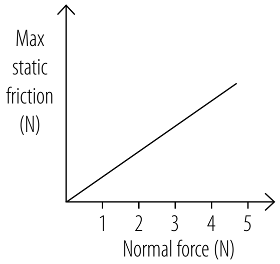
Kind of material, weight, roughness and lubricants can all have an impact on the amount of friction.

Investigation 1: Investigate the relationship between normal force, maximum static friction and kinetic friction

Follow the method in the Learner's Book.

5





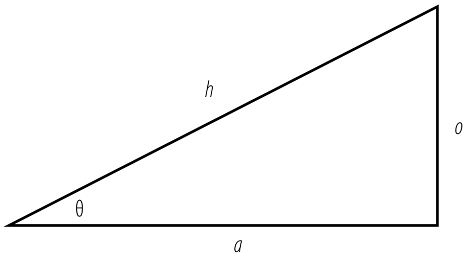
6 The normal force is directly proportional to the maximum static frictional force, and also to the kinetic frictional force.

Investigation 2: Investigate the effect of different surfaces on maximum static friction by keeping the object the same.

A wet floor is slippery because the layer of water acts as a lubricant between your shoes and the floor. Oil and grease are used to lubricate moving parts in engines and machines to reduce friction. This reduces wear and tear.

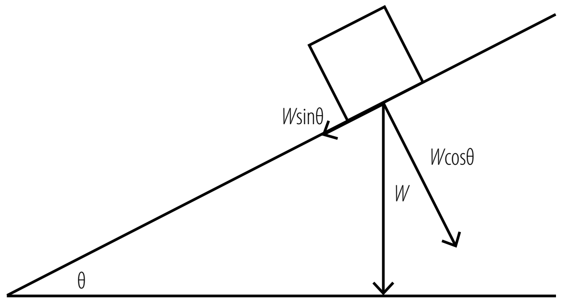
Investigation 3: Determine the coefficients of static friction by using a ramp

Explanation: From the diagram on page 25 of the Learner's Book, we have:



$\sin\theta = \frac{o}{h}$ and $\cos\theta = \frac{a}{h}$; therefore, $\tan\theta = \frac{\sin\theta}{\cos\theta}$

The weight has two components: $W\cos\theta = N$, and $W\sin\theta$ = pulling force of gravity down the ramp



When the object just starts to slide down the ramp, the pulling force of the weight = frictional force:

$W\sin\theta = f_s^{max}$, but $f_s^{max} = \mu_s N$ and $N = W\cos\theta$

and so, $W\sin\theta = \mu_s W\cos\theta$, and $\mu_s = \frac{W\sin\theta}{W\cos\theta} = \tan\theta = \frac{o}{a}$

We can therefore determine the coefficient of static friction from either the angle of inclination, or from the lengths of the sides if they are known.

Checklist for teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Stays focused on experiment/demonstration			
Understands experimental method			
Follows method in orderly manner			
Uses time efficiently			
Uses equipment correctly			
Helpful/ assists teacher/ valuable member of group			
Answers simple questions during experiment/ demonstration			
Records results correctly in suitable table			
Draws graphs correctly			
Explains results correctly			
Writes a well structured conclusion			

Test yourself 8 (LB p. 52)

1 a) i) The pencil continues to move forwards in the direction that the car was moving, and will probably hit the windscreen.
ii) The pencil will remain at rest, but the car moves out underneath it, so the pencil appears to move backwards.
b) Newton's First Law of Motion
c) Property of inertia

LB p. 55 »

Activity 3 Prescribed experiment for formal assessment

G

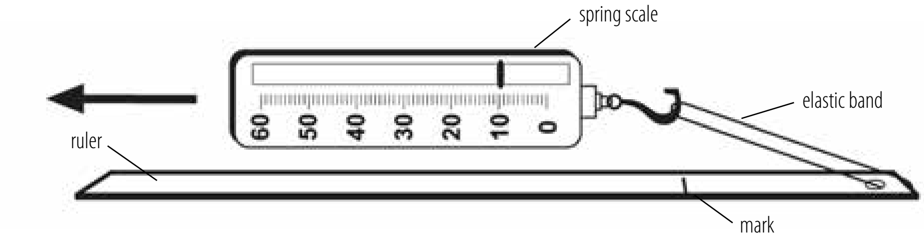
Verify Newton's Second Law

The trolley experiments can be used to investigate the relationship between applied force, acceleration and mass of an object. Learners can derive Newton's Second Law from their experimental results.

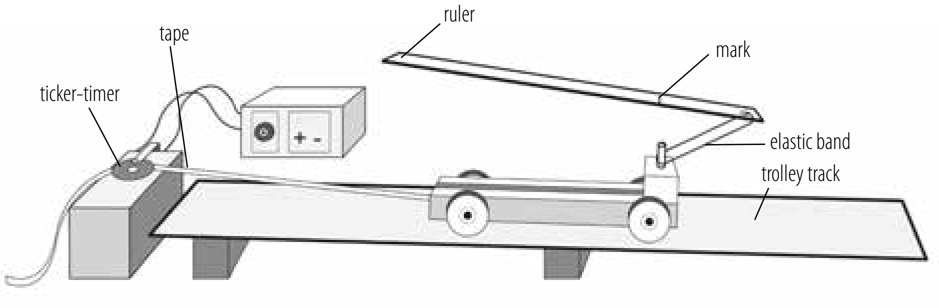
Experimental procedure

Prepare the apparatus

- Cut four equal lengths of elastic and tie a loop at each end. Alternatively use elastic bands of the same length. Hook one end of each elastic band in turn to a corner of a ruler and the other end to a spring balance. Stretch to a convenient length and mark the stretched length on the ruler. Ensure that all four elastic bands produce the same force on the spring balance when stretched to the same length on the ruler.



- Assemble a trolley track, trolley, ticker-timer with a length of tape, and wooden blocks or other objects to support the trolley track.



- Lift one end of the track with blocks until the trolley rolls without accelerating.
- Determine the trolley mass with a mass meter. Load the trolley with mass pieces to make its mass exactly 1kg. This will make calculations easier. Stick the mass pieces to the trolley with Prestik. Assemble a 1 kg and a 2 kg mass piece. These are the easiest to load onto the trolley to obtain total masses of 2 kg, 3 kg and 4 kg. Alternatively use bricks of equal mass.

Investigation 1: Determine the relationship between force and acceleration on an object with constant mass

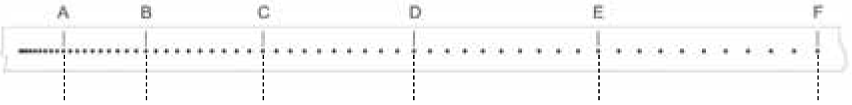
Method

- Switch on the ticker-timer.
- Using one elastic band, push the trolley with constant force across the trolley track. Make sure that neither the ruler nor a hand touches the trolley. The learners need to practice to make sure they are doing it correctly before they take results.
- Repeat with two, three and four identical elastic bands.
- Label the ticker-tapes.

Results

Process each ticker-tape as follows:

- Inspect the tape. Find a starting point where the dots are easily distinguishable. Mark every 10th dot A, B, C, and so on. Measure the distances between every 10th dot.



- If the ticker-timer was connected to the mains, the frequency is 50 Hz. That means that the time taken to make 10 dots is 0,2 s. Other battery-operated ticker-timers are also available. Make sure you know what the frequency setting on the ticker-timer is before working out the period. Learners used ticker-tapes in Grade 10 to calculate velocity and acceleration. Make sure that they remember how to do these calculations.

Investigation 2: Determine the relationship between mass and acceleration when a constant force is applied to an object

Method

- Use the same apparatus and method as for the previous experiment.
- Hook two elastic bands to the peg of the trolley. (Test with the largest mass to see if two bands still produce an acceleration. If not, use three bands.)
- Mark two ticker-tapes with dots by using the constant force to accelerate the trolley on its own, and then loaded with 1 kg, 2 kg and 3 kg masses. Alternatively use bricks.

Results

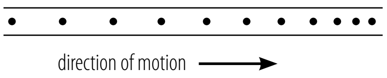
- Process the results in the same way as in the previous experiment.

Answers to the questions in the Learner's Book

1 The trolley has constant motion. The dots are evenly spaced and the trolley must be moving at a constant velocity – it travels equal distances in equal time intervals.

2 The trolley is not accelerating; therefore the net force must be zero.

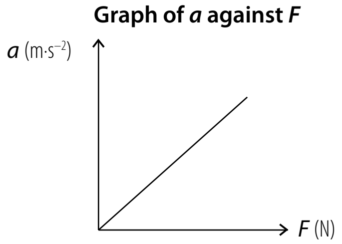
3 Accelerated motion:



4 The force is supplied by the elastic bands. More elastic bands provide a larger force, resulting in a greater acceleration. The gradient of the graphs indicates the magnitude of the acceleration. A steeper gradient implies a greater acceleration.

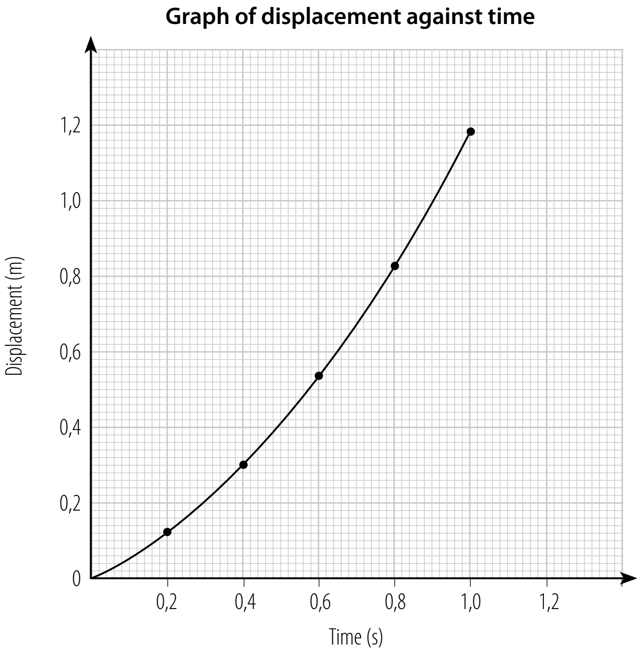
5 Mathematical relationship: The graphs are straight lines through the origin. The relationship between v and t is linear, so $v \propto t$, or $v = kt$ where k, the constant, represents the gradient of the graph. This is similar to the familiar form for a straight line, $y = mx$, where m is the gradient.

6


Graph of *a* against *F*

7 a)

Time (s)	0,2	0,4	0,6	0,8	1,0
Displacement (m)	0,125	0,303	0,541	0,833	1,186


Graph of displacement against time

The shape of the graph is a parabola. This is expected since we know that displacement and time are related by $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$; thus $\Delta x \propto \Delta t^2$.

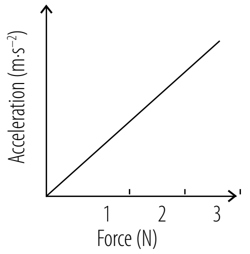
b) Results as in table below:

Interval	**Displacement s (m)**	**Time between 10 dots Δt (s)**	**Average velocity $\bar{v} = \frac{\Delta x}{\Delta t}$ (m·s^{-1})**	**Instantaneous velocity v (m·s^{-1})**	**Change in velocity Δv (m·s^{-1})**	**Acceleration $a = \frac{\Delta v}{\Delta t}$ (m·s^{-2})**
A to C	0,125 + 0,178 = 0,303	0,2	0,303 ÷ 0,4 = 0,758			
B				0,758		
B to D	0,178 + 0,238 = 0,416	0,2	0,416 ÷ 0,4 = 1,040		1,040 – 0,758 = 0,282	0,282 ÷ 0,2 = 1,41
C				1,040		
C to E	0,238 + 0,292 = 0,530	0,2	0,530 ÷ 0,4 = 1,325		1,325 – 1,040 = 0,285	0,285 ÷ 0,2 = 1,43
D				1,325		
D to F	0,292 + 0,353 = 0,645	0,2	0,645 ÷ 0,4 = 1,613		1,613 – 1,325 = 0,288	0,288 ÷ 0,2 = 1,44
E				1,613		

Experimental error

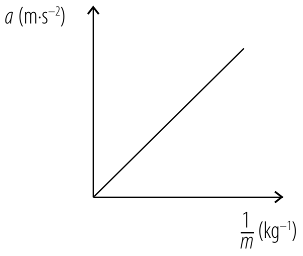
Notice that there is a slight increase in acceleration as the velocity increases. Explain to the learners that there is always a certain amount of experimental error in all experiments. It is important that the method is followed exactly and that measurements are done as accurately as possible. We also repeat experiments at least three times to determine the possible variation. There is a distinction between the contributing errors, statistical (which is inherent in the measuring instruments used, which is usually due to incorrect calibration but is reduced with more trials), and systematic (which is more a calibration issue including some friction not accounted for). The percentage deviation in the recorded values is acceptable for this type of experiment.

9 **Graph of force (number of elastic bands) against acceleration**



10 The shape of the graph is a hyperbola. This is expected, since, according to Newton, acceleration and mass are inversely proportional, i.e. $y \propto \frac{1}{x}$ or $y = \frac{k}{x}$. We can confirm this by plotting a graph of a vs. $\frac{1}{m}$.

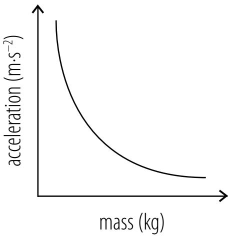
11 **Graph of a against $\frac{1}{m}$**



12 The shape of the graph is a straight line through the origin with a positive gradient.

13 The acceleration is inversely proportional to the mass: $a \propto \frac{1}{m}$.
From the straight line graph we know that the variables on the two axes are related by $a = k'\frac{1}{m}$, where k' is a constant representing the constant gradient (similar to $y = mx + c$). Measure the gradient and convince yourself that the gradient is F, and thus $a = \frac{F}{m}$, and that the intercept is zero.

14



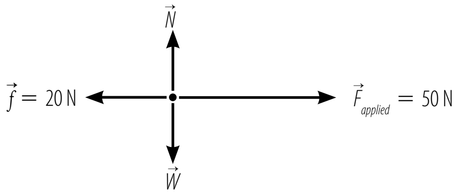
15 Mathematical relationship: $a \propto \frac{F}{m}$

16 Newton's Second Law of Motion: When a net force is exerted on an object, it causes the object to accelerate in the direction of the force. The acceleration is directly proportional to the force and inversely proportional to the mass of the object.

Test yourself 9 (LB p. 62)

1 a) Frictional force is 20 N backwards. The applied force is balanced by the frictional force and there is no net force to accelerate the wheelbarrow.

b) Free-body diagram:



c) $\vec{F}_{net} = F_{applied} + (-f) = 50 \text{ N} + (-20 \text{ N}) = 30 \text{ N}$ to the right

$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{30 \text{ N}}{30 \text{ kg}} = 1{,}0 \text{ m·s}^{-2}$ to the right/forward/direction of motion

2 a) $a = \frac{F_{net}}{m} = \frac{-9{,}00 \times 10^3 \text{ N}}{1{,}50 \times 10^3 \text{ kg}} = -6{,}00 \text{ m·s}^{-2}$

b) $v_f = 0 \text{ m·s}^{-1}$; $v_i = 30 \text{ m·s}^{-1}$; $a = -6{,}00 \text{ m·s}^{-2}$

$v_f^2 = v_i^2 + 2a\Delta x$

$(0 \text{ m·s}^{-1})^2 = (30 \text{ m·s}^{-1})^2 + 2 \times (-6{,}00 \text{ m·s}^{-2}) \Delta x$

$\therefore \Delta x = 75 \text{ m}$

c) $v_f = v_i + a\Delta t$

$0 \text{ m·s}^{-1} = 30 \text{ m·s}^{-1} + (-6{,}00 \text{ m·s}^{-2})\Delta t$

$\therefore \Delta t = 5{,}0 \text{ s}$

d) The acceleration will be smaller, since a is inversely proportional to the mass of the minibus (NII). The driver needs to apply his brakes 25 m sooner if he wants to stop his taxi in time.

The extra mass will be 10 × 50 = 500 kg.

The total mass will be $1{,}50 \times 10^3 + 500 = 2{,}00 \times 10^3$ kg.

His negative acceleration with 10 passengers will be:

$a = \frac{F_{net}}{m} = \frac{-9{,}00 \times 10^3 \text{ N}}{2{,}00 \times 10^3 \text{ kg}} = -4{,}50 \text{ m·s}^{-2}$

His stopping distance will now be:

$v_f = 0 \text{ m·s}^{-1}$; $v_i = 30 \text{ m·s}^{-1}$; $a = -4{,}50 \text{ m·s}^{-2}$

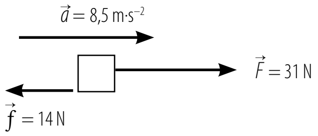
$v_f^2 = v_i^2 + 2a\Delta x$

$(0 \text{ ms}^{-1})^2 = (30 \text{ ms}^{-1})^2 + 2 \times (-4{,}50 \text{ m·s}^{-2}) \Delta x$

$\therefore \Delta x = 100 \text{ m}$

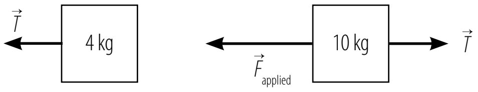
3 a) The pulling force balances the frictional force:
$f = F = 14$ N against direction of motion

b)



$F_{\text{net}} = F - f = 31\text{ N} - 14\text{ N} = 17\text{ N}$
$m = \frac{F_{\text{net}}}{a} = \frac{17\text{ N}}{8{,}5\text{ m·s}^{-2}} = 2{,}0\text{ kg}$

4 a)



b) Take the direction to the right as positive.
4 kg block: $-T = 4a$
10 kg block: $F_{\text{net}} = -F_{\text{applied}} + T = 10a \Rightarrow -28 + T = 10a$
Substitute $-T = 4a$ into expression for 10 kg block:
$-28 - 4a = 10a$
$\therefore 14a = -28 \Rightarrow a = -2\text{ m·s}^{-2}$

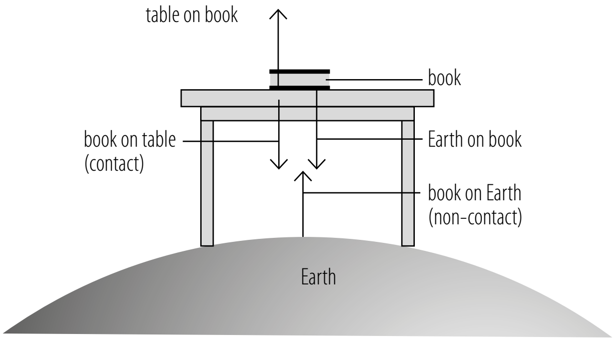
c) Net force on the 10 kg block: $\vec{F}_{\text{net}} = ma = 10\text{ kg} \times (-2\text{ m·s}^{-2})$
$= 20$ N to the left

d) Force T on the 4 kg block: $-T = 4\text{ kg} \times (-2\text{ m·s}^{-2})$
$\therefore \vec{T} = 8$ N to the left
The 4 kg and 10 kg blocks form a force pair: force $\vec{T}$ that the 4 kg block exerts on the 10 kg block is the same force $\vec{T}$ that the 10 kg block exerts on the 4 kg block, but opposite in direction.
Force $\vec{T}$ on the 10 kg block = 8 N to the right

e) $v_i = 20\text{ m·s}^{-1}$; $v_f = -10\text{ m·s}^{-1}$; $a = -2\text{ m·s}^{-2}$
$v_f = v_i + a\Delta t$
$-10\text{ m·s}^{-1} = 20\text{ m·s}^{-1} + (-2\text{ m·s}^{-2})\,\Delta t$
$\therefore \Delta t = \frac{-30\text{ m·s}^{-1}}{-2\text{ m·s}^{-2}} = 15\text{ s}$

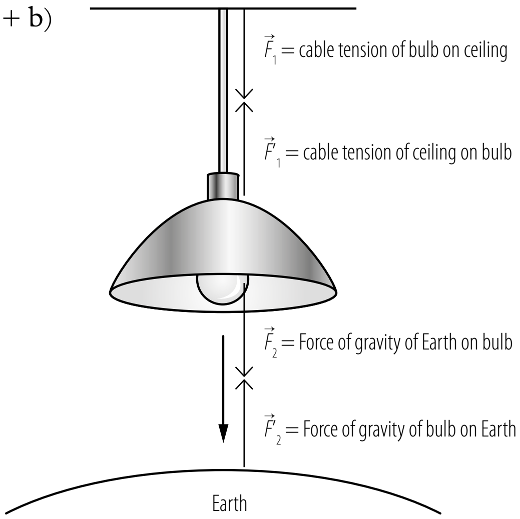
Test yourself 10 (LB p. 66)

1 The book and the table form a force pair that is in contact. The book and the Earth form a force pair that acts over a distance.



2 The two forces acting on the bulb (F'_1 and F_2) are the same size, so the bulb is in equilibrium.

a) + b)



Test yourself 11 **(LB p. 70)**

1 According to Newton's Law of Universal Gravitation: $F = G\frac{Mm}{d^2}$, where F = your weight. The factors that determine your weight are therefore: m (your mass), M (mass of the moon) and d (the radius of the moon).

2 $F = 1\ 000$ N; $m_1 = 100$ kg; $m_2 = 6{,}00 \times 10^{24}$ kg; $r = ?$

$1\ 000\ \cancel{\text{N}} = 6{,}67 \times 10^{-11}\ \cancel{\text{N}}\cdot\text{m}^2\cdot\cancel{\text{kg}^{-2}}\ \frac{100\ \cancel{\text{kg}} \times (6{,}00 \times 10^{24}\ \cancel{\text{kg}})}{r^2}$

$\therefore r^2 = 4{,}00 \times 10^{13}\ \text{m}^2$

$\therefore r = 6\ 326\ 136\ \text{m} = 6{,}33 \times 10^3\ \text{km}$

Test yourself 12 **(LB p. 73)**

1 a) The attractive force is the man's weight.
$\vec{F} = \vec{W} = m\vec{g} = 80{,}0\ \text{kg} \times 9{,}80\ \text{m}\cdot\text{s}^{-2} = 784$ N downwards

b) The magnitude of the attractive force that the Earth exerts on the man is equal to the magnitude of the force that the man exerts on the Earth (Newton III).

c) $d^2 = G\frac{mM}{F} = 6{,}67 \times 10^{-11}\ \cancel{\text{N}}\cdot\text{m}^2\cdot\cancel{\text{kg}^{-2}}\ \frac{80{,}0\ \cancel{\text{kg}} \times (6{,}00 \times 10^{24}\ \cancel{\text{kg}})}{784\ \cancel{\text{N}}}$

$= 4{,}08 \times 10^{13}\ \text{m}^2$

$\therefore d = 6{,}39 \times 10^6\ \text{m}$

2 a) $F = G\frac{Mm}{d^2} = (6{,}67 \times 10^{-11}\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{kg}^{-2}})\ \frac{80{,}0\ \cancel{\text{kg}} \times (\frac{1}{80} \times 6{,}00 \times 10^{24}\ \cancel{\text{kg}})}{(\frac{1}{4} \times 6{,}40 \times 10^6\ \cancel{\text{m}})^2}$
$= 156$ N

or, using ratios (if the mass and radius of the Earth is not known),

$g_E = G\,\frac{M_E}{{d_E}^2}$ and $g_M = G\,\frac{(\frac{1}{80})M_E}{(\frac{1}{4}d_E)^2} = G(\frac{1}{80})(\frac{16M_E}{{d_E}^2})$

$g_M = G(\frac{16}{80})(\frac{M_E}{{d_E}^2}) = (\frac{16}{80})\,g_E$

weight on moon $= mg_M = m \times (\frac{16}{80})\,g_E = (\frac{1}{5})\,mg_E = 156$ N

b) The new force is $F = G\frac{mM}{(3d)^2}$, which is $\frac{1}{9}$ of the original weight

$= \frac{156}{9} = 17{,}4$ N

3 g on the Earth is $g_E = G\,\frac{M_E}{{d_E}^2}$

On Saturn the mass $M_S = 90\ M_E$ and the radius $d_S = 10\ d_E$
Substitute these values in the equation:

$g_S = G\,\frac{90M_E}{(10d_E)^2} = G\,\frac{90M_E}{100{d_E}^2} = 0{,}90\ G\,\frac{M_E}{{d_E}^2}$

but $G\,\frac{M_E}{{d_E}^2} = g_E = 9{,}8\ \text{m}\cdot\text{s}^{-2}$

Therefore, $g_S = 0{,}90g = 0{,}90 \times 9{,}8\ \text{m·s}^{-2} = 8{,}8\ \text{m·s}^{-2}$
The gravitational acceleration on Saturn is $8{,}8\ \text{m·s}^{-2}$

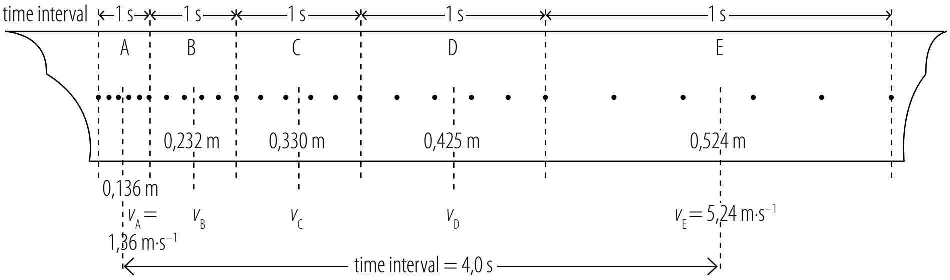
LB p. 74

Activity 4 Experiment

Verify the value for *g*

Use the method in the Learner's Book.

Tape section	**Time at start (s)**	**Time interval (s)**	**Length of section (m)**	**Velocity (m·s^{-1})**
A	0,0	0,10	0,136	$v_A = 1{,}36$
B	0,1	0,10	0,232	$v_B = 2{,}32$
C	0,2	0,10	0,330	$v_C = 3{,}30$
D	0,3	0,10	0,425	$v_D = 4{,}25$
E	0,4	0,10	0,524	$v_E = 5{,}24$



8 Follow these steps to calculate the value of *g*:

a) Calculate the velocities $v_A - v_E$:
From the table $v_A = 1{,}36\ \text{m·s}^{-1}$ and
$v_E = 5{,}24\ \text{m·s}^{-1}$

b) Calculate the gravitational acceleration:

$$g = \frac{v_E - v_A}{0{,}40} = \frac{5{,}24 - 1{,}36}{0{,}40} = 9{,}7\ \text{m·s}^{-2}$$

Motion equations require instantaneous velocity. But for constant acceleration (linear relationship between *v* and *t*) the instantaneous *v* is equal to the average *v* at a time halfway into the time interval (from the geometry of triangles). So the four time intervals are three 5-dot intervals + two $\times \frac{1}{2}$ intervals.

Hand out mass pieces with different shapes and masses. Each group can determine the value for *g* of a different mass piece. Ask the learners to compare the results of all the experiments and discuss the effects of friction on the experimental values.

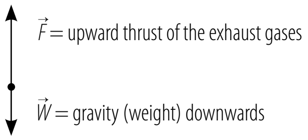
9 a) Round compact mass pieces should all give round about the same answer for *g*. Mass pieces with a flat shape will experience more air friction and their values for *g* will be lower. In general, in the absence of dissipative frictional forces, *g* is not dependent on the shape or the mass of the object that accelerates towards the Earth.

b) The values will generally be smaller than the theoretical value, because air friction and friction of the ticker tape through the timer will hold the mass piece back and not allow it to accelerate at the expected value for *g*. More accurate results can be obtained by minimising friction.

A more accurate way to determine *g* is to use the data to draw a *v-t* graph where *v* is the average velocity over the 5-dot intervals and *t* is halfway in the time intervals. The acceleration *g* is then the gradient of the straight line through the data points. In this experiment, the data points fall very accurately on the straight line, so the formula used here is also just that of the gradient.

Test yourself 13 **(LB p. 77)**

1 a)



b) $\vec{F}_{net} = ma = 5{,}00 \times 10^3 \text{ kg} \times 3{,}00 \text{ m·s}^{-2} = 1{,}50 \times 10^4$ N upwards

c) $\vec{F}_{up} = W + F_{net} = 4{,}90 \times 10^4 \text{ N} + 1{,}50 \times 10^4 \text{ N}$
$= 6{,}40 \times 10^4$ N upwards

2 a) The gravity on the skydiver is determined by the skydiver's mass, the mass of the Earth and the distance between the skydiver and the centre of the Earth.

b) As the skydiver's velocity increases, the force of the air friction upwards also increases. His weight downwards remains the same, so the net force downwards decreases. The skydiver's acceleration will then also decrease ($F \propto a$).

c) $\vec{F}_{net} = ma = 80 \text{ kg} \times 20 \text{ m·s}^{-2} = 1{,}6 \times 10^3$ N upwards

d) Terminal velocity is the constant maximum velocity reached by a falling object.

e) The skydiver reaches terminal velocity when the net force on him in the vertical direction is zero. Here the downward gravitational force is balanced by the upward force due to air resistance.

3 a) 2 kg block: Assume that the two connected blocks will move together towards the right with an acceleration of *a*, and choose that to be the positive direction. So, $T - (2 \times 9{,}8) = 2a$.
4 kg block: $(4 \times 9{,}8) - \text{T} = 4a$.
The *T*'s are equal (NIII), so combined it gives you an expression of
$a = \frac{(4 - 2) \times 9{,}8}{(4 + 2)} = 3{,}3 \text{ m·s}^{-2}$
You will notice that the *T* forces can be treated as internal forces, much like intermolecular forces holding the atoms and molecules of the blocks together. This allows us to treat the two blocks as a single system/combined mass experiencing two opposite forces i.e. their weights. The solution simplifies tremendously, but be very careful as this simplification can only be made if you are sure that there are no other forces acting on the individual masses not part of action-reaction pairs like *T*!

b) $\vec{F}_{net} = 39{,}2 + (-19{,}6) = 19{,}6$ N towards the pulling force
$\vec{a} = \frac{F_{net}}{m} = \frac{19{,}6 \text{ N}}{2 \text{ kg}}$
$= 9{,}8 \text{ m·s}^{-2}$ towards the pulling force

LB p. 80 »

Activity 5 Extension activity

P

Investigate circular motion and satellites

1 Another sport using centripetal force is discus. A slingshot is also under centripetal force. The moment you release the sling, the pellet will

continue at a tangent to the circle according to NI (inertia), and not radially outwards.

2 No. There is no mountain high enough to exclude the effect of the atmosphere and its drag as a factor.

3 When the speed of the object is correct, it remains in orbit. Gravity is constantly pulling towards the centre of the Earth, but at the same time the surface of the Earth is curving away below the object. The shell continues along a circular path, called its orbit, around the Earth.

When the speed of the object is too low, it does not remain in orbit; as before, gravity is constantly pulling towards the centre of the Earth, but now the surface of the Earth is not curving away as fast below the object. The shell does not continue along a circular path, but falls back to the Earth.

4 The force of gravity acts on a satellite.

5 The moon takes 28 days to orbit the Earth.

6 A low-orbit satellite must maintain a speed of 8 $km \cdot s^{-1}$.

7 The satellite must reduce its speed in order to orbit the moon. The force on the satellite orbiting the moon will be less than that on a satellite orbiting the Earth. For a satellite to maintain its position in orbit, it must balance its speed with its acceleration towards the body it is orbiting. Therefore, the speed for a satellite that stays in orbit around the moon is less than that of a satellite that orbits Earth.

8 Geostationary satellites need to maintain their relative positions towards the Earth because various detection/receiver devices on the Earth are pointed towards them and are in fixed positions. If geostationary satellites did not maintain their position in relation to the Earth, these devices would have to be adjusted constantly.

9 The spacecraft orbits the Earth under the pull of gravity. Therefore, while the astronauts are in the vicinity of the Earth, they will experience gravity, although weaker than on the Earth's surface.

10 If the astronauts and their spacecraft did not experience the Earth's pull, they would not orbit at all, but disappear into space at a tangent to the orbit.

11 Free-fall. Because the spacecraft and the astronauts have the same acceleration, they fall at the same rate, and the astronauts never reach the floor of the spacecraft. Being weightless while in orbit is, therefore, the same as being in free-fall – you are moving freely under the pull of gravity; the only force acting on you is your weight.

12 When the lift cable breaks and the passenger and the lift are in free-fall.

13 Learners' own opinions.

LB p. 81 »

Activity 6 Extension activity

G I

Evaluate the relevance of Einstein for school learners

Learners who have a natural interest in science may come up with wonderful ideas and arguments. Please encourage learners to express their views, even if you do not agree with them. The important principle that must be stressed is the Correspondence Principle which states that Einstein's Laws do not contradict Newton's Laws, but broaden their perspective. Popular science often write about Einstein, and learners should also find out about this great scientist in the classroom.

Albert Einstein – some biographical notes

Einstein developed many theories, including the theory of relativity

- 1879: born in Germany, 14 March
- 1895: failed an examination that would have allowed him study for a diploma in electrical engineering at the Zurich Polytechnic
- 1900: graduated from Zurich Polytechnic as a secondary school teacher of mathematics and physics
- 1902: while employed at the Swiss patent office in Bern, completed an astonishing range of publications in theoretical physics
- 1905: submitted one of his scientific papers to the University of Zurich to fulfil the requirements for a PhD or doctoral degree (used Planck's quantum hypothesis to describe visible electromagnetic radiation, or light; explained the photoelectric effect; formed the bases for much of quantum mechanics; proposed what is today called the special theory of relativity)
- 1907: proposed that if mass was equivalent to energy, then the principle of equivalence required that gravitational mass would interact with the apparent mass of electromagnetic radiation, which includes light
- 1909: was recognised throughout German-speaking Europe as a leading scientific thinker
- 1914: advanced to the post of Director of the Kaiser-Wilhelm Gesellschaft in Berlin; was professor of Theoretical Physics at the University of Berlin until 1933; remained a pacifist and did not support Germany's war aims
- 1915: published the definitive form of the general theory of relativity; $E = mc^2$ where E is the energy, m is the mass and c is the velocity of light
- 1921: received the Nobel Prize, not for relativity, but for his 1905 work on the photoelectric effect
- 1933: moved to the United States and abandoned his pacifism
- 1939: sent a letter to President Franklin D Roosevelt urging the United Stated to proceed to develop an atomic bomb before Germany did
- Later: until the end of his life sought a Unified Field Theory, whereby the phenomena of gravitation and electromagnetism could be derived from one set of equations
- 1955: died in USA, 18 April

Learner's Book page 82

Units 1–2 Summative assessment: Mechanics

TERM 1, MODULE 1

1 a) vector quantity
   b) normal force
   c) frictional force
   d) equilibrium
   e) inertia
   f) mass
   g) gravitational field
   h) weight
   i) mass

2 a) The equilibrant is equal in magnitude, *but acts in the opposite direction to the resultant*.
   b) *Force and weight* can be measured with a spring balance.

c) The magnitude of kinetic friction is *usually* smaller than that of the *maximum* static friction.

d) In a *free-body* diagram, the object of interest is drawn as a dot and all forces acting on it are drawn as arrows pointing away from the dot. / In a force diagram *the pictures of the objects are drawn with all the forces acting on them as arrows.*

e) The horizontal component of a vector *R* can be calculated using $R_x = R \cos \theta$

f) We wear seatbelts to protect us against our *inertia*.

g) $1 \text{ N} = 1 \text{ kg·m·s}^{-2}$

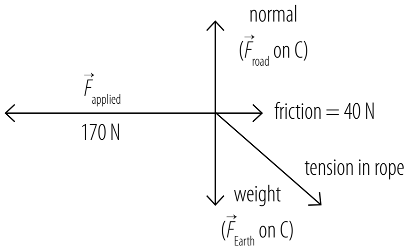
h) Newton's *Third* Law described action–reaction pairs.

i) '*g*' is *not* a universal constant and its value *will vary from place to place*.

j) According to Newton's Law of Universal Gravitation, the force between two objects is inversely proportional to *the square of the* distance between them.

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

4 a)



b) Take left as positive

$\vec{F}_{net} = \vec{F}_{applied} + \vec{f} + \vec{F}_{\text{hor. comp. of rope on C}} = m\vec{a}$

$ma = 170 \text{ N} + (-40 \text{ N}) + (-T \cos 30°)$

$240 \text{ kg} \times 0{,}3 \text{ m·s}^{-2} = 170 \text{ N} - 40 \text{ N} - T \cos 30°$

$T = \frac{58 \text{ N}}{\cos 30°} = 67 \text{ N}$

ii) $58 \text{ N} \longleftarrow\!\bullet\!\longrightarrow \vec{f}$

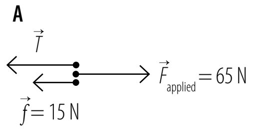
$\vec{F}_{net} = \vec{F}_{\text{hor. comp. of rope on W}} + \vec{f} = m\vec{a}$

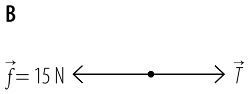
$80 \text{ kg} \times 0{,}3 \text{ m·s}^{-2} = 58 \text{ N} - f$

$\vec{f} = 58 \text{ N} - 24 \text{ N} = 34 \text{ N}$

$= 34$ N right / opposite to direction of motion

5 a)





b) Take the direction to the right as positive

A: $\vec{F}_{net} = \vec{F}_{applied} + \vec{T} + \vec{f} = m\vec{a}$

$65 \text{ N} + (-T) + (-15 \text{ N}) = 25 \text{ kg} \times a \Rightarrow 50 - T = 25a \ldots$ (1)

B: $\vec{F}_{net} = \vec{T} + \vec{f} = m\vec{a}$

$T + (-15 \text{ N}) = 25 \text{ kg} \times a \Rightarrow T - 15 = 25a \ldots$ (2)

Add expressions (1) and (2): $T - 15 + 50 - T = 25a + 25a$

$\therefore 50a = 35 \Rightarrow a = 0{,}70 \text{ m·s}^{-2}$

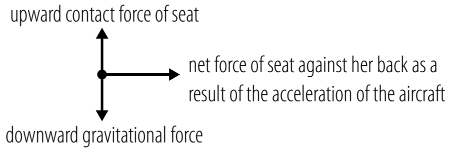
c) A: $50 - T = 25a$

$\therefore T = 50 - 25(0{,}70) = 33 \text{ N}$

B: $T - 15 = 25a$

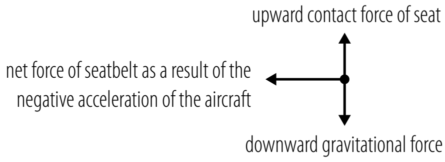
$\therefore T = 25(0{,}70) + 15 = 33 \text{ N}$

6 a)



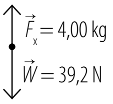
b) There are no forces acting on Ann in a backwards direction. According to Newton's Second Law ($a \propto F$), Ann experiences a net force forwards as a result of acceleration of the aircraft. She exerts an equal force backwards on the seat, as explained by Newton's Third Law ($F_1 = F_2$). Her inertia causes her to maintain her rest position (Newton's First Law), and this makes her feel as if she is being pushed back.

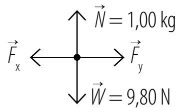
c)

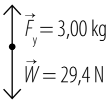


d) Ann is moving at the same velocity as the aircraft. When the aircraft slows down, she continues to move forward at her original velocity due to her inertia (Newton's First Law). To prevent her from being injured, she has to wear a seat belt. The seat belt exerts a force on her, which causes her to decelerate (Newton's Second Law). She exerts an equal force on the seat belt. Seat belts are manufactured from strong fabric to withstand these forces.

7 a)







b) Write expressions for each block; take anticlockwise as positive:

4,00 kg: $\vec{F}_{net} = \vec{F}_x + \vec{W} = m\vec{a}$

$-F_x + 39,2 \text{ N} = 4,00 \text{ kg} \times a \Rightarrow 39,2 - F_x = 4,00a \ldots \quad (1)$

1 kg: $\vec{F}_{net} = \vec{F}_x + \vec{F}_y = m\vec{a}$

$F_x - F_y = 1 \text{ kg} \times a \Rightarrow F_x - F_y = a \ldots \quad (2)$

3,00 kg: $\vec{F}_{net} = \vec{F}_y + \vec{W} = m\vec{a}$

$F_y - 29,4 \text{ N} = 3,00 \text{ kg} \times a \Rightarrow F_y - 29,4 = 3,00a \ldots \quad (3)$

Add expressions (1), (2) and (3):

$39,2 - 29,4 = 8,00a \therefore a = 1,23 \text{ m·s}^{-2}$

c) Tension at X: $39,2 - F_x = 4,00a \therefore F_x = 39,2 - 4,00(1,23) = 34,3$ N

Tension at Y: $F_y - 29,4 = 3,00a \therefore F_y = 29,4 + 3(1,23) = 33,1$ N

8 a) At constant velocity, the acceleration is zero, so the net force on the system = 0

The weight must be balanced by the tension in the cable.

$W = mg = 1,20 \times 10^3 \text{ kg} \times 9,80 \text{ m·s}^{-2} = 1,18 \times 10^4 \text{ N}$

The force exerted by the cable on the lift = $1,18 \times 10^4$ N

b) The lift must experience a negative acceleration to stop.

Take downwards as positive.

$v_i = 9 \text{ m·s}^{-1}$; $v_f = 0 \text{ m·s}^{-1}$; $\Delta x = 18$ m; $a = ?$

$v_f^2 = v_i^2 + 2a\Delta x$

$(0 \text{ m·s}^{-1})^2 = (9 \text{ m·s}^{-1})^2 + (2 \times a \times 18 \text{ m})$

$\therefore a = -2{,}25 \text{ m·s}^{-2}$

$\vec{a} = 2{,}25 \text{ m·s}^{-2}$ against the direction of motion/ opposite to the positive direction

c) $\vec{F}_{net} = \vec{F}_{applied} + \vec{W} = m\vec{a}$

$-F_{applied} + 1{,}18 \times 10^4 \text{ N} = 1{,}20 \times 10^3 \text{ kg} \times (-2{,}25 \text{ m·s}^{-2})$

$F_{applied} = 1{,}18 \times 10^4 \text{ N} + 2{,}70 \times 10^3 \text{ N} = 1{,}45 \times 10^4 \text{ N}$

MODULE 2: MATTER AND MATERIALS

Background information for Module 2

Grade 10 Matter and materials gave learners a good base to study chemistry, with core knowledge of the Periodic Table, the atom and bonding. We assume that learners know the commonly used elements, compounds and their symbols. It is a good idea to give them a test on the symbols as baseline assessment task.

This module explores chemical bonding in greater detail, with the emphasis on simple covalently bonded molecules and the intermolecular forces between them. We will also look at the water molecule, bonding between water molecules, and how the chemical properties of the molecule can be linked to the macroscopic physical properties of water.

The last unit on gases and thermal properties follows Module 3 (Waves, sound and light) in Term 2. The laws of Boyle, Charles and Gay-Lussac are investigated, as well as calculations using the Ideal Gas Equation.

Matter and materials makes up 15% of the total Grade 11 Physical Sciences curriculum. Units 1 and 2 will fill the last 16 hours of the first term, and Unit 3 uses 8 hours of Term 2. There are two experiments for informal assessment, one in each term, as well as a prescribed experiment for formal assessment. Although the experiment is done in Term 1, it will count towards the marks for Term 2.

Models in science: benefits and shortcomings

Models are used to explain difficult concepts and to make the concepts more tangible. We also use models to make and test predictions. Models are as accurate as the data that is used to create them.

Some models are scaled up – for example, models of the atom – and some are scaled down – for example, the solar system. Three-dimensional models of the atom or the solar system make it easy to grasp concepts that we cannot see.

It is quite common to have different models to explain the same phenomenon – for example, the electron-sea model and the band theory to explain bonding in metals.

Models can also be misleading, for example, by treating gas atoms as bouncing balls or electricity as flowing water. It is very important to convey to learners that we use these examples as analogies. Models do not necessarily represent an accurate picture.

Models are only as accurate as the current state of scientific knowledge on the subject. As more information becomes available, the model must be adjusted or a new one created.

Lewis diagrams

Lewis diagrams form an important part of Unit 1: Atomic combinations. The following steps can be used to write Lewis diagrams. These steps may help to write diagrams of more advanced examples.

Follow these steps to write the Lewis diagrams of compounds:

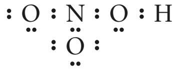
1 Write the chemical symbols of the elements in the compound. Place the bonded atoms next to each other. The central atom is usually the least electronegative.
2 Count the total number of valence electrons present.
3 Place dots around the symbols to represent the valence electrons. Allow for single bonds between the central atom and each of the surrounding atoms.
4 Complete the octets of the atoms bonded to the central atom. Remember that hydrogen can have a maximum of two electrons. Show lone pairs that might belong to atoms.
5 If the octet rule is not satisfied for the central atom, try adding double or triple bonds by using the lone pairs from the surrounding atoms. Make sure that the total number of valence electrons is present.

Example: Draw the Lewis structure of nitric acid HNO_3

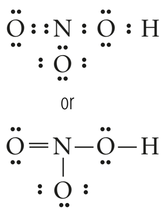
Step 1: Write the chemical symbols:
O N O H
  O

Step 2: Add the total valence electrons of N, O and H:
$5 + (3 \times 6) + 1 = 24$

Steps 3: and 4 Place dots around the symbols to allow for single bonds between all the bonded atoms. Add dots to satisfy the octet rule for all the O atoms. You will notice that all 24 electrons have been used.



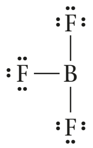
Step 5: We can see that the N atom has only 6 electrons. By moving a lone pair of one of the O atoms to make a double bond, the octet rule also satisfies the N atom.



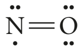
Exceptions to the octet rule

The octet rule applies mainly to Period 2 elements of the Periodic Table. A few molecules that do not follow the octet rule are:

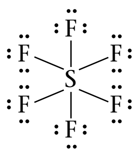
- an incomplete octet – for example, in BF_3 the B atom is surrounded by six valence electrons



- an odd number of electrons – for example, NO



- more than eight valence electrons around the central atom – for example, there are twelve electrons around sulfur in sulfur hexafluoride (SF_6)



Test yourself 1 **(LB p. 91)**

1 The core electrons are in the inner energy levels and cannot easily be removed from the atom. The valence electrons are the electrons in the highest occupied energy levels of atoms and interact with one another to form chemical bonds.

2 a) A Lewis dot symbol consists of the symbol of an element and one dot for each valence electron in an atom of an element.

b) $\mathrm{Na}\cdot$: 1 bond $\quad$ $:\ddot{\mathrm{O}}\cdot$: 2 bonds

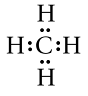
$\cdot\underset{\cdot}{\mathrm{Al}}\cdot$: 3 bonds $\quad$ $:\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}\cdot$: 1 bond

$\cdot\underset{\cdot}{\ddot{\mathrm{N}}}\cdot$: 3 bonds

Test yourself 2 **(LB p. 95)**

1 a) $\mathrm{H}:\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}:$

b)



$\begin{matrix} & \mathrm{H} & \\ \mathrm{H}: & \ddot{\underset{\cdot\cdot}{\mathrm{C}}} & :\mathrm{H} \\ & \mathrm{H} & \end{matrix}$

c) $\mathrm{H}:\mathrm{C}\vdots\vdots\mathrm{C}:\mathrm{H}$

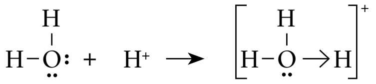
d) $\mathrm{H}:\underset{\cdot\cdot}{\ddot{\mathrm{O}}}:\underset{\cdot\cdot}{\ddot{\mathrm{O}}}:\mathrm{H}$

2 a) $:\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}\cdot + \cdot\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}: \longrightarrow :\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}:\underset{\cdot\cdot}{\ddot{\mathrm{Cl}}}:$

b) $\cdot\underset{\cdot}{\dot{\mathrm{C}}}\cdot + \cdot\underset{\cdot\cdot}{\ddot{\mathrm{S}}}\cdot + \cdot\underset{\cdot\cdot}{\ddot{\mathrm{S}}}\cdot \longrightarrow :\ddot{\mathrm{S}}::\mathrm{C}::\ddot{\mathrm{S}}:$

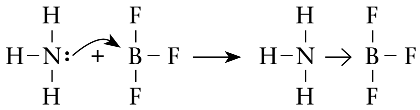
3 a) One of the atoms must have a lone pair of electrons that it can donate to another atom to form a bond.

b) i)

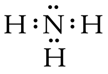


$\mathrm{H}-\underset{\cdot\cdot}{\overset{\overset{\displaystyle\mathrm{H}}{|}}{\mathrm{O}}}: + \mathrm{H}^+ \longrightarrow \left[\mathrm{H}-\underset{\cdot\cdot}{\overset{\overset{\displaystyle\mathrm{H}}{|}}{\mathrm{O}}}\rightarrow\mathrm{H}\right]^+$

The water molecule has two lone pairs of electrons on the oxygen atom. During the formation of the oxonium ion, one of the lone pairs bond with a hydrogen ion that has no electrons to form a coordinate covalent bond.

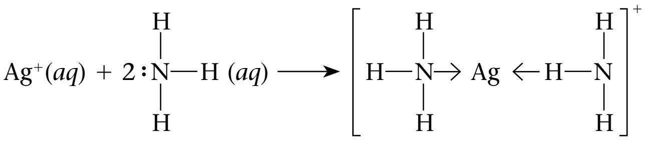
ii) 

The central N atom in ammonia has a lone pair of electrons. The central atom, B, in BF_3 has only six electrons around it. The lone pair of nitrogen can form a bond with the BF_3 molecule to form a coordinate covalent bond between NH_3 and BF_3.

4 a) 

$\mathrm{H}:\underset{\mathrm{H}}{\underset{\cdot\cdot}{\overset{\cdot\cdot}{\mathrm{N}}}}:\mathrm{H}$

b) NH_3 has a lone pair that it can share with the silver ion.

c) 

LB p. 100

Activity 1 Practical activity

Build molecular shapes

Allow learners to bring their own Jelly Tots and tooth picks to school or build the models yourself as a demonstration. Follow the pictures on pages 96–97 of the Learner's book.

3 Geometric shapes:
- two balloons show a linear arrangement
- three balloons show a trigonal planar arrangement
- four balloons show a tetrahedral arrangement
- five balloons show a trigonal bipyramidal arrangement
- six balloons show an octahedral arrangement.

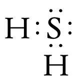
5 Geometric shapes:
- two balloons in colour A and one in colour B: bent or angular arrangement
- two balloons in colour A and two balloons in colour B: bent or angular arrangement
- three balloons in colour A and one balloon in colour B: trigonal pyramidal arrangement

6 Ideal molecular shapes

7 SO_2; NH_3; H_2O

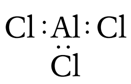
Test yourself 3 (LB p. 101)

1 H_2S: angular



$\mathrm{H}:\underset{\mathrm{H}}{\underset{\cdot\cdot}{\overset{\cdot\cdot}{\mathrm{S}}}}:$

$AlCl_3$: trigonal planar

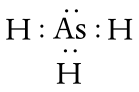


$\mathrm{Cl}:\underset{\mathrm{Cl}}{\underset{\cdot\cdot}{\mathrm{Al}}}:\mathrm{Cl}$

$ZnCl_2$: linear

$:\underset{\cdot\cdot}{\overset{\cdot\cdot}{\mathrm{Cl}}}:\mathrm{Zn}:\underset{\cdot\cdot}{\overset{\cdot\cdot}{\mathrm{Cl}}}:$

AsH_3: trigonal pyramidal

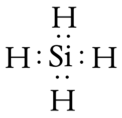


$$\begin{array}{ccc} & \cdot\cdot & \\ H: & As & :H \\ & \cdot\cdot & \\ & H & \end{array}$$

OF_2: linear

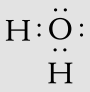
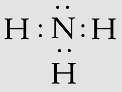
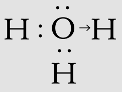
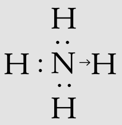
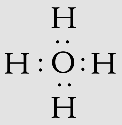
$$:\ddot{\underset{\cdot\cdot}{F}}:\ddot{\underset{\cdot\cdot}{O}}:\ddot{\underset{\cdot\cdot}{F}}:$$

SiH_4: tetrahedral



$$\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & Si & :H \\ & \cdot\cdot & \\ & H & \end{array}$$

2.

H_2O	bent/ angular	 $\begin{array}{cc} H: & \ddot{\underset{\cdot\cdot}{O}}: \\ & H \end{array}$
NH_3	trigonal planar	 $\begin{array}{ccc} & \cdot\cdot & \\ H: & N & :H \\ & \cdot\cdot & \\ & H & \end{array}$
H_3O^+	trigonal planar with coordinate bond	 $\begin{array}{ccc} & \cdot\cdot & \\ H: & O & \rightarrow H \\ & \cdot\cdot & \\ & H & \end{array}$
$NH_4{}^+$	tetrahedral with coordinate bond	 $\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & N & \rightarrow H \\ & \cdot\cdot & \\ & H & \end{array}$
CH_4	tetrahedral	 $\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & O & :H \\ & \cdot\cdot & \\ & H & \end{array}$

All the molecules have tetrahedral arrangements of the structural electron pairs around the central atoms. The CH_4 and NH_4^+ molecules show the tetrahedral shape because they have no lone pairs. In NH_4^+, the nitrogen atom donate its lone pair to the H^+ ion, which has no electrons. In both cases a non-polar molecule forms. NH_3 and H_3O^+ both have one lone pair on the central atom. The remaining structural electron pairs form bonds with H atoms and the resultant shape is trigonal pyramidal. In H_2O only two of the structural pairs make bonds with two hydrogen atoms and the shape of the water molecule is bent.

LB p. 104 »

Activity 2 Practical activity

G

Determine bond and molecular polarity from molecular shapes

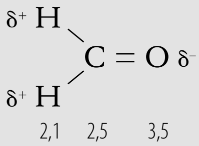
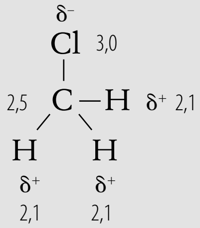
1 Ideal molecular shapes.

Ideal shape	Molecule	Bond polarity (difference in electronegativities)	Molecular polarity
AX	Cl_2	3,0 – 3,0 = 0,0	Non-polar
AX_2	$BeCl_2$	3,0 – 1,5 = 1,5	Non-polar
AX_3	BF_3	4,0 – 2,0 = 2,0	Non-polar

Ideal shape	Molecule	Bond polarity (difference in electronegativities)	Molecular polarity
AX_4	CH_4	2,5 – 2,1 = 0,4	Non-polar
AX_5	PCl_5	3,0 – 2,1 = 0,9	Non-polar
AX_6	SF_6	4,0 – 2,5 = 1,5	Non-polar

The most polar bond is between B and F in BF_3. All the molecules are non-polar because of their symmetrical shapes.

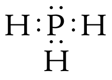
2

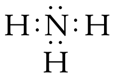
Molecule	Shape and partial polarities	Molecular polarity
HCl	$\underset{2,1}{\overset{\delta^+}{H}} - \underset{3,0}{\overset{\delta^-}{Cl}}$	polar
HCN	$\underset{2,1}{\overset{\delta^+}{H}} - \underset{2,5}{C} \equiv \underset{3,0}{\overset{\delta^-}{N}}$	polar
CH_2O		polar
CH_3Cl		polar

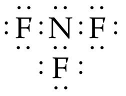
Test yourself 4 (LB p. 104)

1 HCl: polar covalent
KF: ionic
CC bond in H_3CCH_3: pure covalent

2 a)

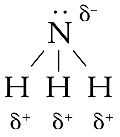


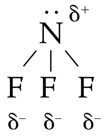




b) All three molecules are triangular pyramids. Compare the differences in electronegativity:
N–H: 3,0 – 2,1 = 0,9
P–H: 2,1 – 2,1 = 0,0
N–F: 4,0 – 3,0 = 1,0

The bonds in PH_3 are non-polar, but the P atom has a lone pair, so we can expect a higher electron density on the P side of the molecule. The molecule will be marginally polar. The dipoles that form in NH_3 and NF_3 are given as:





Note that the polarity of the two molecules is reversed. Although the N–F bond is more polar, the molecule as a whole will be less polar, because some of the polarity of the molecule is cancelled by the negative lone pair on the nitrogen atom. The compound formed between nitrogen and hydrogen (NH_3) will have strongest dipoles.

3 a) and b)

Molecule	Shape	Polarity of molecule
CCl_4	Tetrahedral	Non-polar
CO_2	Linear	Non-polar
BF_3	Trigonal planar	Non-polar
Br_2	Linear	Non-polar
HCl	Linear	Polar
PCl_5	Trigonal bipyramidal	Non-polar
PF_3	Trigonal pyramidal	Polar

c)

Bond	$\Delta\chi$
C–Cl	3,0 – 2,5 = 0,5
C–O	3,5 – 2,5 = 1,0
B–F	4,0 – 2,0 = 2,0
Br–Br	2,8 – 2,8 = 0,0
H–Cl	3,0 – 2,1 = 0,9
P–Cl	3,0 – 2,1 = 0,9
P–F	4,0 – 2,1 = 1,9

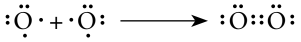
The most polar single bond can be found where the difference in electronegativity is the greatest – that is, in the B–F bond.

4

Bond	Difference in electronegativity	Bond type	Reason
Na–Cl	3,0 – 0,9 = 2,1	Ionic	Difference in EN = 2,1 – e^- transfer
C–N	3,0 – 2,5 = 0,5	Weakly polar covalent	N attracts e^- pair slightly more than C
O–H	3,5 – 2,1 = 1,4	Polar covalent	O attracts e^- pair more strongly than H
F–F	4,0 – 4,0 = 0,0	Non-polar covalent	No difference in EN – e^- pair shared equally

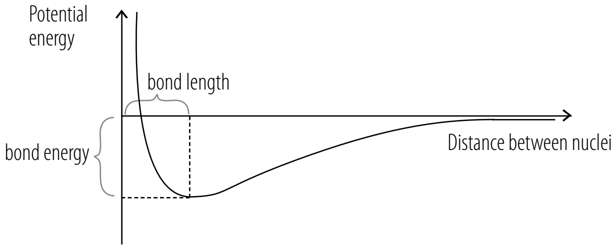
Test yourself 5 **(LB p. 106)**

1 a) Two oxygen atoms approach each other. The nucleus of the one atom attracts the electrons of the other and vice versa. As the atoms get closer, their half-filled orbitals overlap. They form two covalent bonds. The Lewis dot symbol of oxygen has two unpaired electrons. When two oxygen atoms bond they share two pairs of electrons.



$$:\ddot{O}\cdot + \cdot\ddot{O}: \longrightarrow :\ddot{O}::\ddot{O}:$$

b)



2 a) $\Delta\chi$: C–F: 4,0 – 2,5 = 1,5
C–O: 3,5 – 2,5 = 1,0
C–N: 3,0 – 2,5 = 0,5
C–C: 2,5 – 2,5 = 0,0
The C–F bond has the highest bond energy, because a larger difference in EN results in a stronger bond.
b) The C–C bond is non-polar.

3 a) In both bonds $\Delta\chi = 0$, but the H atom is much smaller than the P atom, so the atoms in the H–H bond will be closer to each other. This results in a shorter bond length and a stronger bond.
b) The double bond is stronger than the single bond, and so the C atom and the O atom are closer to each other.

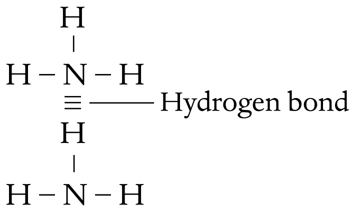
Unit 2 Intermolecular forces

TERM 1, MODULE 2

Test yourself 6 (LB p. 110)

1 a) HBr and H_2S: dipole–dipole forces
b) I_2 and NH_3: dipole–induced dipole forces
c) H_2O and HF: hydrogen bonds
d) H_2O and Na^+: ion–dipole forces
e) H_2O and CH_4: dipole–induced dipole forces
f) CO_2 and O_2: induced dipole–induced dipole forces (dispersion forces)

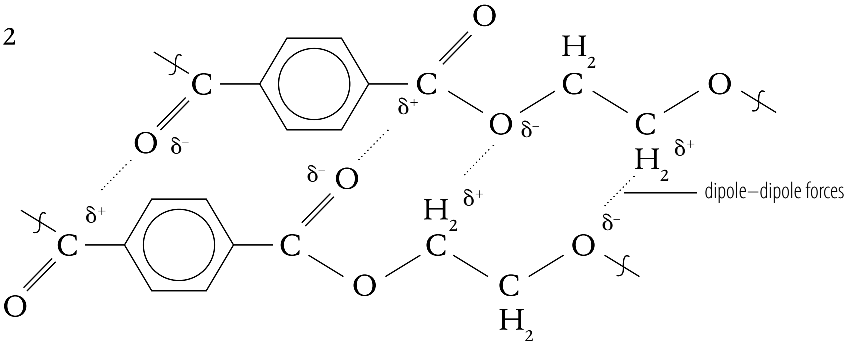
2



Test yourself 7 (LB p. 112)

1 a) CH_3Cl: dipole–dipole forces
b) PF_3: induced dipole–induced dipole forces
c) NaCl: ionic bonding/ coulomb forces
d) CS_2: induced dipole–induced dipole forces
e) HF: hydrogen bonding
f) C: covalent bonding

2



Test yourself 8 (LB p. 118)

1 a) covalent bonds
   b) induced dipole–induced dipole forces
   c) Diatomic iodine molecules are held together in a crystal lattice by induced dipole–induced dipole forces. When the crystal is heated, the molecules absorb the energy and they move around more vigorously. They break free from the forces that hold them in the lattice and move up into the air as separate iodine molecules.
   d) Each carbon atom in diamond is covalently bonded to four other carbon atoms to form an interconnected tetrahedral structure. This structure is very stable and the bonds are very strong. A large amount of energy is needed to break these bonds to release the individual C atoms.

2 There are hydrogen bonds between the molecules in $NH_3$and H_2O, which account for the high boiling points of these compounds. Hydrogen bonds form between the H atom on one molecule and a small, highly electronegative atom (N, O and F) on another molecule. Carbon is a small atom, but its electronegativity is not high enough to allow the formation of hydrogen bonds.

LB p. 118

Activity 3 Prescribed experiment for formal assessment

G

Investigate intermolecular forces and their effects

Safety
- You and the learners should always wear safety goggles during all chemical experiments.
- Avoid skin contact with chemicals.
- Wash hands after handling chemicals.
- Dilute solutions of acids, bases and salts are regarded as low hazard chemicals.
- Glass apparatus must be handled with care. Breakages must be reported immediately and skin cuts must be treated and monitored.
- Chloroform, ethanol, methanol and nail polish remover have harmful vapours. Do not breathe the vapours; use in a well ventilated room or in a fume cupboard.
- Chloroform is toxic and prolonged exposure can cause cancer; it is dangerous to the environment.
- Ethanol, methanol and nail polish remover are toxic and flammable; extinguish open flames.
- Solid $KMnO_4$ is an oxidiser; avoid skin contact and handle with care.

- Iodine will stain your skin, so avoid skin contact. Iodine sublimes at a low temperature and the vapours are unpleasant to breathe.
  Iodine also reacts violently with some powdered metals, such as magnesium and aluminium, in the presence of water as a catalyst.
- $KMnO_4$ and glycerol/glycerine react vigorously when mixed (they actually catch on fire – quite pretty, but not ideal in a school lab!).

Experiment 1: Evaporation

A measure of the strength of intermolecular forces in a liquid is the molar heat of vaporisation. This is the energy required to vaporise one mole of a liquid. If the intermolecular forces are strong, it takes a lot of energy to free the molecules from the liquid phase and the heat of vaporisation is high. The boiling points and heats of vaporisation are:

Substance	Boiling point (°C)	Heat of vaporisation (kJ/mol)
Water	100	41
Ethanol (CH_3CH_2OH)	78	39
Methanol (CH_3OH)	65	35
Acetone (dimethyl ether) ($(CH_3)_2CO$)	56	31
Ethyl acetate ($CH_3COOCH_2CH_3$)	77	32

Methylated spirits contains methanol and other additives.

Nail polish remover is a mixture of different compounds. Acetone used to be its main component. Acetone-free nail polish remover uses ethyl acetate as a solvent.

The evaporation rate should increase in this order: water, ethanol, methylated spirits, nail polish remover. There are hydrogen bonds between the molecules of all these solvents, which is why they are liquids at room temperature; the hydrogen bonds, however, are more effective in water.

This experiment will probably take more than one hour, depending on the room temperature, moisture in the air, etc. We recommend that you apply heat, for example, place the watch glasses on a water bath. Warn learners about the dangers of the vapours and flammability of ethanol and methylated spirits. Due to the invisibility of ethanol and water we recommend that you place the watch glasses on a sheet of white paper to increase visibility.

Experiment 2: Surface tension

The weak short-distance forces between similar molecules are called cohesive forces. The cohesive forces between molecules in a liquid phase are responsible for the phenomenon of surface tension. In the middle of the liquid, each molecule is pulled equally in every direction by neighbouring liquid molecules, resulting in a net force of zero. The molecules at the surface do not have other molecules above them and therefore are pulled sideways and inwards. This forces liquid surfaces to contract to the minimal area. The surface of the liquid behaves like an elastic film and is called surface tension.

An object that is denser than the liquid can, under these circumstances, float on its surface (if it is not wet and its weight is small enough to be supported by the forces arising from surface tension).

The needle should float on water and glycerine, and sinks immediately to the bottom in oil, nail polish remover and methylated spirits. Different types of oil might yield different results.

Warn learners to place the needles on the liquids with great care. When placing the needle slightly in the water, it will immediately sink, but when placing it with care, it will float.

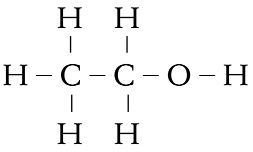
Experiment 3: Solubility

Solubility is a measure of how much solute will dissolve in a solvent at a specific temperature. Generally, like dissolves like. Two substances with intermolecular forces of a similar type and magnitude are likely to be soluble in each other. For example, both iodine and tetrachloromethane (carbon tetrachloride)(CCl_4) are non-polar substances. The intermolecular forces present in these substances are induced dipole–induced dipole forces (dispersion forces). When iodine is stirred into tetrachloromethane , it will dissolve because the magnitude of the forces between iodine molecules is similar to those between tetrachloromethane molecules.

Ionic solids that consist of ions packed in a crystal lattice will dissolve in polar solvents. The forces between the solute and solvent will be ion–dipole forces. When sodium chloride dissolves in water, the ions are stabilised in solution by hydration. Ionic solids do not dissolve well in non-polar solvents. They form weak ion–induced dipole forces and solubility is very low.

The polar nature of the hydroxyl group (OH) causes ethanol to dissolve many ionic compounds. Because the ethanol molecule also has a non-polar end, it will also partially dissolve non-polar substances, such as iodine. Ethanol is also miscible both with water, which has polar molecules, and with petrol, which is non-polar.

Ethanol:



$$\begin{array}{ccccccccc} & & \mathrm{H} & & \mathrm{H} & & & & \\ & & | & & | & & & & \\ \mathrm{H} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{O} & - & \mathrm{H} \\ & & | & & | & & & & \\ & & \mathrm{H} & & \mathrm{H} & & & & \end{array}$$

Sodium chloride and potassium permanganate are both ionic solids. They dissolve the best in water, which is polar. Potassium permanganate is a strong oxidising agent and might oxidise the chloroform to form brown MnO_2.

Iodine has non-polar molecules and dissolves the best in non-polar tetrachloromethane. It will also partially dissolve in ethanol.

NaCl	water	soluble
	ethanol	insoluble
	chloroform	partially soluble
$KMnO_4$	water	soluble
	ethanol	partially soluble
	chloroform	partially soluble
I_2	water	insoluble
	ethanol	partially soluble
	chloroform	partially soluble

Experiment 4: Boiling points

Substance	Boiling point (°C)
Glycerine	290
Water	100
Ethyl acetate	77

Substance	Boiling point (°C)
Acetone	57
Ethanol	78
Olive oil	300
Sunflower oil	230

Please note that the determination of boiling points can be hazardous. Water is the only liquid for which it is safe to determine the boiling point in an open beaker. Please use only the prescribed apparatus for organic solvents. Methylated spirits and nail polish remover are flammable. The vapours of chloroform can be dangerous. Oil could catch alight and cause a fire.

Experiment 5: Capillarity
Capillarity is the ability of a liquid to flow against gravity, where the liquid rises spontaneously in a narrow space. It occurs because there are stronger attractive forces (adhesion) between the liquid and the solid surrounding surface than between the liquid molecules themselves (cohesion). When water molecules are in contact with glass, the adhesion forces are stronger than the cohesion forces and the water will rise in a narrow tube. Capillarity will decrease in this order:

water, oil, glycerine, nail polish remover, methylated spirits

LB p. 121 »

Activity 4 Research project

P

Consider the effect of intermolecular forces on liquids

1 Motor oil (or engine oil) is used for lubrication of various internal combustion engines. The main function is to lubricate the moving parts of the engine. The oil creates a separating film between the surfaces of adjacent moving parts, so reducing friction. Motor oils are derived from crude oil (hydrocarbons between C_{18} and C_{34}) and have synthetic organic compounds as additives.

The most important physical property of motor oil is its viscosity, which means its resistance to flow. The thicker the oil, the higher its viscosity and the slower it will flow. The viscosity of the oil must be high enough to maintain a lubricating film, but low enough for the oil to flow when the engine is cold. The Society of Automotive Engineers (SAE) has established a numerical code system for grading motor oils according to their viscosity characteristics. The numbers, from low to high viscosity, are 0, 5, 10, 15, 20, 25, 30, 40, 50, and 60. The numbers 0, 5, 10, 15 and 25 are followed by a letter W, which stands for winter or cold-start viscosity. The number 20 comes with or without the W, depending on whether it is being used as a cold or a hot viscosity grade.

A mono-grade engine oil contains no added viscosity improvers. Such oils are suitable for applications where the temperature ranges in use are not very wide – for example, in lawn mowers, industrial applications and vintage cars.

The oil in most vehicle engines are exposed to a wide range of temperatures, from cold temperatures in winter and when the engine is started up, to hot operating temperatures in hot summer weather. A specific oil will have a high viscosity when cold and a low viscosity when the engine is running. The difference in viscosity is too large for the extremes of temperature. Special polymers, called viscosity index improvers, are added to the oil to bring the difference in viscosities closer together. These additives are used to make the oil a multi-grade oil. It allows the engine to run on the same oil all year round. The SAE number for multi-grade oils includes two viscosity grades and combines the properties of two single-grade oils. Therefore, an oil labelled 15W40 must pass the test for both a 15W and a 40 grade oil.

Source: Taken from Wikipedia

2 Used engine oil is contaminated with many harmful chemicals and additives. These chemicals are an environmental hazard and can contaminate ground water and soil. Used oil recycling is the most environmentally friendly way of disposing of used oil.

Around 50 000 tonnes of used oil is generated per year and an estimated 85 % thereof is re-refined. The used oil is collected from various sources like service stations, industries, mines as well as private persons by used motor oil collectors. There are many companies that collect and recycle used motor oil. There are four used oil re-refineries in South Africa namely Chemco (Chamdor, Krugersdorp), Fuchs (Islando), Flexilube (Meyerton) and Kudu (Nelspruit). Oilkol also has four other well-established companies that are using oil for other purposes than re-refining. The ROSE foundation (Recycling Oil Saves the Environment) is a non-profit organisation that manages the environmentally acceptable collection, storage and recycling of used lubricating oil in South Africa.

3 The forces of attraction between similar molecules are called cohesive forces. Adhesive forces exist between the molecules of different types of substances.

When a liquid is poured into a glass container, the curved surface that forms at the top is known as a meniscus. Water molecules are attracted to glass more than to other water molecules and adhesion is stronger than cohesion. So, where the water touches the glass, it ‘climbs up’ the glass and the meniscus curves downwards to form a concave meniscus. Mercury does the opposite. Cohesion between mercury particles is stronger than adhesion between mercury and the glass. So a mercury meniscus curves upwards to form a convex meniscus.

Safety

You must make sure you take adequate safety precautions when you work with mercury. Mercury is a very toxic substance — even more toxic than arsenic and cadmium. It can be inhaled, ingested and absorbed through the skin. Do not allow your learners to handle mercury.

- Always use protective gloves when handling mercury and do experiments in a fume cupboard or well ventilated room. Take care not to inhale mercury fumes.
- Do not use mercury where it would come into contact with a hot surface and vaporise.
- Contact a professional chemical disposal company to dispose of mercury waste. Never wash it down the drain!
- Never wear gold or silver jewellery when working with mercury – it forms an amalgam with these metals and irreversibly damages jewellery.
- If a mercury spill occurs, sprinkle with zinc dust. Zinc dust reacts with mercury to form a safe mixture that is easy to handle and dispose of. Alternatively, put on gloves and suck up the mercury with a plastic dropper. Then put everything that has touched the mercury into a ziploc bag and call a chemicals disposal company.

4 Thermal conductivity is the ability of a material to conduct heat. Copper is a metal and has a lattice structure of positive metallic ions surrounded by a sea of delocalised electrons. Heat is conducted via lattice vibrations and by free electrons. When the one end of a piece of copper is heated, the copper ions at the hot end vibrate faster and conduct the energy to their neighbours. The free-flowing electrons collide with the hotter part of the metal, gain energy and speed up. They move towards the colder side of the metal, where they transfer the energy to the colder ions and they, in turn, heat up. In this way energy is transferred through copper, from hot parts to cold parts.

Graphite is a non-metal with a layered planar structure. In each layer the carbon atoms are arranged in a hexagonal lattice. Electrons are delocalised within the planes. The delocalised electrons carry the energy along the layers to conduct heat.

Test yourself 9 (LB p. 123)

1 a) The atoms in a water molecule are held together strongly by covalent bonds to form an angular molecule. The electrons are not evenly spread around the molecule. Oxygen has a higher electronegativity than hydrogen and the oxygen side of the water molecule is partially negative, while the hydrogen side is partially positive. Water molecules are polar and they form dipoles.

b) The hydrogen bonds between the water molecules make water a liquid at normal temperatures. Most compounds with molecules similar to water, such as carbon dioxide and methane, are gases. Without hydrogen bonds between the molecules, water would be a gas at normal temperatures and there would be no life as we know it on the Earth.

The polar water molecules vibrate, which enable them to absorb heat (infrared radiation) from the sun. The water in lakes and oceans can absorb large amounts of heat in summer and give off heat in winter, with only small changes in the temperature of the water. This effect moderates the climate of adjacent land masses. In this way, the oceans act as reservoirs of heat and are able to ensure that the Earth has a moderate climate.

LB p. 124

Activity 5 Practical activity

G C

Investigate the properties of water

The water molecules in ice are packed into a regular crystal lattice. The molecules in liquid water are further apart (at temperatures above 4 °C) and can glide over one another. The molecules in water vapour are far apart.

To build a model of ice: Ice forms a three-dimensional structure of hexagonal symmetry. Each oxygen atom forms two covalent bonds with hydrogen atoms and two hydrogen bonds with adjacent hydrogen atoms. The ratio of the covalent bonds to the hydrogen bonds are 1,0 Å to 1,75 Å. Comfortable bond lengths to work with are 2,0 cm for the covalent bonds and 4,25 cm for the hydrogen bonds. Start by building two hexagonal structures and then link them together. Use the model on page 122 of the Learner's Book as a guide.

LB p. 125 »

Activity 6 Research project

P

Investigate traditional cooling apparatus

The cooling effect of evaporation has been used for the past 5 000 years by people. Many earthenware pots that were used to cool water and keep food fresh have been found in ancient Egypt and Northern India.

Evaporation is a cooling process. Water molecules in a liquid move around randomly. Some have more energy than others and move around faster. At the surface of the water, the most energetic molecules have enough energy to break free from the intermolecular forces that hold them in a liquid phase and they escape into the air. The average speed of the remaining water molecules slows down and the temperature of the water decreases.

When a porous canvas bag is slung on the outside of a car bumper, the water molecules are exposed to heat. The fast-moving water molecules escape through the surface of the bag. The slower molecules left behind are colder. The faster the hot molecules evaporate, the colder the water in the bag becomes. Hanging the bag on the front of a fast-moving car is a good way to remove the hot molecules quickly.

Clay terracotta pots and water carafes have been used for centuries to store food and water. When a carafe is left outside in the sun, water will evaporate through the porous clay to cool the contents inside.

A pot-in-pot refrigerator, also known as a Zeer, consists of a porous outer earthenware pot lined with wet sand. The inner pot is glazed to prevent contamination of the food it contains. Evaporation of the water in the sand draws heat from the food in the inner pot.

Test yourself 10 (LB p. 127)

1 Cohesive forces are responsible for the phenomenon of surface tension. Water molecules at the surface stick together and form a tight surface film that can support an object, such as a needle, that is denser than water. Washing-up liquid breaks the cohesive forces and also the surface tension. The needle sinks.

2 Water evaporates when the individual water molecules have enough energy to break free from the hydrogen bonds that attach them to other water molecules. This process happens at ambient temperatures and the rate of evaporation increases with an increase in temperature. When water is decomposed, the water molecules are broken down into their constituent atoms, hydrogen and oxygen. This process requires a relatively large amount of energy and can be achieved through the process of electrolysis.

3 Possible statements:
   - The density of very cold water is higher than ice and this allows ice to float on top of the ocean in the cold arctic regions of our planet. The ice forms an insulating layer and sea life can continue to thrive underneath the ice.
   - The bodies of most living organisms contain large percentages of water (65% in humans; 90-95% in plants).
   - The water cycle circulates the water on the Earth and affects the climate.
   - Water is a greenhouse gas that absorbs long-wave radiation from the Earth and helps to keep the temperature on the Earth constant and suitable for life.

Activity 7 Recommended experiment for informal assessment

Investigate the physical properties of water

Many of the experiments in this activity overlap with the experiments described in Activity 3: Prescribed activity for formal assessment: Investigate intermolecular forces and their effects. Here the focus is on water.

Experiment 1: Density

You will need: 100 ml measuring cylinder, balance, water

Weigh the empty measuring cylinder. Add 100 ml of water to the cylinder and weigh again. Calculate the density of water in grams per cubic centimetre (g/cm^3). Repeat the experiment three times and give the average value for density. Alternatively, collate the results of the whole class and find the average value for density.

Experiment 2: Melting point and boiling point

You will need: ice, thermometer, 100 ml beaker, Bunsen burner, tripod, wire gauze

Add ice into the beaker to half its volume. Place the beaker on the wire gauze on the tripod and light the Bunsen burner underneath. Measure and record the temperature of the ice as it is melting. This is the melting point of water. Measure the temperature of the water every five minutes until the water boils rapidly. Record the boiling point of water.

Experiment 3: Efficacy as a solvent

You will need: 100 ml beakers, water, spatulas, salts: NaCl; $KMnO_4$; CuO; $CuSO_4$; $CaCO_3$

Add a spoonful of each of the salts to a beaker. Half-fill each beaker with water. Stir to dissolve the solid. Record which salts are soluble and which are insoluble.

Experiment 4: Capillarity

You will need: narrow capillarity tubes of different diameters, 100 ml beaker filled with water

Place the tubes in the beaker with water and compare the water levels in the tubes.

The conclusion must explain why water is unique by referring to the polar nature of the molecule and the hydrogen bonds between the molecules.

Checklist for teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Stays focused on experiments			
Understands experimental methods			
Follows methods in orderly manner			
Uses time efficiently			
Uses apparatus and equipment correctly			

Task skills	Yes	No	Comments
Helpful/ valuable member of group			
Answers simple questions during experiments			
Records results correctly in suitable tables			
Explains results correctly			
Writes a well structured conclusion			

LB p. 128

Activity 8 Extension activity

I

Consider the importance of water

The activity can be divided into two sections:

1 Facts about water:
  - Each oxygen atom is covalently bonded to two hydrogen atoms.
  - The oxygen atom attracts the bonding electron pair more strongly.
  - A shift in the average position of the electron pairs results in the oxygen side becoming slightly negative, and the hydrogen sides, slightly positive.
  - The shape of the water molecule is bent or angular.
  - A polar water molecule results.
  - Intermolecular hydrogen bonds form between individual water molecules.
  - Water is a liquid at ambient temperatures.

2 How water affects humans:
  - About 70% of the human body consists of water.
  - Water is used for all chemical and physical processes in the human body.
  - All other life on the Earth is dependent on water.
  - The lower density of ice allows sea life to exist in the water under the ice.
  - Many recreational activities involve water – swimming, sailing, diving, fishing, etc.

The two sections should contribute equally to the total mark for the activity. Other variations on the above scheme are possible. Learners should be credited for ingenious and original ideas.

Learner's Book page 129

Units 1–2 Summative assessment: Matter and materials

TERM 1, MODULE 2

1 A molecule contains a small number of atoms that function together as a unit.
2 A chemical bond is the net electrostatic force that two atoms that share electrons exert on each other.
3 Covalent bonding, ionic bonding and metal bonding
4 Two atoms share one or more pairs of electrons. The result can be simple molecules of giant covalent structures.
5 The valence electrons react because they are in the outermost energy levels of the atoms and come into contact with other atoms.

6 Noble gases are chemically inert because they have completely filled outer energy levels. They do not bond and are therefore stable.

7

Element	**Valence electrons**
S	6
B	3
Ba	2
Li	1
I	7
Si	4
P	5

8 Both the shape of a molecule and the polarity of the bonds determine whether the molecule will have a dipole. When atoms in a molecule have different electronegativities, the more electronegative atom will attract the bonding electron pair more strongly and that side of the bond will become partially negative. The other side will be partially positive and a dipole forms. Molecules that have a symmetrical shape will be non-polar, although the individual bonds might be polar.

9 a) covalent bond
b) coordinate covalent bond
c) VSEPR model
d) trigonal pyramidal
e) electronegativity
f) dipole–dipole forces
g) capillarity
h) adhesion forces

10 a) When a substance cools down, it *releases* energy *into* the environment.
b) *All* solids will melt if you apply enough heat.
c) The temperature of a substance measures *the average kinetic energy of the particles*.
d) There are hydrogen bonds between molecules in *ice and water*.
e) There are *dipole–dipole forces* between the molecules in hydrogen chloride.
f) The amount of energy that is *released when a bonds forms* is called the bond energy.
g) When two atoms each contribute one electron to a shared electron pair, it is known as a *bonding pair.* / *The atoms around a central atom that determine the molecular shape* is known as the structural electron pairs.

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

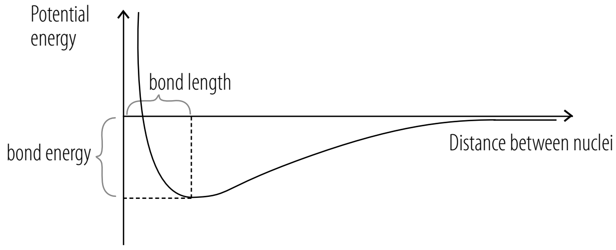
12

	Property	**CO_2**	**H_2O**
a)	Lewis structures	$\mathrm{O}::\mathrm{C}::\mathrm{O}$	$\mathrm{H}:\underset{\mathrm{H}}{\underset{\cdot\cdot}{\ddot{\mathrm{O}}}}:$
b)	Molecular shape	Linear	Bent or angular
c)	Polarity of bonds	Polar	Polar
d)	Polarity of molecules	Non-polar	Polar

13 a) $\cdot\underset{\cdot}{\ddot{\mathrm{N}}}\cdot + \cdot\underset{\cdot}{\ddot{\mathrm{N}}}\cdot \rightarrow \ddot{\mathrm{N}}\vdots\vdots\ddot{\mathrm{N}}$

b) When two nitrogen atoms approach each other, the nucleus of the one atom attracts the electrons of the other atom. The atoms move closer together and the electrons shift towards the region between the two atoms. The potential energy of the system becomes negative as the system becomes more stable. Bonding between the two atoms is reached when the potential energy of the system is at a minimum value and the system is most stable.

c)

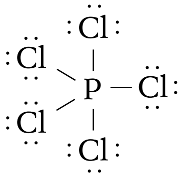


d) The bond in a nitrogen molecule is stronger because it comprises the sharing of three electron pairs. The bond length is shorter than when two electron pairs are shared in the oxygen molecule. A shorter bond length will result in a stronger bond.

e) The intermolecular forces between nitrogen molecules are very weak, because the boiling point of nitrogen is very low (−196 °C). A very small amount of energy is necessary to overcome the intermolecular forces between individual nitrogen molecules.

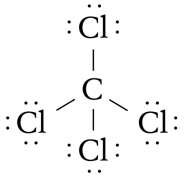
f) The intermolecular forces in liquid nitrogen are induced dipole–induced dipole forces (Van der Waals forces).

14 a) PCl_5



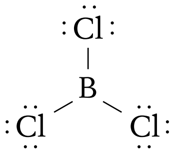
trigonal bipyramidal shape

b) CCl_4



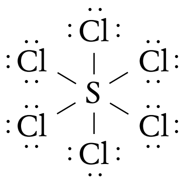
tetrahedral shape

c) BCl_3:



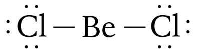
trigonal planar shape

d) SCl_6:



octahedral shape

e) $BeCl_2$:



linear shape

15 There is a difference in electronegativity between the hydrogen and the chlorine atoms. In a bond, the chlorine atom ($\chi = 3{,}0$) attracts the

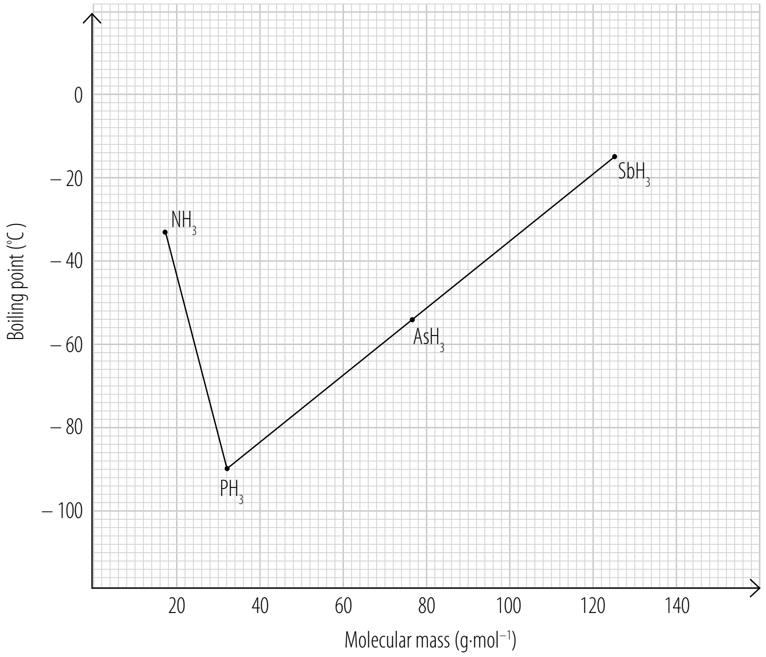
bonding electron pair more strongly than the hydrogen atom ($\chi = 2{,}1$). The electron pair spends more time closer to the chlorine atom, which becomes partially negative. The hydrogen side of the molecule becomes partially positive. The shift in electron density forms a polar molecule with a partially positive side and a partially negative side.

16 a) Cl_2 and CBr_4: induced dipole–induced dipole forces
b) NH_3 and CH_4: dipole–induced dipole forces
c) H_2O and CH_3OCH_3: hydrogen bonds
d) H_2O and Cl^-: ion–dipole forces
e) H_2O and SO_2: dipole–dipole forces

17 a) SiO_2: dipole–dipole forces
b) LiF: ionic bonding/ coulomb forces
c) C_6H_6: induced dipole–induced dipole forces
d) HCl: dipole–dipole forces
e) O_2: induced dipole–induced dipole forces
f) CH_3OH: hydrogen bonding

18 a)

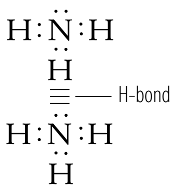
Graph of boiling points of Group 15 hydrides



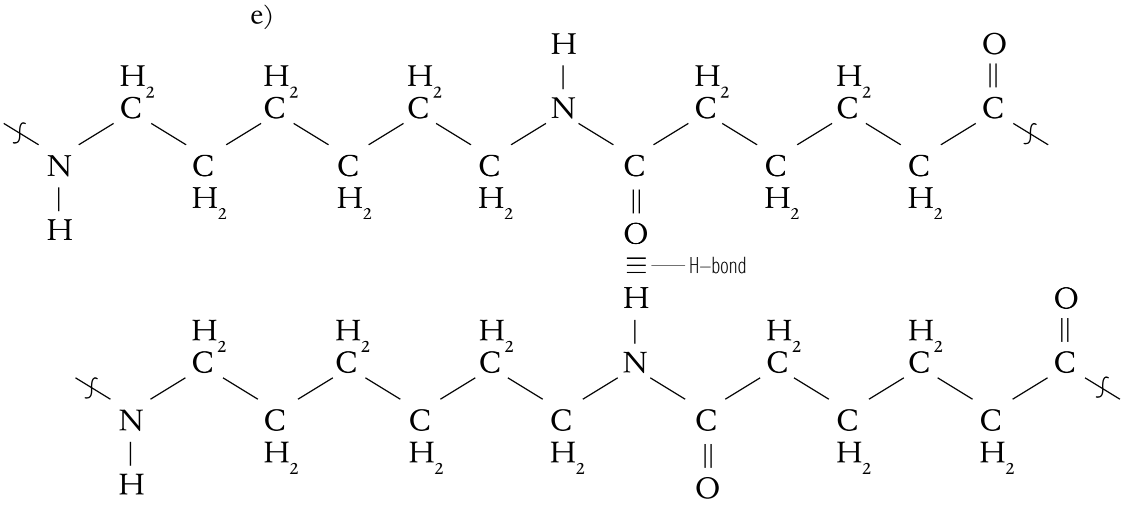
b) The molecular mass increases from phosphine (PH_3) to stibine (SbH_3). Boiling points increase with increasing molecular mass.

c) There are hydrogen bonds between the ammonia molecules. These forces are stronger than the dispersion forces between the molecules of PH_3, AsH_3 and SbH_3.

d)



e)



19 a) The adhesion forces between water and glass are greater than the cohesion forces between water molecules. The strong adhesion forces will cause the water molecules to attach to the glass container as a wet layer.

b) Car wax is hydrophobic – it does not like water. The cohesion forces between the water molecules are stronger and the droplets keep their shape.

c) The thin hairline spaces between clay particles are smaller than those between sandy soil particles; water molecules will experience a stronger capillary force in the narrower spaces and thus capillarity occurs to a greater extent in clay soils.

d) All the heat that is transferred to the water while boiling is used for work to break the intermolecular hydrogen bonds between the water molecules.

e) The alcohol is a volatile substance (evaporates easily) and, in the process, removes heat from your skin to gain enough energy to change from liquid alcohol to a gas.

20 At the coast the adjacent water mass of the sea has a moderating effect on the climate. Water has a high specific heat. That means that a large transfer of heat will have only a small effect on the temperature of the water. During the day the water absorbs large amounts of heat from the sun. This results in only a relatively small increase in sea temperature. In inland areas the ground absorbs all the heat and it gets very hot. During the night the ground radiates the heat quickly and the temperature drops sharply.

MODULE 3: WAVES, SOUND AND LIGHT

Background information for Module 3

Some schools may have apparatus, such as ripple tanks and ray boxes, with the accompanying vibrators, obstructions, slits and Perspex blocks. We strongly advise that you incorporate demonstrations and experiments into your lessons. Learners will remember the properties of waves and light so much better if they can see them firsthand. A darkened room makes the measurements with a ray box much easier.

Unit 1 of this module deals with refraction of light as it moves through media of different optical densities. You can use an optical set with a ray box and Perspex blocks of various shapes to illustrate refraction. The learners must use the optical sets to measure the angles of incidence and refraction and use Snell's Law to calculate refractive indexes and critical angles, and to observe total internal reflection. The determination of the critical angle of a rectangular glass block is a recommended experiment for informal assessment. Verifying Snell's Law is one of the two choices for a prescribed project.

In Unit 2 you will teach the learners about waves in two and three dimensions, and how the diffraction of waves can be explained through Huygens' Principle. Use a ripple tank to show diffraction of water waves around obstacles and through apertures. Activity 4 is a demonstration to observe the diffraction of light through a single slit. A darkened room is essential for this demonstration.

You should spend 13 hours on waves, sound and light, which make up 8,13% of the total physical science content of the year.

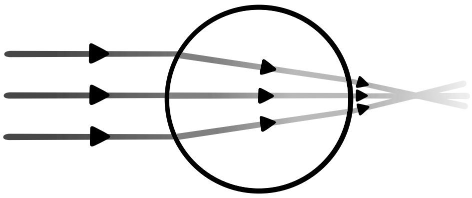
Test yourself 1 (LB p. 136)

1 a) An optical medium is a medium through which light can pass.
  b) An opaque object does not allow light to pass through.
  c) A transparent object allows light to pass through.
  d) An incident ray is a ray of light that strikes a surface.
  e) A normal to a surface is a line that is perpendicular to the surface.
  f) The reflected ray is the light ray that is reflected and moves away from a surface.
  g) The angle of incidence is the angle between the incident ray and the normal.
  h) The angle of reflection is the angle between the reflected ray and the normal.
  i) Diffuse reflection is the reflection from a rough surface.
  j) Specular reflection is the reflection from a smooth surface, such as a mirror.

2 The angle of reflection is equal to the angle of incidence.

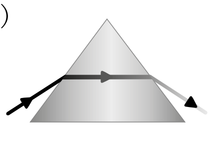
Test yourself 2 (LB p. 139)

1 a)

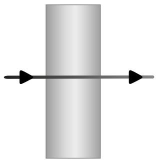


  b) Refraction is the bending of light when it travels from one material into another in which it has a different velocity.

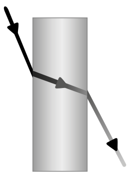
2 a)



b)

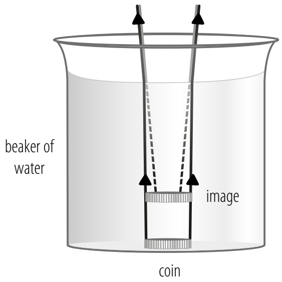


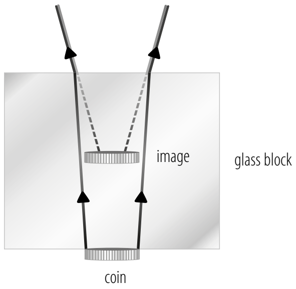
c)



Test yourself 3 (LB p. 140)

1 The water has a lower refractive index than the glass. The refraction between the water and air is less than between the glass and air. The virtual image that is formed inside the water is 'deeper' than in the glass block. The image in the glass block is closer to the observer's eye, and so will appear 'shallower'.





LB p. 142 »

Activity 1 Practical investigation

Investigate refraction

Experiment 1: Propagation of light from air into glass and back into air

1 Slide a converging lens and single slit gate into the slots at the front of the ray box. Slide the light bulb holder into place along the top of the ray box. Connect the ray box to the power source and switch on.

2 Place a glass block or Perspex block on the turntable with its long edge on one of the lines. The turntable is graduated and the degrees can be read off directly.

Alternatively, learners can place the glass block or Perspex block on an A4 sheet of paper. They should draw the outline of the block with a pencil and mark the incident ray and emerging ray with pencil dots. Caution them not to move the block from its pencilled position while conducting the measurements.

3 Learners must draw diagrams of a light ray hitting a rectangular block perpendicularly and at an angle. They must also draw the normal lines and label all rays and angles.

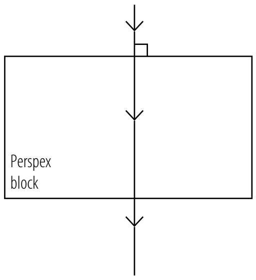
Possible values for Perspex:

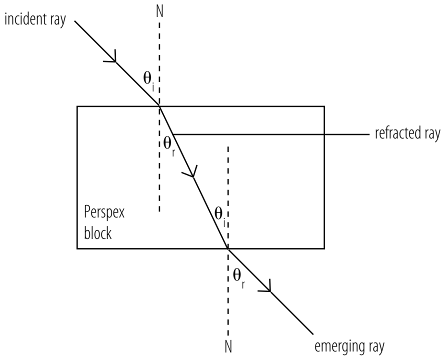
Angle of incidence	Angle of refraction
20°	13°
31°	20°
40°	25°

The angle of incidence is larger than the angle of refraction when the light enters the block (when the light enters an optically denser medium).

The angle of incidence is smaller than the angle of refraction when the ray leaves the block (when the light enters an optically less dense medium).

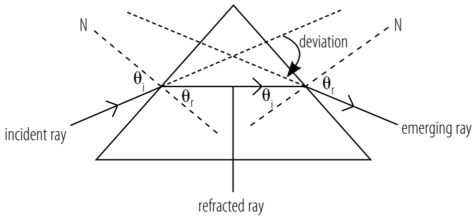
4 Diagrams should resemble the following:





5 Use the same method described above for a 60° prism.

7 The ray diagram should resemble the following:



8 a) Incident angle for the position of minimum deviation: ≈ 49° (for Perspex)

b) When light enters a medium with higher optical density, such as from air to glass, the speed of the light slows down and the light ray changes direction. The ray bends towards the normal and the angle of incidence is larger than the angle of refraction.

c) No, the amount of deviation depends on the angle of incidence and the difference in optical densities of the two media.

d) When light leaves the prism, it moves from a higher optical density in glass to a lower optical density in air. The ray bends away from the normal.

e) The position of minimum deviation is where the emerging ray deviates by the smallest angle from the incident ray. This position is reached where the refracted ray is parallel to the base of the prism.

Experiment 2: Propagation of light from one medium into another medium

1 Follow the same method to determine the path of a light ray through water as in experiment 1.

2 Possible values for water:

Angle of incidence	Angle of refraction
20°	15°
27°	20°
40°	29°

a) refractive index, $n = \frac{c}{v} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{2{,}26 \times 10^8 \text{ m·s}^{-1}} = 1{,}33$

3 The ray is refracted towards the normal when it enters the water and again towards the normal when it goes into the Perspex. Perspex is more optically dense than water.

LB p. 145 »

Activity 2 Prescribed project for formal assessment

G

Verify Snell's Law

Discuss the steps for a practical investigation with the class and refer them to the information in the introduction on page 12. Explain to them how to use the laboratory equipment with care. The learners must use the same set-up for the ray box as in Activity 1 in the Learner's Book (page 142) and a method similar to the one in Activity 1 to measure at least three values for the angles of incidence and refraction for each experiment. Values can be listed in a table similar to the one below:

Angle of incidence	Angle of refraction

To verify Snell's Law: Learners must use the table of known refractive indices and the angles they measured to calculate the values for $n_1 \sin \theta_1$ and $n_2 \sin \theta_2$. For these values to verify Snell's Law they should be equal.

To measure the refractive index of an unknown material: Use Snell's Law to calculate the unknown refractive index (n_2) from the equation $n_2 = n_1 \frac{\sin \theta_1}{\sin \theta_2}$

The learner's scientific report should include the following steps:

- Identify an answerable question to guide your investigation.
  For example, does the numerical value for $n_1 \sin \theta_1$ equal the numerical value for $n_2 \sin \theta_2$?
- Design an experiment to answer your question.
  For example, slide a converging lens and single slit gate into place; connect the ray box to the power source and switch on; shine the light ray into the block at an angle and measure the angle of incidence and angle of refraction; repeat with different angles of incidence; record the corresponding angles of refraction in a table; calculate the values for $n_1 \sin \theta_1$ and $n_2 \sin \theta_2$.
- Present your results in an appropriate table and diagram.
  Learners draw diagrams of the path of the light rays and record the angles in a suitable table.
- Check if your hypothesis was correct or your question was answered; if not, repeat the experiment or change your hypothesis.
  Learners should check whether the numerical values are equal and so verify Snell's Law. They must use Snell's Law to calculate the unknown refractive index.
- Write a conclusion for your investigation.

Answers to questions that must be included in the learners' reports:

1. The ratio of the speed of light in a vacuum (*c*) to the speed in a given material (*v*) is called the refractive index (*n*) of a material. (3)
2. The speed of light differs according to the optical medium through which it passes. As the optical density increases, the refractive index also increases. (3)
3. The refractive index compares the speed of light through two media and is a ratio, so it has no units. (2)
4. We use Snell's Law to determine the direction of light rays as they move through different optical media. (2)

Test yourself 4 (LB p. 147)

1 a) Critical angle

b) The critical angle is that angle of incidence that results in an angle of refraction of 90°, and the refracted ray is parallel to the boundary between the two media.

c) The refractive index (*n*) is the ratio of the speed of light in a vacuum (*c*) to the speed in a given material (*v*): $n = \frac{c}{v}$.

d) $n_1 \sin \theta_c = n_2 \sin \theta_2$

$n_1 = n_2 \frac{\sin 90°}{\sin 49°}$

$= 1,0 \times \frac{1,00}{0,75} = 1,3$

2 a) $n_1 = 1,00$ (*n* for air); $n_2 = 2,42$ (*n* for diamond)

$n_1 \sin \theta_1 = \text{n}_2 \sin \theta_2$

$1,00 \times \sin 40° = 2,42 \times \sin \theta_2$

$\therefore \sin \theta_2 = \frac{1,00}{2,42} \sin 40° = 0,266$

so $\theta_2 = 15,4°$

b) $v = \frac{c}{n} = \frac{3,00 \times 10^8 \text{ m·s}^{-1}}{2,42}$

$= 1,24 \times 10^8 \text{ m·s}^{-1}$

3 a) $n_1 = 1,00$ (*n* for air); $n_2 = 1,46$ (*n* for plastic)

$n_1 \sin \theta_1 = \text{n}_2 \sin \theta_2$

$1,00 \times \sin 50° = 1,46 \times \sin \theta_p$

$\therefore \sin \theta_p = \frac{1,00}{1,46} \sin 50° = 0,525$

and so $\theta_p = 31,6°$

b) The sides of the plastic are parallel, so the incident angle is θ_p, and $\sin \theta_p = 0,525$.

$\sin \theta_a = \frac{1,46}{1,00} \sin \theta_p = 1,46 \times 0,525 = 0,767$

so $\theta_a = 50,0°$

LB p. 148 »

Activity 3 Recommended experiment for informal assessment

G

Determine the critical angle of a rectangular glass block

Method:

1 Use the same set-up for the ray box as in Activity 1.

2 Use the same method as in Activity 1, but increase the angle of incidence until the angle of refraction reaches 90° and the refracted ray is on the outer edge of the glass block.

  a) Angle of incidence for this position = 41° (glass); 42° (Perspex)
  b) Critical angle
  c) that provides an angle of refraction of 90°, and the refracted ray is parallel to the boundary between the two media.

3 a) All the light is reflected back into the optically denser medium and no refracted light leaves the denser medium.

  b) Total internal reflection
  c) Light must move from an optically dense medium to an optically less dense medium; the angle of incidence must be greater than the critical angle of the medium involved.

Checklist of teacher's assessment of individual in a group during learner experiment

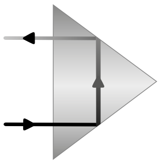
Task skills	Yes	No	Comments
Stays focused on experiment			
Understands experimental method			
Follows method in orderly manner			
Uses time efficiently			
Uses equipment correctly			
Helpful/ valuable member of group			
Answers simple questions during experiment			
Records results correctly			
Answers questions correctly			

Teacher demonstration: Real and apparent depth

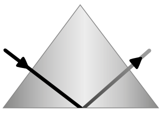
Place a coin in a plastic bowl or any opaque container. Learners must be able to see the coin and then move backwards until the coin is just out of sight. They must remain still in this position while looking at where the coin was last seen. Slowly fill the container with water. Make sure that you don't disturb the coin. As the water level rises, the coin will become visible. Ask learners to draw a diagram of what they saw.

Test yourself 5 (LB p. 150)

1 a)



b)



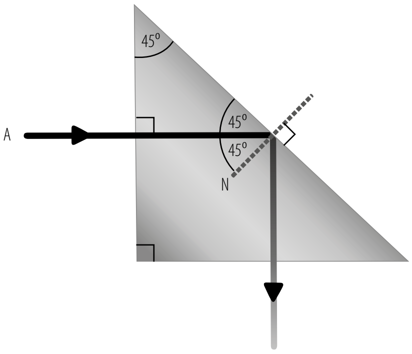
2 a) The light ray enters the glass at 90° on the normal and will not undergo refraction.

b) The third angle in the triangle is 45°. Therefore the angle of incidence must be 45°.

c) $\sin \theta_c = \frac{n_2}{n_1} \sin 90° = \frac{1{,}00}{1{,}54} \times 1{,}00 = 0{,}649$

$\therefore \theta_c = 40{,}5°$

d)



e) When light moves from an optically dense medium to an optically less dense medium; the angle of incidence is greater than the critical angle of the medium involved.

Unit 2 2D and 3D wavefronts

TERM 2, MODULE 3

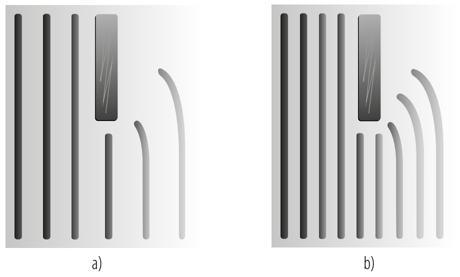
Teacher demonstration: Diffraction of water waves

A ripple tank is used to demonstrate the formation and properties of waves. You should familiarise yourself with the type of ripple tank you will be using and its attachments, before attempting the demonstration in front of the class.

- Add a small amount of water to the ripple tank. The water should be 10–20 mm deep. Make sure that the shadows cast by the ripples are clearly visible.
- Generate a plane wave by using a vibrating bar.
- Place obstacles of different sizes in the path of the waves. Observe the shapes of the diffracted waves. Point out the following to the learners: the difference between a small obstruction and a larger one in the path of the waves; what happens in the shadow behind an obstruction.
- Use a second obstruction to form a barrier with an opening. Vary the width of the opening and the wavelength of the waves (by changing the frequency). Ask the learners to deduce the relationship between wavelength and width of the opening.

Test yourself 6 (LB p. 154)

1



a) b)

2 The wavelength must be large in comparison to the size of the aperture.

Test yourself 7 (LB p. 155)

1 According to Huygens' Principle, when a wavefront hits an obstruction, the wavelets are partially interrupted at the edges of the obstruction. The wavelets interfere destructively at all points except in the forward direction. They normally combine to form straight wavefronts. The secondary wavelets on the outside edges have no wavelets next to them to interfere with and cancel their sideward movement. They bend around the edge of the obstruction into the shadow region behind it.

2 Sound wavelengths are much longer than the wavelengths of light. Audible wavelengths are comparable to the width of a door opening and sound waves diffract around the door, so that we can hear a person's voice. The wavelengths of light are extremely small compared to the width of the door; the light waves reflected off a person are too small in relation to the door opening to be diffracted by it to reach you.

LB p. 155 »

Activity 4 Experiment

P

Demonstrate diffraction of light

You will need: small plane mirror or small rectangular plane sheet of glass, matt black spray paint, razor blade, straight filament bulb, blue and red colour filters

Method:

1 Let each pair use a small rectangular piece of plane glass and spray paint it black on one side. Ensure that the learners take care not to cut themselves on the edges of the glass. When the paint is dry, instruct them to draw a single slit in the black paint with the edge of a sharp razor blade, or make the slit on the painted side of a small plane mirror.

3 Learners should hold the light bulb with a straight filament in a darkened room in such a way that the filament is vertical. The learners should hold the glass with the slit close to their eyes and their partners should hold the light bulb at the other side of the classroom, at least three metres away.

4 The wide bright band in the middle of the pattern is white with coloured edges. The fringes show the spectrum colours with blue nearest to the centre white band and red on the outsides.

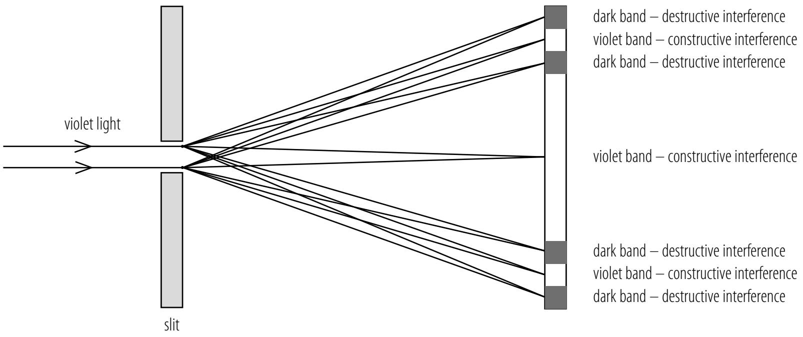
6 The colour of the band is determined by the type of light that was used. Destructive interference produces a dark band. The diffraction pattern consists of a wide central bright band. On either side of the central bright band are alternate dark and bright bands that are narrower and less intense than the central band.

When red and green monochromatic light is used, the lines are more pronounced. The red bands are further apart than the green bands.

Test yourself 8 (LB p. 156)

a) Degree of diffraction $\propto \frac{\lambda}{w}$, where λ is the wavelength and w is the slit width. For the same slit width, the degree of diffraction $\propto$ wavelength. Orange light has a larger wavelength and will experience more diffraction.

b)



Learner's Book page 157

Units 1–2 Summative assessment: Waves, sound and light

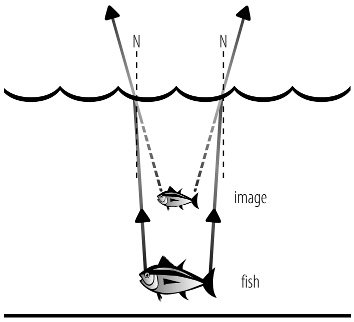
TERM 2, MODULE 3

1 a) optical medium
  b) refraction
  c) critical angle
  d) diffraction
  e) Huygens' Principle

2 a) When waves are *reflected*, the incident ray, reflected ray and normal all lie on the same plane.
  b) Endoscopes work on the principle of *total internal reflection*.
  c) An angle *larger than* the critical angle produces the phenomenon of total internal reflection.
  d) Waves bend and spread out when they pass through a gap. This is known as *diffraction*.
  e) Diffraction demonstrates the *wave nature* of light.

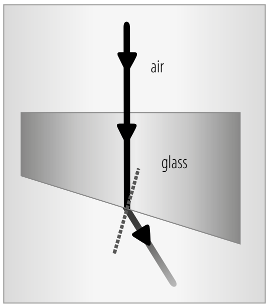
3 a) B b) C c) A d) C e) D

4 The image of the fish is shallower than the real position of the fish, but the apparent position is vertically above the real position. If the bird should dive at an angle, he might miss the fish because the image would not be above the real position.

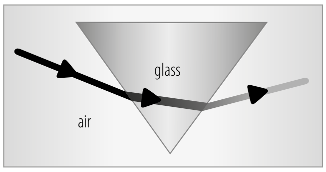


5 The apparent position of the part of the seal that is submerged in the water is closer than the actual position, to the person's eye, due to refraction. The seal's head is in the air and does not undergo refraction, thereby appearing to be further away than its body.

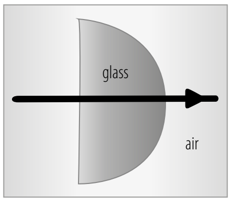
6 a)



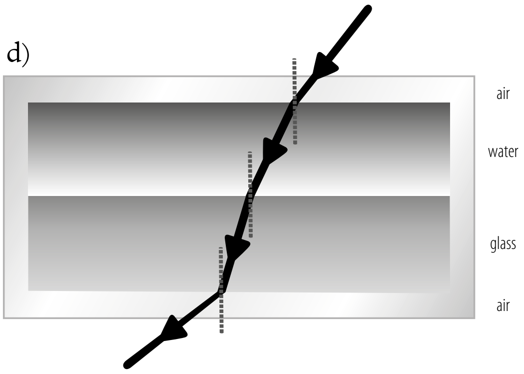
b)



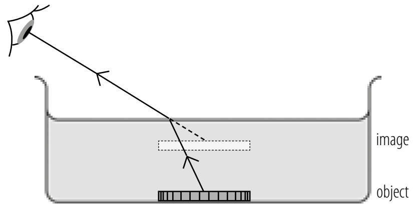
c)



d)



7 When there is no water in the bowl, the light rays coming from the coin travel in straight lines and do not meet the eye. However, when water is poured into the dish, the light rays from the coin that would have gone over the head of the observer are now refracted away from the normal towards the water surface and into the eye of the observer.



8 a) Snell's Law states: $n_1 \sin \theta_1 = n_2 \sin \theta_2$, where θ_1 is the angle of incidence, θ_2 is the angle of refraction, and n_1 and n_2 are the respective refractive indices in the optical media.

b) refractive index = ratio of the speeds in the two media

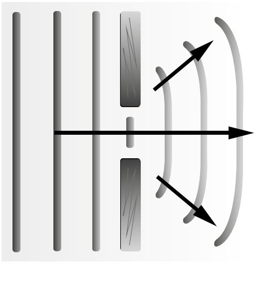
$$= \frac{\text{speed of light in B}}{\text{speed of light in A}} = \frac{2{,}0 \times 10^8 \text{ m}\cdot\text{s}^{-1}}{2{,}2 \times 10^8 \text{ m}\cdot\text{s}^{-1}} = 0{,}91$$

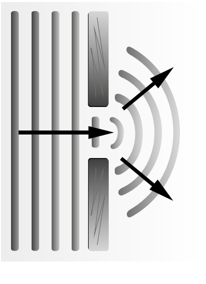
c) $n_1 \sin \theta_1 = \text{n}_2 \sin \theta_2 \Rightarrow \frac{n_2}{n_1} = \frac{\sin \theta_2}{\sin \theta_1} = 0{,}91$

$\sin \theta_2 = 0{,}91 \times \sin 70^\circ = 0{,}854$

$\therefore \theta_2 = 58{,}7^\circ$

9

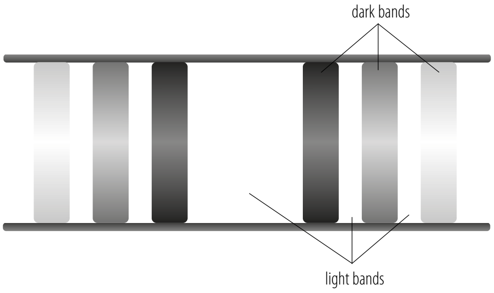




10 All particles in the wave have the same movement at the same time.

11 Diffraction is the process by which a wave is spread out as a result of passing through a narrow aperture or around an obstruction.

12 a) The diffraction pattern consists of a wide central bright band. On either side of the central bright band are alternate dark and bright bands that are narrower and less intense than the central band.



b) The waves that are in phase will experience constructive interference and the ones that are out of phases will interfere destructively. Constructive interference produces a bright band. Destructive interference produces a dark band.

c) All three colour light beams will produce diffraction patterns that are similar. The red and blue monochromatic lights produce patterns with lines that are more pronounced. The red bands are further apart than the blue bands.

Unit 3 Ideal gases and thermal properties

TERM 2, MODULE 2

LB p. 162

Activity 9 Recommended experiment for informal assessment

Verify Boyle's Law

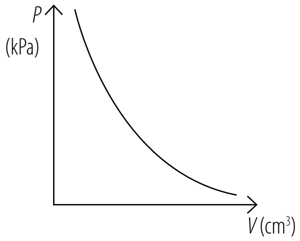
A set of experimental results are recorded in the table:
Example of a set of results:

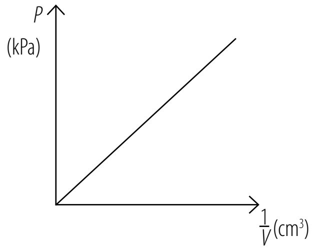
Volume (V) in cm³	Pressure (P) in kPa	$\frac{1}{P}$ in kPa^{-1}	PV in J × 10³
$V_1 = 8$	$P_1 = 0{,}866$	$\frac{1}{P_1} = 1{,}15$	$P_1V_1 = 6\,928$
$V_2 = 6$	$P_2 = 1{,}867$	$\frac{1}{P_2} = 0{,}54$	$P_2V_2 = 11\,202$
$V_3 = 4$	$P_3 = 2{,}840$	$\frac{1}{P_3} = 0{,}35$	$P_3V_3 = 11\,360$
$V_4 = 2$	$P_4 = 3{,}800$	$\frac{1}{P_4} = 0{,}26$	$P_4V_4 = 7\,600$

1 How does the pressure change when the volume is changed?

2 Fixed variables: temperature; amount (mass) of gas
Dependent variable: pressure
Independent variable: volume

3 The pressure of a fixed amount of gas at constant temperature increases as the volume is decreased; the pressure of a fixed amount of gas is inversely proportional to volume at constant temperature





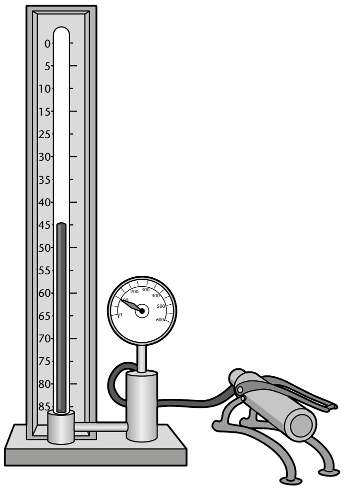
$V \propto \frac{1}{P} \qquad VP = k$

4 P is measured in Pa and V in m^3.
$PV = \mathrm{Pa} \times \mathrm{m}^3 = \frac{\mathrm{N}}{\cancel{\mathrm{m}^2}} \times \mathrm{m}^{\cancel{3}} = \mathrm{N} \times \mathrm{m} = \mathrm{J}$

5 The particles in a gas have kinetic energy and move around at high speeds. They collide with the sides of a container to exert a pressure. The magnitude of the pressure is determined by the number of collisions on an area and the intensity of the collisions. If the temperature in the experiment remains constant, the average kinetic energy of the gas particles also remains constant. The intensity of the collisions does not change. The pressure is therefore determined only by the number of collisions on a specific area. When the volume is decreased, the area for collisions also decreases. The number of gas particles is the same, so a larger number of collisions per area will occur. The pressure will thus increase.

Alternative experiment for Boyle's Law

Many school laboratories have the traditional Boyle's apparatus, as shown in the diagram. Here is the method to prove Boyle's Law using this apparatus.



Method

1 Open the tap on the apparatus and then connect the pump.
2 Pump enough air into the cylinder to reach a maximum reading.
3 Adjust the pressure to reach a marked off volume on the tube.
4 Record the volume reading on the tube and the corresponding pressure reading on the Bourdon pressure gauge.
5 Obtain four further readings of volume and pressure by decreasing the pressure progressively on the enclosed gas in the tube. Wait for about two minutes after adjusting the pressure before taking each reading.

Checklist for teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Stays focused on experiment			
Understands experimental method			
Follows method in orderly manner			
Uses time efficiently			
Uses apparatus and equipment correctly			
Helpful/ valuable member of group			
Answers simple questions during experiment			
Records results correctly in suitable table			
Draws graphs correctly			
Answers questions correctly			
Writes a well structured conclusion			

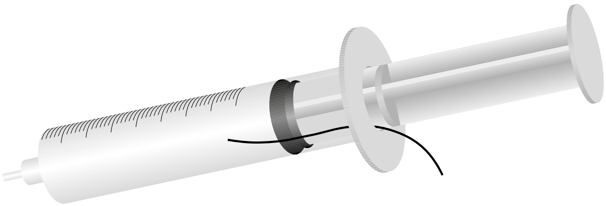
LB p. 167 »

Activity 10 Experiment

G

Verify Charles' Law

It is difficult to move the plunger when the tip of the syringe has been sealed. Follow this method to prepare the syringe:



Make sure the plunger can move freely inside the syringe. If the plunger is sticky, lubricate it with a small amount of silicone lubricant. Remove the plunger. Seal the tip of the syringe with an epoxy or silicone sealant. Allow to dry thoroughly and cure before proceeding with the experiment. When you are ready to do the experiment, insert the plunger into the syringe, along with a thin wire or strong cotton, as shown in the diagram. The wire will allow you to push the plunger in because air can escape. When the plunger is at the 5 cm mark, pull out the wire. Make sure the syringe is air-tight. The plunger should spring back when given a small downward push.

The air inside the syringe will make it buoyant, so you need to keep it submerged under the surface of the water by holding it down with a pair of tongs or placing a weight on it.

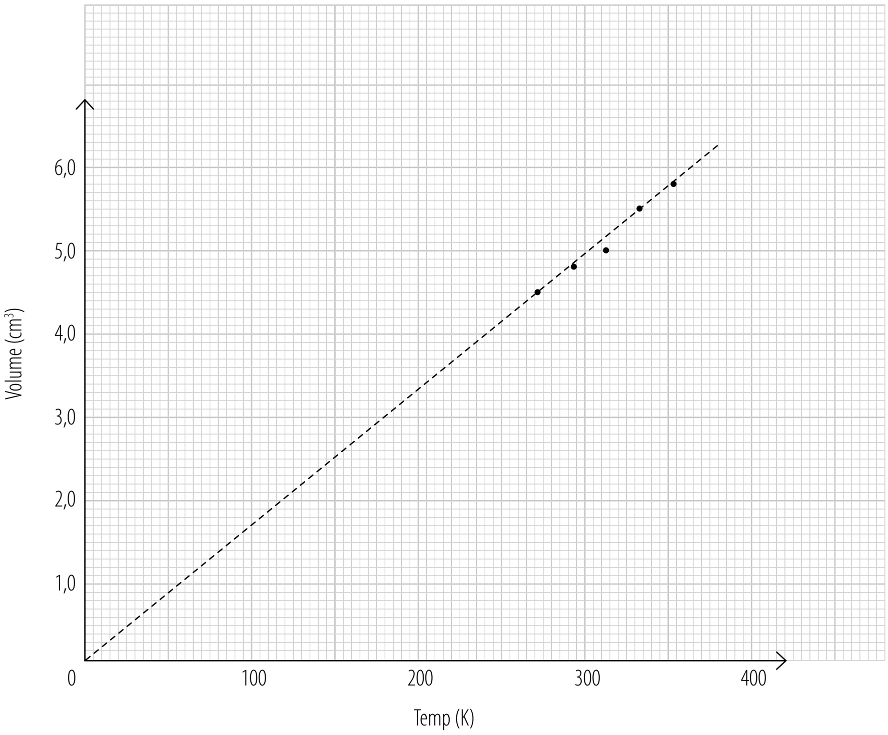
Conduct the experiment using the method in the Learner's Book. A set of experimental results are recorded in the table.

Temperature (°C)	Temperature (K)	Volume (cm^3)	$\frac{V}{T}$ (cm^3/K]
0	273	4,5	0,01648
20	293	4,8	0,01638
40	313	5,0	0,01597
60	333	5,5	0,01652
80	*353	5,8	0,01643
100	*373	6,2	0,01662

* not required

1

Graph of volume against temperature of an enclosed gas



2 The volume of a fixed amount of gas maintained at atmospheric pressure is directly proportional to the temperature of the gas. $V \propto T$ or $V = kT$

3 When the temperature of a gas is increased, the average kinetic energy of the gas particles also increases. The speed of the particles increases and they can cover larger distances than they could at a lower temperature, in the same time period. This means that the volume of the gas increases.

LB p. 169

» Activity 11 Experiment

G

Verify Gay-Lussac's Law

Complete the table:

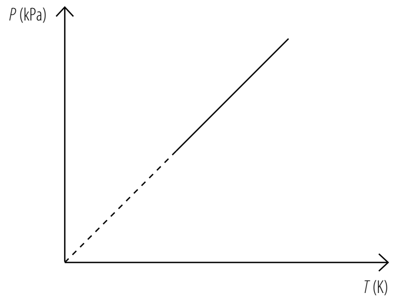
	Ice	Tap water	Boiling water
Pressure in kPa			
Temperature in °C	0	20	100
Temperature in K	273	293	363

In this experiment the volume of a gas is kept constant while the pressure changes are measured as the temperature is changed. Pressure is directly proportional to temperature and a P versus T graph should give a straight line. A reading for the absolute zero temperature (0 K or –273 °C) can be obtained by extrapolating (extending) the graph to the point where it intercepts the x-axis.

1 When the temperature of a fixed volume of gas is increased, the pressure rises.

2 Learners' own pressure and temperature readings recorded in a table

3 and 4 The pressure of a fixed amount of gas is directly proportional to the absolute temperature.



$P \propto T$ or $\frac{P}{T} = k$

5 If the melting point of ice was used to calibrate both thermometers, they should give the same readings. The melting point of ice is always 273 K. If the boiling point of water was used for calibration, the thermometer calibrated in Durban is more accurate because the boiling point of water is 373 K at sea level. The boiling point of water is less than 373 K in Johannesburg, due to the lower atmospheric pressure.

LB p. 170

Activity 12 Practical investigation

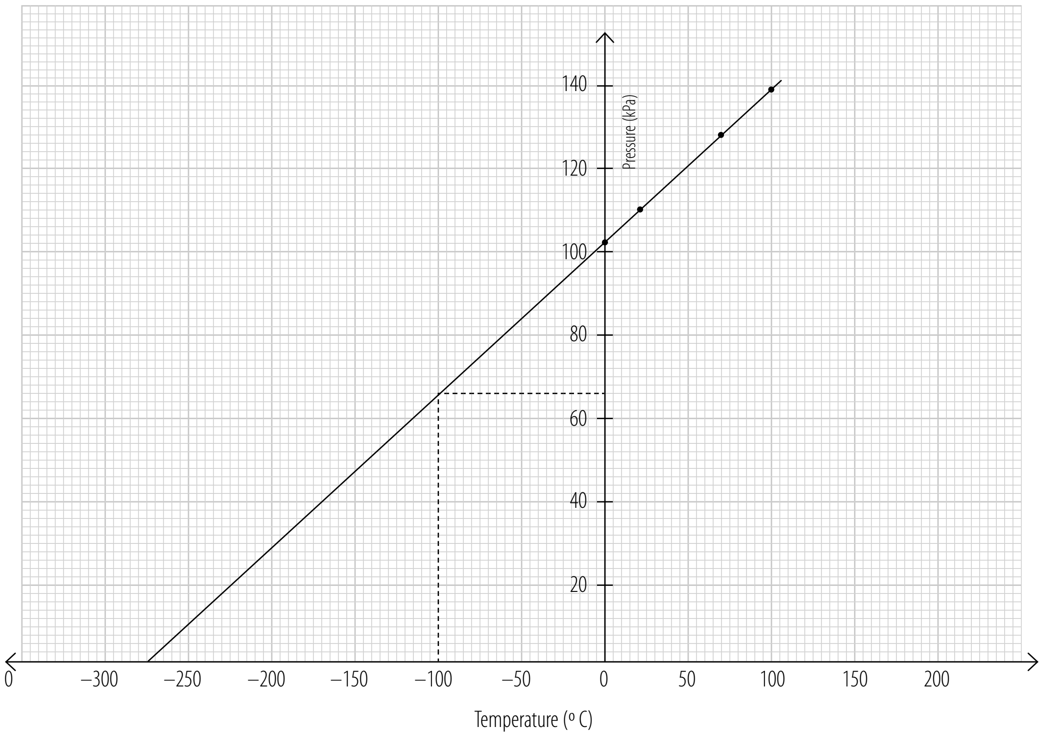
Investigate pressure-temperature relationships in a gas

1 The pressure of a gas increases as the temperature of the gas increases.

2 Dependent variable: pressure
Independent variable: temperature
Fixed variables: volume; mass/number of moles of gas

3

Graph of pressure against temperature



4 −273 °C

5 The pressure of a fixed mass of gas is directly proportional to the temperature in Kelvin.
$P \propto T$
Yes, the hypothesis was correct.

6 $t = (T - 273)$

$= 173 - 273 = -100\ °\text{C}$

On the graph −100 °C corresponds to a pressure of 64 kPa.

7 The gradient will increase: From the ideal gas equation:

$\frac{P}{T} = \frac{nR}{V}$

The gradient will increase when a larger mass is used (number of moles increased) or when the volume decreases.

8 $P = 1{,}013 \times 10^5\ \text{Pa};\ V = 250 \times 10^{-6}\ \text{m}^3;\ R = 8{,}31\ \text{J·K}^{-1}\text{·mol}^{-1};\ T = 0 + 273\ \text{K}$

$PV = nRT \Rightarrow n = \frac{PV}{RT} = \frac{(1{,}013 \times 10^5\ \text{Pa}) \times (250 \times 10^{-6}\ \text{m}^3)}{8{,}31\ \text{J·K}^{-1}\text{·mol}^{-1} \times 273\ \text{K}}$

$= 0{,}011\ \text{mol}$

LB p. 174 »

Activity 13 Research discussion

G

Explain the interdependence of gas temperature, pressure and volume

1 The pressure at the top of a mountain is lower than at the bottom of the mountain. As warm air rises in the atmosphere, it moves to a region of lower pressure. The temperature of the air decreases in direct proportion to the pressure, and so it cools.

2 At the beginning of a journey the air molecules in the tyre are cold. During the journey the temperature will rise, and so will the pressure ($T \propto P$). The recommended pressure of car tyres refers to the pressure in tyres at ambient temperatures.

3 As the bubble of methane rises, its volume will increase. The reasons are:

- The pressure decreases because the pressure at the bottom of the lake is higher than at the surface. $V \propto \frac{1}{P}$.
- The temperature increases because the temperature of the water at the bottom is colder than at the surface. $V \propto T$.

4 The difference between the types of tennis balls is the internal pressure. High altitude balls are used in areas where the atmospheric pressure is lower. They need to have a lower internal pressure. At sea level the atmospheric pressure is higher and low altitude balls must have a higher internal pressure to respond in the same way as high altitude balls. A high altitude ball hit with the same force at the coast will not move as far or bounce as high as a low altitude ball.

LB p. 174 »

Activity 14 Application exercises

I

Apply the ideal gas equation

1 $P_1 = 440{,}0\ \text{kPa};\ P_2 = ?;\ V_1 = 150{,}0\ \text{dm}^3;\ V_2 = 200{,}0\ \text{dm}^3;$

$T_1 = 12\ °\text{C} + 273 = 285\ \text{K};\ T_2 = 180\ °\text{C} + 273 = 453\ \text{K}$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\therefore P_2 = \frac{P_1V_1T_2}{V_2T_1}$

$= \frac{440{,}0\ \text{kPa} \times 150{,}0\ \cancel{\text{dm}^3} \times 453\ \cancel{\text{K}}}{200{,}0\ \cancel{\text{dm}^3} \times 285\ \cancel{\text{K}}}$

$= 525{,}0\ \text{kPa}$

The tyre will not burst.

2 a) $P = 200{,}0\ \text{kPa} = 2{,}000 \times 10^5\ \text{Pa};\ V = ?;\ n = 0{,}50\ \text{mol};$

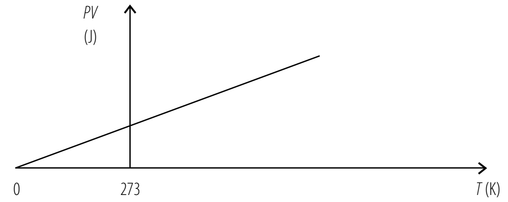
$R = 8{,}31\ \text{J·K}^{-1}\text{·mol}^{-1};\ T = 20\ °\text{C} + 273 = 293\ \text{K}$

$PV = nRT$

$$\therefore V = \frac{nRT}{P}$$
$$= \frac{0{,}50 \text{ mol} \times 8{,}31 \text{ J·K}^{-1}\text{·mol}^{-1} \times 293 \text{ K}}{(2{,}000 \times 10^5 \text{ Pa})}$$
$$= 6{,}087 \times 10^3 \text{ m}^3$$
$$= 6\,087 \text{ cm}^3$$

b) At high pressure, real gases such as ammonia deviate from ideal gas behaviour. The ammonia molecules have volume, and intermolecular forces act between them. The real volume of the ammonia is higher than it would be for an ideal gas, because the volume of the ammonia molecules must be added to the volume of the container. Repulsive forces between ammonia molecules further increase the volume.

3 a)



b) $n = 2{,}00$ mol; $R = 8{,}31$ J·K^{-1}·mol^{-1}; $T = 273$ K

$$PV = nRT$$
$$= 2{,}00 \text{ mol} \times 8{,}31 \text{ J·K}^{-1}\text{·mol}^{-1} \times 273 \text{ K}$$
$$= 4\,537 \text{ J}$$

4 a) $P_1 = 120$ kPa; $P_2 = 148$ kPa; $V_1 = V_2$; $T_1 = 18$ °C $+ 273 = 291$ K; $T_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

V remains constant

$$\therefore T_2 = \frac{T_1P_2}{P_1}$$
$$= \frac{291 \text{ K} \times 148 \cancel{\text{kPa}}}{120 \cancel{\text{kPa}}}$$
$$= 358{,}9 \text{ K}$$
$$= 85{,}9 \text{ °C}$$

b) No. If the ball is made of a material that can stretch, the ball will increase in volume if the temperature and pressure increase.

c) $P = 120$ kPa $= 1{,}20 \times 10^5$ Pa; $V = 0{,}400$ dm^3 $= 4{,}00 \times 10^{-4}$ m^3; $n = ?$;
$R = 8{,}31$ J·K^{-1}·mol^{-1}; $T = 18$ °C $+ 273 = 291$ K

$$PV = nRT$$
$$\therefore n = \frac{PV}{RT} = \frac{(1{,}20 \times 10^5 \text{ Pa}) \times (4{,}00 \times 10^{-4} \text{ m}^3)}{8{,}31 \text{ J·K}^{-1}\text{·mol}^{-1} \times 291 \text{ K}}$$
$$= 0{,}020 \text{ mol}$$

5 $P = 150$ kPa $= 150 \times 10^3$ Pa; $V = 2{,}00$ dm^3 $= 2{,}00 \times 10^{-3}$ m^3;
$T = 273 + 27 = 300$ K; $R = 8{,}31$ J·K^{-1}·mol^{-1}; $m = 3{,}36$ g

$$n = \frac{PV}{RT} = \frac{(150 \times 10^3 \text{ Pa})(2{,}00 \times 10^{-3} \text{ m}^3)}{8{,}31 \text{ J·K}^{-1}\text{·mol}^{-1} \times 300 \text{ K}}$$
$$= 0{,}120 \text{ mol}$$
$$M = \frac{m}{n} = \frac{3{,}36 \text{ g}}{0{,}120 \text{ mol}} = 28{,}0 \text{ g·mol}^{-1}$$

The gas is N_2

6 $V = 21{,}0$ dm^3 $= 21{,}0 \times 10^{-3}$ m^3; $T = 20 + 273 = 293$ K;
$R = 8{,}31$ J·K^{-1}·mol^{-1}; $M = 44{,}0$ g·mol^{-1}; $m = 70{,}0$ g

$$n = \frac{m}{M} = \frac{70{,}0 \text{ g}}{44{,}0 \text{ g·mol}^{-1}} = 1{,}59 \text{ mol}$$
$$P = \frac{nRT}{V} = \frac{1{,}59 \text{ mol} \times 8{,}31 \text{ J·K}^{-1}\text{·mol}^{-1} \times 293 \text{ K}}{(21{,}0 \times 10^{-3} \text{ m}^3)}$$
$$= 184\,351 \text{ Pa} = 184 \text{ kPa}$$

7 $P_1 = 101{,}3$ kPa; $V_1 = (20 \times 0{,}450) + 5{,}00 = 14{,}0$ dm^3; $V_2 = 5{,}00$ dm^3;
$T_1 = 19 + 273 = 292$ K; $T_2 = 24 + 273 = 297$ K

a) The container is filled with air.

b) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\therefore P_2 = \frac{P_1V_1T_2}{V_2T_1}$

$= \frac{101{,}3 \text{ kPa} \times 14{,}0 \cancel{\text{dm}^3} \times 297 \cancel{\text{K}}}{5{,}00 \cancel{\text{dm}^3} \times 292 \cancel{\text{K}}}$

$= 288 \text{ kPa}$

Learner's Book
page 178

Unit 3 Summative assessment: Matter and Materials

TERM 2, MODULE 2

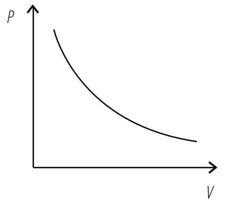
1 Give one word/ term for each of these descriptions:
  a) Kinetic Molecular Theory
  b) inversely proportional
  c) pressure

2 Correct each of the following statements:
  a) The melting point of ice is zero on the *Celsius* scale. /The melting point of ice is *273* on the Kelvin scale.
  b) The graph of V against $\frac{1}{P}$ to verify Boyle's Law is a straight line./ The graph of V against T to verify Charles' Law is a straight line.
  c) Real gases deviate from ideal gases at high pressure and low temperature.

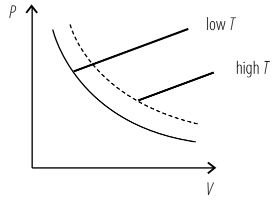
3 Choose the correct option:
  a) A
  b) D
  c) B

4 Pressure is defined as the number and intensity of collisions per unit area in a certain time. When the temperature increases, the average kinetic energy of the air molecules also increases. They collide more over the same time period and their collisions are more intense, which increases the pressure.

5 a)



  b) For all the values of P and V, PV is constant ($PV = 1{,}2$ J).
  c) $P \propto \frac{1}{V}$
  d) Boyle's Law
  e)



6 $P_1 = 108$ kPa; $P_2 = ?$; $V_1 = 400 \text{ cm}^3$; $V_2 = 410 \text{ cm}^3$;
$T_1 = 21\ °\text{C} + 273 = 294$ K; $T_2 = 210\ °\text{C} + 273 = 483$ K

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\therefore P_2 = \frac{P_1V_1T_2}{V_2T_1}$

$= \frac{108 \text{ kPa} \times 400 \cancel{\text{cm}^3} \times 483 \cancel{\text{K}}}{410 \cancel{\text{cm}^3} \times 294 \cancel{\text{K}}}$

$= 173$ kPa

7 According to the kinetic model, ideal gases have no volume and no intermolecular forces between the gas particles. At high pressures and low temperatures, real gases deviate from this behaviour; the molecular volume and intermolecular forces between the particles now play a role. Real gases have a larger volume than expected from an ideal gas. Real gases also liquefy at low temperature, which means that there must be intermolecular forces between the particles.

8 $V_1 = 250 \text{ cm}^3$; $T_1 = 17 + 273 = 290$ K; $P_1 = 196$ kPa; $V_2 = ?$;
$T_2 = 67 + 273 = 340$ K; $P_2 = 80{,}0$ kPa

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

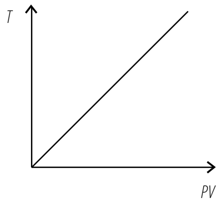
$\therefore V_2 = \frac{P_1V_1T_2}{P_2T_1}$

$= \frac{196 \cancel{\text{kPa}} \times 250 \text{ cm}^3 \times 340 \cancel{\text{K}}}{80{,}0 \cancel{\text{kPa}} \times 290 \cancel{\text{K}}}$

$= 718 \text{ cm}^3$

9 a) P = pressure exerted by the gas
V = volume occupied by the gas
T = temperature of the gas

b) $PV = kT \Rightarrow PV \propto T$



c) High pressure and low temperature

d) $32{,}0 \text{ g } O_2 = 1 \text{ mol } O_2$ molecules
$P_1 = 112$ kPa; $V_1 = 24{,}1 \text{ dm}^3$; $T_1 = 49 + 273 = 322$ K; $P_2 = 101{,}3$ kPa;
$V_2 = ?$; $T_2 = 273$ K

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\therefore V_2 = \frac{P_1V_1T_2}{P_2T_1}$

$= \frac{112 \cancel{\text{kPa}} \times 24{,}1 \text{ dm}^3 \times 273 \cancel{\text{K}}}{101{,}3 \cancel{\text{kPa}} \times 322 \cancel{\text{K}}}$

$= 22{,}6 \text{ dm}^3$

10 $P_1 = 260$ kPa; $V_1 = 200 \text{ dm}^3$; $T_1 = -13 + 273 = 260$ K; $P_2 = 101{,}3$ kPa;
$V_2 = ?$; $T_2 = 273$ K

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\therefore V_2 = \frac{P_1V_1T_2}{P_2T_1}$

$= \frac{260 \cancel{\text{kPa}} \times 200 \text{ dm}^3 \times 273 \cancel{\text{K}}}{101{,}3 \cancel{\text{kPa}} \times 260 \cancel{\text{K}}}$

$= 539 \text{ dm}^3$

11 a) $PV = nRT \Rightarrow PV = kT$ where $k = nR$

b) The pressure of a given mass of gas is directly proportional to the temperature of the gas. If we assume that the volume of the can and the amount of gas remains constant while the temperature increases, the pressure can become so great that it may explode.

12 a) $M(\text{Cl}_2) = 2 \times 35{,}5 = 71{,}0\ \text{g}\cdot\text{mol}^{-1}$

$n(\text{Cl}_2) = \frac{m}{M} = \frac{28{,}4\ \cancel{\text{g}}}{71{,}0\ \cancel{\text{g}}\cdot\text{mol}^{-1}} = 0{,}400\ \text{mol}$

$V = 3{,}324\ \text{m}^3;\ T = 273 + 25 = 298\ \text{K};\ R = 8{,}31\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

$PV = nRT$

$\therefore P = \frac{nRT}{V} = \frac{0{,}400\ \text{mol} \times 8{,}31\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \times 298\ \text{K}}{3{,}324\ \text{m}^3} = 298\ \text{Pa}$

b) The pressure is fairly low and the molecules are therefore relatively far apart, but some forces of attraction exist between the molecules. These forces cause the molecules to move close together. The actual volume of Cl_2 is less than the value one would predict, had Cl_2 been an ideal gas.

13 a) The nitrogen exerts more pressure than the oxygen.

$PV = nRT \Rightarrow P = \frac{nRT}{V}$

$\therefore P \propto n$ (R, T and V constant)

It then follows that the pressure (P) is directly proportional to the quantity of the gas (n). There is double the amount of nitrogen in the air than there is oxygen.

b) The temperature increases due to the friction between the tyres and the road. Hence there is also an increase in the kinetic energy of the molecules ($T \propto E_k$). The faster the molecules move, the more collisions per unit area of the tyre occur. The pressure thus increases. They also require a greater space in which they can move. The volume of the tyre increases and it appears more rigid.

MODULE 4: CHEMICAL CHANGE

Background information for Module 4

The learners were introduced to the mole concept in Grade 10. Unit 1 of this module revisits the mole concept with more information and advanced questions. They will also have the opportunity to familiarise themselves with the idea of titrations and acid–base neutralisation, which will continue in Grade 12.

Unit 2 deals with energy changes in chemical reactions and learners will investigate a variety of reactions and classify them as endothermic or exothermic in one of the two prescribed projects of the year. The marks for this project count towards the Term 3 term mark for physical science.

In Unit 3 learners will investigate two types of reaction – acid–base and redox. Link these reactions to the prior knowledge from Grade 10 where learners investigated reactions in aqueous solution. Emphasise that there is a wide variety of chemical reactions that occur spontaneously on Earth and that scientists classify them in different categories to better understand the behaviour of chemicals.

Chemical change comprises 17,5% of the total Grade 11 curriculum and is spread out through Terms 2, 3 and 4. Twelve hours of stoichiometry is done at the end of Term 2, and it contains one recommended experiment for informal assessment. Term 3 covers energy and change (4 hours), as well as acid-base reactions (6 hours). It includes the prescribed project mentioned earlier as well as another recommended experiment for informal assessment. Six hours are spent on redox reactions in Term 4 and they also contain a recommended activity for informal assessment.

LB p. 182

Activity 1 Revision exercises

I

Calculations using the mole concept

1 $M(\text{Na}) = 23\ \text{g·mol}^{-1}$
$\therefore 34{,}5\ \text{g Na} = \frac{34{,}5\ \cancel{\text{g}}}{23\ \cancel{\text{g}}\,\text{mol}^{-1}}$
$= 1{,}5\ \text{mol}$
2 $1\ \text{mol Cu} = 63{,}5\ \text{g}$
$\therefore 0{,}2\ \text{mol Cu} = 0{,}2\ \cancel{\text{mol}} \times 63{,}5\ \text{g·}\cancel{\text{mol}^{-1}} = 7{,}3\ \text{g}$
3 $1\ \text{mol P} = 31\ \text{g P} = 6{,}02 \times 10^{23}\ \text{P atoms}$
$\therefore 77{,}5\ \text{g P} = \frac{77{,}5\ \cancel{\text{g}}}{31\ \cancel{\text{g}}} \times 6{,}02 \times 10^{23} = 1{,}51 \times 10^{24}\ \text{P atoms}$
4 $1\ \text{mol CH}_4 = 12 + 4 = 16\ \text{g·mol}^{-1}$
$\therefore 32\ \text{g CH}_4 = \frac{32\ \cancel{\text{g}}}{16\ \cancel{\text{g}}\,\text{mol}^{-1}} = 2\ \text{mol}$
5 $M[(\text{NH}_2)_2\text{CO}] = 2(14 + 2) + 12 + 16 = 60\ \text{g·mol}^{-1}$
6 $M[(\text{NH}_2)_2\text{CO}] = 60\ \text{g·mol}^{-1}$
$\therefore 40\ \text{g}\ (\text{NH}_2)_2\text{CO} = \frac{60\ \cancel{\text{g}}\,\text{mol}^{-1}}{40\ \cancel{\text{g}}} = 1{,}5\ \text{mol}$
$\therefore$ number of H atoms $= 1{,}5 \times 4 \times 6{,}02 \times 10^{23} = 3{,}6 \times 10^{24}$ H atoms

LB p. 188

Activity 2 Experiment

G

Make a standard solution

Learners work in groups to make up standard solutions. Use the method in the Learner's Book. You can also demonstrate the technique. Use the list below to make up 1 mol·dm⁻³ solutions.

Salt	Mass of salt to be made up to 100 ml	Mass of salt to be made up to 200 ml	Mass of salt to be made up to 250 ml
NaCl	5,84 g	11,69 g	14,61 g
$(\text{COOH})_2\text{·2H}_2\text{O}$	12,61 g	25,21 g	31,52 g
KCl	7,46 g	14,91 g	18,64 g
NaOH	4,00 g	8,00 g	10,00 g

LB p. 188

Activity 3 Application exercises

I

Use concentration formulae

1 $M(\text{AgNO}_3) = 107{,}9 + 14{,}0 + (3 \times 16{,}0) = 169{,}9\ \text{g·mol}^{-1}$
$V = 250\ \text{cm}^3 = 0{,}250\ \text{dm}^3$
$c = \frac{m}{MV} = \frac{5{,}10\ \cancel{\text{g}}}{169{,}9\ \cancel{\text{g}}\,\text{mol}^{-1} \times 0{,}250\ \text{dm}^3}$
$= 0{,}120\ \text{mol·dm}^{-3}$
2 $M(\text{Na}_2\text{CO}_3\text{·10H}_2\text{O}) = (2 \times 23{,}0) + 12{,}0 + (3 \times 16{,}0) + (10 \times 18{,}0)$
$= 286{,}0\ \text{g·mol}^{-1}$
$V = 200\ \text{ml} = 0{,}200\ \text{dm}^3$
$m = cMV = 0{,}100\ \cancel{\text{mol}}\text{·}\cancel{\text{dm}^{-3}} \times 286{,}0\ \text{g·}\cancel{\text{mol}^{-1}} \times 0{,}200\ \cancel{\text{dm}^3}$
$= 5{,}72\ \text{g Na}_2\text{CO}_3\text{·10H}_2\text{O}$
3 $M(\text{KMnO}_4) = 39{,}1 + 54{,}9 + (4 \times 16{,}0) = 158{,}0\ \text{g·mol}^{-1}$

$V = \frac{m}{cM} = \frac{3{,}95\,\cancel{g}}{0{,}100\,\cancel{mol}{\cdot}dm^3 \times 158{,}0\,\cancel{g}{\cdot}\cancel{mol^{-1}}} = 0{,}250\ dm^3$

You should use the 250 ml flask.

4 $M(MgCl_2) = 24{,}3 + (2 \times 35{,}5) = 95{,}3\ g{\cdot}mol^{-1}$

$n(MgCl_2) = \frac{m}{M} = \frac{20{,}0\,\cancel{g}}{95{,}3\,\cancel{g}{\cdot}mol^{-1}} = 0{,}210\ mol$

$n(Cl^-\ ions) = 2 \times 0{,}210 = 0{,}420\ mol$

$M(NaCl) = 23{,}0 + 35{,}5 = 58{,}5\ g{\cdot}mol^{-1}$

$n(NaCl) = \frac{m}{M} = \frac{20{,}0\,\cancel{g}}{58{,}5\,\cancel{g}{\cdot}mol^{-1}} = 0{,}342\ mol$

$n(Cl^-\ ions) = 1 \times 0{,}342 = 0{,}342\ mol$

Total n Cl^- ions = 0,420 mol + 0,342 mol = 0,762 mol Cl^- ions

$c(Cl^-\ ions) = \frac{n}{V} = \frac{0{,}762\ mol}{2{,}00\ dm^3}$

$= 0{,}381\ mol{\cdot}dm^{-3}$

Note: $c(Cl^-)$ can also be written as $[Cl^-]$

5 a) $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$

b) $\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$

$\frac{1\,\cancel{mol}}{2\,\cancel{mol}} = \frac{c_a \times 30{,}0\,\cancel{cm^3}}{0{,}180\ mol{\cdot}dm^{-3} \times 70{,}0\,\cancel{cm^3}}$

$\therefore c_a = 0{,}210\ mol{\cdot}dm^{-3}$

c) $M(NaOH) = 23{,}0 + 16{,}0 + 1{,}0 = 40{,}0\ g{\cdot}mol^{-1}$; $V = 70\ cm^3 = 0{,}070\ dm^3$

$m = cMV = 0{,}180\,\cancel{mol}{\cdot}\cancel{dm^{-3}} \times 40{,}0\ g{\cdot}\cancel{mol^{-1}} \times 0{,}070\,\cancel{dm^3} = 0{,}504\ g\ NaOH$

6 a) $M(KOH) = 39{,}1 + 16{,}0 + 1{,}0 = 56{,}1\ g{\cdot}mol^{-1}$

$c = \frac{m}{MV} = \frac{14{,}0\,\cancel{g}}{56{,}1\,\cancel{g}{\cdot}mol^{-1} \times 1{,}00\ dm^3}$

$= 0{,}250\ mol{\cdot}dm^{-3}$

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

$\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$

$\frac{1\,\cancel{mol}}{2\,\cancel{mol}} = \frac{0{,}100\,\cancel{mol{\cdot}dm^{-3}} \times V_a}{0{,}250\,\cancel{mol{\cdot}dm^{-3}} \times 30{,}0\ cm^3}$

$\therefore V_a = 37{,}5\ cm^3$

Test yourself 1 (LB p. 191)

1

Element	g/100g	$n = \frac{m}{M}$	Simplest ratio
K	24,75	$\frac{24{,}75}{39{,}1} = 0{,}63$	$\frac{0{,}63}{0{,}63} = 1$
Mn	34,77	$\frac{34{,}77}{54{,}9} = 0{,}63$	$\frac{0{,}63}{0{,}63} = 1$
O	40,51	$\frac{40{,}51}{16{,}0} = 2{,}53$	$\frac{2{,}53}{0{,}63} = 4$

The empirical formula is $KMnO_4$.

2

Element	mass, *m* (g)	$n = \frac{m}{M}$	Simplest ratio
N	1,52	$\frac{1{,}52}{14{,}0} = 0{,}109$	$\frac{0{,}109}{0{,}109} = 1$
O	3,47	$\frac{3{,}47}{16{,}0} = 0{,}217$	$\frac{0{,}217}{0{,}109} = 2$

The empirical formula is NO_2.

Empirical molar mass = 14,0 + (2 × 16,0) = 46,0 g

Molecular molar mass is between 90 g and 95 g. Number of NO_2 units in molecular mass:

$\frac{90\,\cancel{g}}{46\,\cancel{g}} = 1{,}96$; $\frac{95\,\cancel{g}}{46\,\cancel{g}} = 2{,}06$

The molecular mass is twice the empirical mass, so the molecular formula is N_2O_4.

3

Element	g/100g	$n = \frac{m}{M}$	Simplest ratio
C	74,07	$\frac{74,07}{12,0} = 6,17$	$\frac{6,17}{1,23} = 5$
N	17,28	$\frac{17,28}{14,0} = 1,23$	$\frac{1,23}{1,23} = 1$
H	8,65	$\frac{8,65}{1,0} = 8,65$	$\frac{8,65}{1,23} = 7$

a) The empirical formula is C_5NH_7.

b) Empirical molar mass = $(5 \times 12,0) + 14,0 + (7 \times 1,0) = 81,0$ g

Number of $C_5NH_7 = \frac{\text{molecular mass}}{\text{empirical mass}} = \frac{162,2\,\cancel{g}}{81,0\,\cancel{g}} = 2$

The molecular formula is $C_{10}N_2H_{14}$.

LB p. 195

Activity 4 Recommended experiment for informal assessment

G

Determine the mass of PbO_2 prepared from $Pb(NO_3)_2$

You must read the safety precautions carefully and make the learners aware of the dangers and what to do if an accident happens.

Safety

- You and the learners should wear safety goggles during all chemistry experiments.
- Avoid skin contact with chemicals.
- Wash hands after handling chemicals.
- Dilute solutions of most acids, bases and salts are regarded as low hazard chemicals.
- Handle glass apparatus with care. Report breakages immediately; treat and monitor skin cuts.
- Take care when using a Bunsen burner; handle hot apparatus with a pair of tongs.
- Lead and lead products are toxic: avoid skin contact and wear gloves. Dispose of chemical waste safely (never down the drain); contact the local authority for guidelines.
- Solid NaOH is highly corrosive: Handle with extreme care and avoid skin contact.

Follow the method the Learner's Book

- Use a Buchner funnel and flask to filter the precipitate if the apparatus is available.
- Use the propettes to wash the precipitate on the filter paper with water and nitric acid.

8 The product of the reaction ($Pb(NO_3)_2$) contains water. By drying the product and filter paper, the water evaporates and the dry product and filter paper can be weighed.

9 To determine the weight of the product alone, a clean filter paper must be weighed and this weigh subtracted from the total weight of the product with the filter paper. For calculations such as percentage yield, you need the mass of the product only.

10 Calculating theoretical yield:

1 mol $Pb(NO_3)_2$ gives 1 mol PbO_2

$\therefore (207,2 + 2(14,0) + 6(16,0)) \rightarrow (207,2 + 2(16,0))$

$\therefore$ 331,2 g $Pb(NO_3)_2 \rightarrow$ 239,2 g PbO_2

$\therefore$ 4,0 g $Pb(NO_3)_2 \rightarrow$ 2,9 g PbO_2

11 Calculating percentage yield:

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$
$$= \frac{\text{actual yield (mass of PbO}_2\text{)}}{2{,}9\text{ g}} \times 100\%$$

Checklist for teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Stays focused on experiment			
Understands experimental method			
Follows method in orderly manner			
Uses time efficiently			
Uses apparatus and equipment correctly			
Helpful/ valuable member of group			
Answers simple questions during experiment			
Answers questions correctly and calculations correct			

Test yourself 2 (LB p. 196)

1 a) 1 mol O_2 forms 2 mol NO_2
$\therefore$ 0,25 mol O_2 forms $2 \times 0{,}25 = 0{,}50$ mol NO_2
b) 2 mol NO form 2 mol NO_2
$\therefore 2(14{,}0 + 16{,}0)$ NO form $2(14{,}0 + 2 \times 16{,}0)$ NO_2
$\therefore$ 60,0 g NO form 92,0 g NO_2
$\therefore$ 30,0 g NO form $\frac{30{,}0\ \cancel{g}}{60{,}0\ \cancel{g}} \times 92{,}0\text{ g} = 46{,}0$ g NO_2
Alternative method:
30,0 g NO = 1 mole; therefore, 1 mole of NO_2 is produced
1 mole NO_2 = 46 g

2 $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
$n\ AgNO_3$: $n = cV = 1{,}0\ \text{mol}\cdot\cancel{\text{dm}^{-3}} \times 5{,}0 \times 10^{-3}\ \cancel{\text{dm}^3}$
$= 5{,}0 \times 10^{-3}$ mol (= 0,005 mol)
n NaCl: $n = cV = 0{,}5\ \text{mol}\cdot\cancel{\text{dm}^{-3}} \times 20{,}0 \times 10^{-3}\ \cancel{\text{dm}^3}$
$= 1{,}0 \times 10^{-2}$ mol (= 0,010 mol)
In the balanced equation, 1 mol $AgNO_3$ reacts with 1 mol NaCl.
The $AgNO_3$ is the limiting reagent and all $AgNO_3$ will be used up.
0,005 mol $AgNO_3$ will form 0,005 mol AgCl.
$M(AgCl) = 107{,}9 + 35{,}5 = 143{,}4\ \text{g}\cdot\text{mol}^{-1}$
$m = nM = 0{,}005\ \cancel{\text{mol}} \times 143{,}4\ \text{g}\cdot\cancel{\text{mol}^{-1}} = 0{,}717$ g

3 a) $M(NH_3) = 17{,}0\ \text{g}\cdot\text{mol}^{-1}$; $M(CO_2) = 44{,}0\ \text{g}\cdot\text{mol}^{-1}$;
$M((NH_2)_2CO) = 60{,}0\ \text{g}\cdot\text{mol}^{-1}$
Convert the masses to moles by using $n = \frac{m}{M}$:
mol $NH_3 = \frac{m}{M} = \frac{1\ 352\ \cancel{g}}{17{,}0\ \cancel{g}\cdot\text{mol}^{-1}} = 79{,}53$ mol
mol $CO_2 = \frac{1\ 642\ \cancel{g}}{44{,}0\ \cancel{g}\cdot\text{mol}^{-1}} = 37{,}32$ mol
From the balanced equation we see that 2 mol NH_3 react with 1 mol CO_2.
Therefore, 79,53 mol NH_3 will react with 39,77 mol CO_2.
Since there are only 37,32 mol CO_2, this must be the limiting reagent.
b) 1 mol CO_2 forms 1 mol $(NH_2)_2CO$
$\therefore$ 37,32 mol CO_2 will form $37{,}32\ \cancel{\text{mol}} \times 60{,}0\ \text{g}\cdot\cancel{\text{mol}^{-1}}$
$= 2\ 239$ g $(NH_2)_2CO$
c) 37,32 mol CO_2 react with 74,64 mol NH_3

mol NH_3 left = 79,53 – 74,64 = 4,89 mol
mass NH_3 = 4,89 × 17,0 = 83,13 g NH_3

4 a) $M(\text{Ca}) = 40{,}1\ \text{g·mol}^{-1}$; $M(V_2O_5) = 181{,}8\ \text{g·mol}^{-1}$; $M(\text{V}) = 50{,}9\ \text{g·mol}^{-1}$
First calculate the number of moles of Ca and V_2O_5 initially present:
mol Ca: $n = \frac{m}{M} = \frac{3{,}96 \times 10^4\ \cancel{\text{g}}}{40{,}1\ \cancel{\text{g}}\text{·mol}^{-1}} = 988\ \text{mol}$
mol V_2O_5: $n = \frac{8{,}54 \times 10^3\ \cancel{\text{g}}}{50{,}9\ \cancel{\text{g}}\text{·mol}^{-1}} = 168\ \text{mol}$
From the balanced equation we see that 5 mol Ca react with 1 mol V_2O_5
Therefore, 988 mol Ca will react with 198 mol V_2O_5
There are only 168 mol V_2O_5 available, so V_2O_5 is the limiting reagent.
From the balanced equation we see that 1 mol V_2O_5 forms 2 mol V
Therefore, 168 mol V_2O_5 will form 336 mol V.
The theoretical yield = $336\ \cancel{\text{mol}} \times 50{,}9\ \text{g·}\cancel{\text{mol}^{-1}} = 1{,}71 \times 10^4\ \text{g}\ V_2O_5$.

b) percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$
$= \frac{1{,}38 \times 10^4\ \cancel{\text{g}}}{1{,}71 \times 10^4\ \cancel{\text{g}}} \times 100\% = 80{,}7\%$

Test yourself 3 (LB p. 200)

1 a) $M(CH_3CH_2OH) = 46\ \text{g·mol}^{-1}$
2 mol CH_3CH_2OH react with 6 mol O_2
$\therefore$ 2 × 46,0 g CH_3CH_2OH react with 6 × 22,4 dm^3 O_2
$\therefore$ 209 g CH_3CH_2OH react with $\frac{209\ \cancel{\text{g}}}{2 \times 46{,}0\ \cancel{\text{g}}} \times 6 \times 22{,}4\ \text{dm}^3 = 305\ \text{dm}^3\ O_2$
Alternative method:
1 mol CH_3CH_2OH = 46 g $\Rightarrow$ 209 g $CH_3CH_2OH = \frac{209}{46} = 4{,}5$ mol
2 mol CH_3CH_2OH react with 6 mol O_2,
therefore 4,5 mol CH_3CH_2OH will react with $\frac{4{,}5}{2} \times 6 = 13{,}6$ mol O_2
13,6 mol O_2 = 13,6 × 22,4 = 305 dm^3 O_2

b) 2 mol CH_3CH_2OH release 10 mol gas
$\therefore$ 2 × 46,0 g CH_3CH_2OH release 10 × 22,4 dm^3 gas
$\therefore$ 209 g CH_3CH_2OH release $\frac{209\ \cancel{\text{g}}}{2 \times 46{,}0\ \cancel{\text{g}}} \times 10 \times 22{,}4\ \text{dm}^3 = 509\ \text{dm}^3$ gas

2 a) $M(C_3H_5(NO_3)_3) = 227{,}0\ \text{g·mol}^{-1}$
4 mol $C_3H_5(NO_3)_3$ release 29 mol gas
$\therefore$ 4 × 227,0 g $C_3H_5(NO_3)_3$ release 29 × 22,4 dm^3 gas
$\therefore$ 1 000 g $C_3H_5(NO_3)_3$ release $\frac{1\,000\ \cancel{\text{g}}}{4 \times 227{,}0\ \cancel{\text{g}}} \times 29 \times 22{,}4\ \text{dm}^3 = 715\ \text{dm}^3$ gas

b) The explosion of 4 mol nitroglycerine produces 29 moles of gaseous products. At STP, a sample of nitroglycerine of 1 kg produces 715 dm^3 or litres of gas, which is a huge amount. (It is actually 1 144 times the volume of the original reactant.) The reaction is exothermic and heat is also released.

3 a) The large volume of gas that forms, supports the chromium(III) oxide that spews into the air.

b) $M((NH_4)_2Cr_2O_7) = 252{,}0\ \text{g·mol}^{-1}$; $M(Cr_2O_3) = 152{,}0\ \text{g·mol}^{-1}$
1 mol $(NH_4)_2Cr_2O_7$ forms 1 mol Cr_2O_3
$\therefore$ 252,0 g $(NH_4)_2Cr_2O_7$ form 152,0 g Cr_2O_3
$\therefore$ 20,0 g $(NH_4)_2Cr_2O_7$ form $\frac{20{,}0\ \cancel{\text{g}}}{252{,}0\ \cancel{\text{g}}} \times 152{,}0\ \text{g} = 12{,}1\ \text{g}\ Cr_2O_3$

c) 1 mol $(NH_4)_2Cr_2O_7$ releases 5 mol gas
$\therefore$ 252,0 g $(NH_4)_2Cr_2O_7$ release 5 × 22,4 dm^3 gas
$\therefore$ 20,0 g $(NH_4)_2Cr_2O_7$ release $\frac{20{,}0\ \cancel{\text{g}}}{252{,}0\ \cancel{\text{g}}} \times 112\ \text{dm}^3 = 8{,}89\ \text{dm}^3$ gas

Learner's Book page 201

Unit 1 Summative assessment: Chemical change

TERM 2, MODULE 4

1 a) mole
  b) empirical formula
  c) 22,4 dm^3
  d) explosion (reaction)

2 a) 1 mol C_2H_2 reacts completely with *2,5* mol O_2 to form 2 mol CO_2 and *1* mol H_2O.
  b) A standard solution always has a *known* concentration and can have any concentration.
  c) The effectivity of an explosive is mainly determined by the *amount and temperature of the of gas released during* the reaction.

3 a) B
  b) C
  c) B; A

4 $M(C_6H_{12}O_6) = (6 \times 12,0) + (12 \times 1,0) + (6 \times 16,0) = 180,0\ g \cdot mol^{-1}$

$M(CO_2) = 12,0 + (2 \times 16,0) = 44,0\ g \cdot mol^{-1}$

180,0 g $C_6H_{12}O_6$ produce 44,0 g CO_2

$\therefore$ 856 g $C_6H_{12}O_6$ produce $\frac{856\ \cancel{g}}{180\ \cancel{g}} \times 44,0\ g = 209\ g\ CO_2$

At STP, 1 mol occupies 22,4 dm^3

1 mol CO_2 = 44,0 g CO_2

$\therefore 209\ g\ CO_2 = \frac{209\ \cancel{g}}{44,0\ \cancel{g}} = 4,76\ mol\ CO_2$,

which will occupy $4,76 \times 22,4 = 107\ dm^3$

5 $M(NaNO_3) = 23,0 + 14,0 + (3 \times 16,0) = 85,0\ g \cdot mol^{-1}$

$c = \frac{m}{MV} = \frac{5,68\ \cancel{g}}{85,0\ \cancel{g} \cdot mol^{-1} \times 1\ dm^3}$

$= 0,067\ mol \cdot dm^{-3}$

6 $n = cV = 1,50\ mol \cdot \cancel{dm^{-3}} \times 0,060\ \cancel{dm^3}$

$= 0,09\ mol$

7 $M(KOH) = 40,0 + 16,0 + 1,0 = 57,0\ g \cdot mol^{-1}$

$m = cMV = 5,5\ \cancel{mol \cdot dm^{-3}} \times 57,0\ g \cdot \cancel{mol^{-1}} \times 0,0350\ \cancel{dm^3}$

$= 11,0\ g$

8 Solution:

Element	**g/100g**	$n = \frac{m}{M}$	**Simplest ratio**
C	41,38	$\frac{41,68}{12,0} = 3,45$	$\frac{3,45}{1,15} = 3$
H	8,05	$\frac{8,05}{1,0} = 8,05$	$\frac{8,05}{1,15} = 7$
N	32,18	$\frac{32,18}{14,0} = 2,30$	$\frac{2,30}{1,15} = 2$
O	18,39	$\frac{18,39}{16,0} = 1,15$	$\frac{1,15}{1,15} = 1$

The empirical formula is $C_3H_7N_2O$

$M(C_3H_7N_2O) = (3 \times 12,0) + (7 \times 1,0) + (2 \times 14,0) + (1 \times 16,0)$

$= 87,0\ g \cdot mol^{-1}$

Molecular formula = n(empirical formula)= $n(87,0\ g \cdot mol^{-1})$

$= 174\ g \cdot mol^{-1} \therefore n = 2$

Therefore, the molecular formula is $C_6H_{14}N_4O_2$

9 a) $M(\text{TiCl}_4) = 47{,}9 + (4 \times 35{,}5) = 189{,}9\ \text{g}\cdot\text{mol}^{-1}$; $M(\text{Mg}) = 24{,}3\ \text{g}\cdot\text{mol}^{-1}$; $M(\text{Ti}) = 47{,}9\ \text{g}\cdot\text{mol}^{-1}$

Calculate the number of moles in $6{,}55 \times 10^8$ g TiCl_4:

$n = \frac{m}{M} = \frac{6{,}55 \times 10^8\,\cancel{\text{g}}}{189{,}9\,\cancel{\text{g}}\,\text{mol}^{-1}} = 3{,}45 \times 10^6$ mol

Calculate the number of moles in $3{,}13 \times 10^8$ g Mg:

$n = \frac{m}{M} = \frac{3{,}13 \times 10^8\,\cancel{\text{g}}}{24{,}3\,\cancel{\text{g}}\,\text{mol}^{-1}} = 1{,}29 \times 10^7$ mol

1 mol TiCl_4 reacts with 2 mol Mg

$\therefore$ $3{,}45 \times 10^6$ mol TiCl_4 reacts with $6{,}90 \times 10^6$ mol Mg

TiCl_4 is the limiting reagent.

189,9 g TiCl_4 produce 47,9 g Ti

$\therefore$ $6{,}55 \times 10^8$ g TiCl_4 produce $\frac{6{,}55 \times 10^8}{189{,}9} \times 47{,}9 = 1{,}65 \times 10^8$ g Ti

b) percentage yield $= \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

$= \frac{1{,}26 \times 10^8\,\cancel{\text{g}}}{1{,}65 \times 10^8\,\cancel{\text{g}}} \times 100\% = 76{,}4\%$

MODULE 5: ELECTRICITY AND MAGNETISM

Background information for Module 5

This module builds on the foundation laid in Grade 10 for electricity and magnetism. All three units are done at the beginning of Term 3. Electrostatics is a theoretical Unit and comprises Coulomb's Law and electric fields.

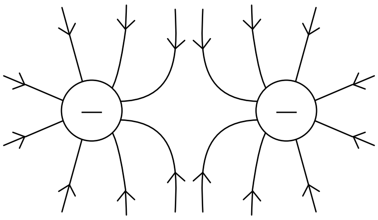
Electromagnetism revolves around Faraday's Law and induction, and contains no informal assessment task.

Electric circuits cover Ohm's Law, one of the recommended experiments for informal assessment, as well as power and energy, with a practical demonstration of the factors that influence the brightness of light bulbs. The practical application of power will make learners more aware of the amount of electricity that they use and how much electric appliances cost in electricity.

The module on electricity and magnetism uses 12,5% of the total allocation for Physical Science and translates into 20 hours of teaching.

Test yourself 1 **(LB p. 211)**

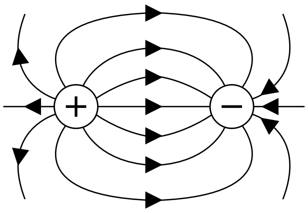
1 a)



b) $k = 9{,}0 \times 10^{9}\ \text{N·m}^{2}\text{·C}^{-2}$; $Q_1 = -0{,}48\ \mu\text{C} = -0{,}48 \times 10^{-6}\ \text{C}$;
$Q_2 = -\,245\ \text{nC} = -\,245 \times 10^{-9}\ \text{C}$; $r = 120 \times 10^{-3}\ \text{m}$; $F = ?$
$F = k\dfrac{Q_1Q_2}{r^2}$
$= (9{,}0 \times 10^{9}\ \text{N·}\cancel{\text{m}^{2}}\text{·}\cancel{\text{C}^{-2}})\dfrac{(0{,}48 \times 10^{-6}\ \cancel{\text{C}})(245 \times 10^{-9}\ \cancel{\text{C}})}{(120 \times 10^{-3}\ \cancel{\text{m})^{2}}}$
$\vec{F} = 7{,}4 \times 10^{2}\ \text{N}$ away from each other (repulsion)

2 a) The field is strongest where the field lines are closest to one another.

b)



c) $\vec{F} = k\dfrac{Q_1Q_2}{r^2}$
$= (9{,}0 \times 10^{9}\ \text{N·}\cancel{\text{m}^{2}}\text{·}\cancel{\text{C}^{-2}})\ \dfrac{(2{,}0 \times 10^{-9}\ \cancel{\text{C}})(3{,}0 \times 10^{-9}\ \cancel{\text{C}})}{(75 \times 10^{-3}\ \cancel{\text{m})^{2}}}$
$\vec{F} = 9{,}6 \times 10^{-6}\ \text{N}$ towards each other (attraction)

3 a) new charge $= \dfrac{+20{,}0\ \text{nC} + (-10{,}0\ \text{nC})}{2} = +5{,}0\ \text{nC}$

b) $F = k\dfrac{Q_1Q_2}{r^2}\ \therefore\ r = \sqrt{k\ \dfrac{Q^2}{F}}$
$r = \sqrt{(9{,}0 \times 10^{9}\ \cancel{\text{N}}\text{·m}^{2}\text{·}\cancel{\text{C}^{-2}})\ \dfrac{(5{,}0 \times 10^{-9}\ \cancel{\text{C})^{2}}}{(7{,}5 \times 10^{-5}\ \cancel{\text{N}}}}$
$= 3{,}0 \times 10^{-3}\ \text{m}$ or $0{,}003\ \text{m}$
$= 3\ \text{mm}$

Test yourself 2 **(LB p. 214)**

1 a) $\vec{F} = k\dfrac{Q_1Q_2}{r^2} = (9{,}0 \times 10^{9}\ \text{N·}\cancel{\text{m}^{2}}\text{·}\cancel{\text{C}^{-2}})\ \dfrac{(4 \times 10^{-9}\ \cancel{\text{C}})(6 \times 10^{-9}\ \cancel{\text{C}})}{(0{,}6\ \cancel{\text{m})^{2}}}$
$= 6 \times 10^{-7}\ \text{N}$ away from B / to the left

b) i) The force will double.
ii) The force will increase fourfold.
iii) The force will increase fourfold.

c) $\vec{E} = \dfrac{\vec{F}}{q} = \dfrac{6 \times 10^{-7}\ \text{N}}{4 \times 10^{-9}\ \text{C}} = 150\ \text{N·C}^{-1}$ to the left

d) $E \propto \dfrac{1}{r^2}\ \therefore$ if r is halved, E will increase fourfold.
$E = 150\ \text{N·C}^{-1} \times 4 = 600\ \text{N·C}^{-1}$

2 a) $E = k\dfrac{Q}{r^2}\ \therefore\ 1{,}2 \times 10^{6}\ \cancel{\text{N}}\text{·}\cancel{\text{C}^{-1}} = (9{,}0 \times 10^{9}\ \cancel{\text{N}}\text{·m}^{2}\text{·}\cancel{\text{C}^{-2}})\ \dfrac{6{,}0 \times 10^{-6}\ \cancel{\text{C}}}{r^2}$
$\therefore\ r^2 = 0{,}045\ \text{m}^2$
$\therefore\ r = 0{,}21\ \text{m}$

b) $F = k\frac{Q_1Q_2}{r^2}$

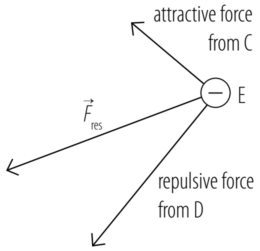
$= (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{C}^{-2}})\frac{(6{,}0 \times 10^{-6}\ \cancel{\text{C}})(12{,}0 \times 10^{-6}\ \cancel{\text{C}})}{(0{,}21\ \cancel{\text{m}})^2}$

$= 15\ \text{N}$

$\vec{F} = 15$ N towards each other (attraction)

c) The acceleration of the electron will be non-uniform.
E increases closer to the charges. Therefore F increases ($E \propto F$) and a increases ($F \propto a$).

d)



Force on E as a result of C:

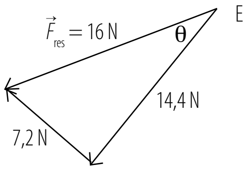
$F = k\frac{Q_CQ_E}{r^2} = 9 \times 10^9\ \text{N}\cdot\text{m}^2\cdot\text{C}^{-2}\ \frac{6 \times 10^{-6}\ \text{C} \times 3 \times 10^{-6}\ \text{C}}{(0{,}15\ \text{m})^2}$

$= 7{,}2$ N attractive

Force on E as a result of D:

$F = k\frac{Q_CQ_E}{r^2} = 9 \times 10^9\ \text{N}\cdot\text{m}^2\cdot\text{C}^{-2}\ \frac{12 \times 10^{-6}\ \text{C} \times 3 \times 10^{-6}\ \text{C}}{(0{,}15\ \text{m})^2}$

$= 14{,}4$ N repulsive



Magnitude of resultant force $= \sqrt{(7{,}2\ \text{N})^2 + (14{,}4\ \text{N})^2} = 16$ N

Direction of resultant force: $\tan\theta = \frac{7{,}2\ \text{N}}{14{,}4\ \text{N}} = 0{,}50\ \therefore\ \theta = 26{,}6°$;
63,4° anticlockwise from the connecting line between C and E

e) Electric field strength at E as a result of C:

$E = \frac{F}{q} = \frac{7{,}2\ \text{N}}{3 \times 10^{-6}\ \text{C}} = 2{,}4 \times 10^6\ \text{N}\cdot\text{C}^{-1}$

Electric field strength at E as a result of D:

$E = \frac{F}{q} = \frac{14{,}4\ \text{N}}{3 \times 10^{-6}\ \text{C}} = 4{,}8 \times 10^6\ \text{N}\cdot\text{C}^{-1}$

Magnitude of resultant E $= \sqrt{(2{,}4 \times 10^6\ \text{N}\cdot\text{C}^{-1})^2 + (4{,}8 \times 10^6\ \text{N}\cdot\text{C}^{-1})^2}$

$= 5{,}37 \times 10^6\ \text{N}\cdot\text{C}^{-1}$

Direction is the same as for the force: 63,4° anticlockwise from the connecting line between C and E

Unit 2 Electromagnetism

TERM 3, MODULE 5

Teacher demonstration

Show magnetic fields around current-carrying wires

You will need: power supply, wire, retort stand, cardboard, several compasses

We use a compass to indicate a magnetic field. When a magnetic field is present, the compass needle will deflect. Use the diagrams in the Learner's Book as guidance on how to connect the circuits and where to place the compasses.

LB p. 218 »

Activity 1 Practical project

P G

Make an electromagnet

The iron with copper wire wound around it forms an electromagnet. It will attract other magnetic materials while it is connected to the batteries and the current flows. As soon as the current stops flowing, the magnetism disappears.

An electromagnet has many uses. For example, in electromagnetic cranes that move large pieces of metal in a scrap-yard, the current is switched on to energise the magnet and pick up a wrecked car. When the metal wreck has been manoeuvred into the correct position, the current is switched off and the metal is released.

Soft magnetic materials, such as iron, are easily magnetised but lose their magnetism when the current is switched off. If the soft iron core in the electromagnet is replaced by a hard magnetic material, such as steel, it is not easily magnetised but retains its magnetic properties after the current has been switched off. In this way a more permanent magnet can be made. It cannot function as an electromagnet.

To increase the strength of an electromagnet with a soft iron core:

- increase the current through the solenoid – the greater the current, the greater the strength of the field
- increase the number of turns of the wire on the coil – this does not mean making the coil longer, but packing more turns into the same space to concentrate the magnetic field.

LB p. 219 »

Activity 2 Practical investigation

G

Investigate the induction of an electric current

1

Action	Galvanometer deflection
N pole into solenoid	Deflection in one direction (direction a)
Magnet stationary inside solenoid	No deflection
N pole out of solenoid	Deflection in the opposite direction (direction b)
S pole into solenoid	Deflection in direction b
Magnet stationary inside solenoid	No deflection
S pole out of solenoid	Deflection in direction a
Speed of magnet motion increased	Larger deflection
Strength of magnets increased	Larger deflection
Increase in number of turns on solenoid	Larger deflection
Coil moved over magnet end	Deflection in both directions
Coil moved over magnet middle	No deflection

2 One possible investigative question: How does the current in a solenoid change if a magnet is moved in relation to the solenoid?

3 When a changing magnetic field induces an emf with the resultant flow of current in a closed conductor, the phenomenon is called electromagnetic induction.

4 The induced current is influenced by:
   - the rate of motion – faster motion induces a larger current
   - the strength of the magnet – a stronger magnet induces a larger current

- the number of turns on the solenoid – more turns packed into the same area increase the induced current.

5 a) A magnetic field exists between the poles of the permanent magnet. When a conductor is moved through the magnetic field, an emf is induced across the ends of the wire. Electromagnetic induction occurs.
b) The poles of the emf will change around.
c) The learner could move the wire faster – an increased speed will increase the induced emf.
d) No emf will be induced, because the direction of motion is the same as the direction of the magnetic field.

Test yourself 3 (LB p. 222)

1. a) A solenoid is a cylindrical coil of wire.
b) We use the Right Hand Rule: Hold the solenoid in your right hand with your curved fingers in the direction of the conventional current. Your extended thumb points in the direction of the north pole of the solenoid.
c) electromagnet
d) An emf is induced.
e) electromagnetic induction
f) electricity generation

Test yourself 4 (LB p. 226)

1 $B = 0{,}01\ \text{T};\ A = 5\ \text{cm}^2 = 5 \times 10^{-4}\ \text{m}^2$
$\Phi = BA\cos\theta = 0{,}01\ \text{T} \times 5 \times 10^{-4}\ \text{m}^2 \times \cos 0°$
$= 5 \times 10^{-6}\ \text{Wb}$

2 $B = 2 \times 10^{-3}\ \text{T};\ A = 0{,}1\ \text{m}^2;\ \theta = 40°$
$\Phi = BA\cos\theta$
$= (2 \times 10^{-3}\ \text{T})(\ 0{,}1\ \text{m}^2)\cos 40°$
$= 1{,}5 \times 10^{-4}\ \text{Wb}$

3 The wire moves at $3{,}3\ \text{m·s}^{-1}$, or 3,3 m in one second. The area A of flux that it moves through is $3{,}3\ \text{m} \times 0{,}20\ \text{m} = 0{,}66\ \text{m}^2$.
$\Phi = BA\cos\theta = 0{,}15\ \text{T} \times 0{,}66\ \text{m}^2 \times \cos 0° = 0{,}099\ \text{Wb}$
This is the change of magnetic flux in 1 second. According to Faraday's Law, the induced emf is equal to the rate of change in magnetic flux, so the emf = 0,099 V.

4 $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -N\ \frac{0 - BA\cos\theta}{\Delta t}$
$= -2\ 500\ \frac{0\ \text{Wb} - (0{,}50\ \text{T} \times 1{,}5 \times 10^{-4}\ \text{m}^2) \times \cos 0°}{0{,}25\ \text{s}}$
$= 0{,}75\ \text{V}$

Unit 3 Electric circuits

TERM 3, MODULE 5

LB p. 230 »

Activity 3 Recommended experiment for informal assessment

G

Determine which components obey Ohm's Law

Use a resistor with a resistance of between 5 and 20 Ω.

Example of results for a 25 Ω resistor:

Number of cells	Potential difference across resistor (V)	Current in resistor (A)	$\frac{V}{I}$
1	1,55	0,060	25,83
2	3,07	0,120	25,58
3	4,54	0,180	25,22

Example of results for light bulb:

Number of cells	Potential difference across light bulb (V)	Current in light bulb (A)	$\frac{V}{I}$
1	1,50	0,21	7,14
2	2,96	0,30	9,87
3	4,37	0,35	12,49

a) The current through the resistor or light bulb increases if the potential difference across it is increased. Each battery that is added in series increases the total energy available to the circuit. When the charge receives more energy, the current will increase. ($I = \frac{Q}{t}$)

b) The potential difference increases when the number of batteries is increased.

c) For the resistor, the increase in current is directly proportional to the increase in potential difference (the increase in number of batteries). For the light bulb, the current is not directly proportional to the increase in potential difference (or number of batteries). The increase in current becomes less with each addition of another battery.

d) For the resistor, the ratio V/I should remain fairly constant. The V/I ratio is not constant for a light bulb.

e) The ratio V/I is called the resistance of a component.

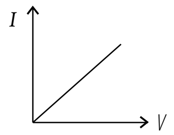
f) Resistance is measured in ohms (Ω).

g) Independent variable: potential difference (voltage)

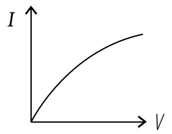
h) Dependent variable: current

i) Fixed variable: temperature

j)



resistor



light bulb

k) Take readings as quickly as possible and open the circuit between readings to minimise the heating effect in the wires and resistors.

l) The resistor is an ohmic conductor, because it obeys Ohm's Law. The voltage across the resistor is directly proportional to the current through it. The light bulb is a non-ohmic conductor, because the current is not directly proportional to the voltage.

Note

- The points on the graph of the resistor are usually slightly scattered about a straight line. Draw the best-fit line. The line should pass through the origin. Draw the best-fit curve for the light bulb.
- The internal energy of conductors and resistors increases when a current flows through them for any length of time. To get reasonable results from the experiments, it is important that learners take their ammeter and voltmeter readings as quickly as possible and then disconnect the resistor and light bulb to allow them to cool down.

- High currents increase the risk of overheating. Emphasise the fact that Ohm's Law is temperature-dependent.

Extension exercise

Provide silicon diodes or LED lights to the groups and repeat the experiment. The diode must be connected in series to a 33 Ω – 100 Ω resistor and an ammeter. Read the potential differences across the diode and resistor, and the current through them, and draw a graph of the results. Repeat the experiment with the diode connected the wrong way round. Point out the differences between diodes and light bulbs. Diodes are also non-ohmic conductors; they conduct a current in one direction only and they need very small currents compared to a light bulb. The resistance of a light bulb increases with an increase in temperature and voltage. The resistance of a diode decreases with an increase in temperature and voltage.

Example for results for a LED:

Number of cells	Potential difference across 47 Ω resistor (V)	Potential difference across LED (V)	Current in conductor (A)
1			current too small
2	0,66	2,20	0,015
3	1,97	2,73	0,04

Example of results for a silicon diode:

Number of cells	Potential difference across 47 Ω resistor (V)	Potential difference across LED (V)	Current in conductor (A)
1	0,92	0,66	0,08
2	2,43	0,70	0,05
3	3,93	0,72	0,05

Checklist for teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Stays focused on experiment			
Understands experimental method			
Follows method in orderly manner			
Uses time efficiently			
Uses apparatus and equipment correctly			
Helpful/ valuable member of group			
Answers simple questions during experiment			
Records results correctly in suitable table			
Draws graphs correctly			
Answers questions correctly			
Writes a well structured conclusion			

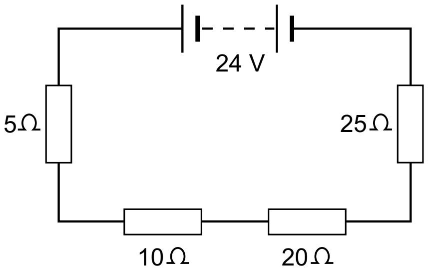
LB p. 234

Activity 4 Application exercises

I

Apply Ohm's Law

1 a)



b) $R_T = R_1 + R_2 + R_3 + R_4 = 5{,}0\ \Omega\ + 10\ \Omega\ + 20\ \Omega\ + 25\ \Omega\ = 60\ \Omega$

c) $I = \frac{V}{R} = \frac{24\text{ V}}{60\ \Omega} = 0{,}40\text{ A}$

2 a) $R_1 = \frac{V}{I} = \frac{2{,}0\text{ V}}{1{,}5\text{A}} = 1{,}3\ \Omega$

b) $R_2 = \frac{V}{I} = \frac{(3{,}0 - 2{,}0)\text{ V}}{1{,}5\text{A}} =0{,}67\ \ \Omega$

3 a) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{6} + \frac{1}{12} + \frac{1}{4} = \frac{2+1+3}{12}$

$\therefore R_p = 2\ \ \Omega$

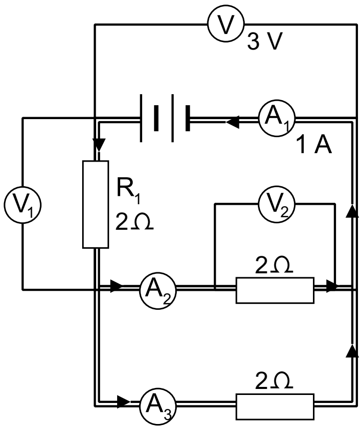
$\therefore R_T = 2\ \Omega + 2\ \Omega = 4\ \Omega$

b) $I_T = \frac{V_T}{R_T} = \frac{12\text{ V}}{4\ \Omega} = 3\text{ A}$

c) $V_p = IR_p = 3\text{ A} \times 2\ \Omega = 6\text{ V}$

d) $I_{12\Omega} = \frac{V_P}{R} = \frac{6\text{ V}}{12\ \Omega} = 0{,}5\text{ A}$

4 a)



b) i) and ii) The current divides equally between the two 2 Ω resistors.

The main current is 1 A.

$I = \frac{1\text{ A}}{2} = 0{,}5\text{ A}$

Reading on A_2 and $A_3 = 0{,}5\text{ A}$

iii) $V_1 = IR_1 = 1\text{ A} \times 2\ \Omega = 2\text{ V}$

iv) $V_2 = I_2R_{2\Omega} = 0{,}5\text{ A} \times 2\ \Omega = 1\text{ V}$

LB p. 238

Activity 5 Teacher demonstration

G

Compare the brightness of bulbs

You will need: light bulbs, batteries, conducting wires, crocodile clips, bulb holders, battery holders, ammeters, voltmeters

Connect the circuits illustrated in the Learner's Book.
Ask the learners to compare the brightness of the bulbs. They should also record the readings on the ammeters and voltmeters. Draw a table like the one below on the black board, and ask one of the learners to fill it in while you do the demonstration. Draw a parallel between the strength of the current and the brightness of the bulbs. A larger current should produce a brighter light if the potential difference across it is kept constant. A larger potential difference across the bulb will result in a brighter light for the same current. In circuit D, light bulbs 6 and 7 do not light up with two batteries in series. The potential difference across them is very low.

Example of results:

Circuit	**Ammeter reading (A)**	**Voltmeter reading(s) (V)**	**$P = VI$ (W)**
A	0,29	2,93	Bulb 1: 0,85
B	0,21	V_1 = 1,52; V_2 = 1,34	Bulb 2: 0,32; Bulb 3: 0,28
C	0,58	2,74	Bulbs 4 and 5: 1,59
D	0,28	V_1 = 0,32; V_2 = 2,61	Bulbs 6 and 7: 0,09; Bulb 8: 0,73

Learners should discuss the example in the Learner's Book. Here is the completed table and answers to the questions:

Circuit X: Parallel		**Circuit Y: Series**	
Bulb A	**Bulb B**	**Bulb A**	**Bulb B**
V_A = 5,6 V	V_B = 5,6 V	V_A = 1,63 V	V_B = 4,05 V
I_A = 0,22 A	I_B = 0,13 A	I_A = 0,11 A	I_B = 0,11 A
P_A = 1,2 **Ω**	P_B = 0,73 **Ω**	P_A = 0,18 **Ω**	P_B = 0,45 **Ω**

1 Bulb A has a smaller resistance than bulb B. They have the same potential difference across them, but the current through A is larger, so the resistance must be smaller.

2 Bulb A is brighter than bulb B. A larger current gives a higher power for the same potential difference.
Note: the power used is proportional to the light output, but a 1,2 W power used does not equal 1,2 W light output. Some energy is lost or dissipated as heat, and so on.

3 Bulb A will be dimmer in circuit Y than in circuit X, because its power is less. We assume that B has a larger resistance than A. In a series circuit, B limits the current flow in the whole circuit. A therefore receives a smaller current. A is dimmer in circuit Y than in circuit X.

4 The bulbs must share the total potential difference when they are connected in series in circuit Y. A lower potential difference across bulb B as well as a smaller current decreases the power ($P = VI$)

Test yourself 5 (LB p. 240)

1 a) $P = \frac{E}{\Delta t} \therefore E = P\Delta t = 100 \text{ W} \times 60 \text{ s} = 6\ 000 \text{ J}$

b) $P = \frac{V^2}{R} \therefore R = \frac{V^2}{P} = \frac{(240 \text{ V})^2}{100 \text{ W}} = 576\ \Omega$

c) The power will be smaller than 100 W, because $P \propto V^2$; if the voltage decreases the power will also decrease.
$P = \frac{V^2}{R} = \frac{(120 \text{ V})^2}{576\ \Omega} = 25 \text{ W}$

2 a) $P = VI \therefore I = \frac{P}{V} = \frac{3 \text{ W}}{6 \text{ V}} = 0{,}5 \text{ A}$

b) Each branch carries a current of 0,5 A, so the total current = 1 A.

$$R_X = \frac{V_x}{I} = \frac{(24 - 6)\text{ V}}{(0,5 + 0,5\text{ A})} = 18\ \Omega$$

c) i) Increase, because the total resistance decreases. More resistors in parallel decrease the equivalent resistance.
ii) Decrease, because the total resistance increases. More resistances in series increase the total resistance.

Test yourself 6 **(LB p. 242)**

1 a) 1 h × 3 000 W = 3 000 Wh = 3 kWh
3 h × 2 000 W = 6 000 Wh = 6 kWh
Total energy transferred = 9 kWh
b) 9 kWh × 70c = R6.30
2 a) 30 kWh were used in 24 hours, so the average power consumption
$= \frac{30\text{ kWh V}}{24\text{ h}} = 1,25$ kW per hour.
b) 30 kWh × 70c = 2 100c = R21.00

Learner's Book page 243

Units 1–3 Summative assessment: Electricity and magnetism

TERM 3, MODULE 5

1 a) electric field
b) electric field strength
c) magnetic flux
d) electromagnetic induction
e) Ohm's Law
f) power
2 a) The direction of the electric field at a point is the direction that *a positive test charge* would move if placed at that point.
b) When placed near a current-carrying wire, the deflection of a compass needle provides sufficient evidence of the existence of a *magnetic field*.
c) The direction of a magnetic field around a straight conductor is most commonly determined by using the *Right Hand Rule*.
d) A diode is a *non*-ohmic conductor.
e) A 6 kW heater switched on for 2 hours uses *12* kWh of energy.
f) A 100 W light bulb connected to a 230 V power supply has a resistance of *529* W.
3 a) C
b) A
c) D
d) A
e) A and D
f) D
g) D
4 a) They are positively charged.
b) The electric field lines are closer together near the charged spheres and are further apart the more distant they are from the charges. The spacing of the field lines is an indication of the strength of the electric field.
c) B, because the field lines are closer together.

d) Coulomb's Law: The electrostatic force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

5 The net force on Q_3 will be the vector sum of the forces exerted by Q_1 and Q_2. First calculate the magnitudes of the forces:

F due to Q_1: $F_{31} = k\,\frac{Q_1Q_3}{r^2}$

$$= (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{C}^{-2}})\ \frac{(8{,}0 \times 10^{-6}\ \cancel{\text{C}})(2{,}0 \times 10^{-6}\ \cancel{\text{C}})}{(0{,}20 + 0{,}10\ \cancel{\text{m}})^2}$$

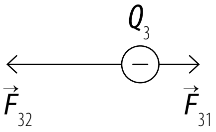
$F_{31} = 1{,}6\ \text{N}$

F due to Q_2: $F_{32} = k\frac{Q_1Q_3}{r^2}$

$$= (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{C}^{-2}})\frac{(3{,}0 \times 10^{-6}\ \cancel{\text{C}})(2{,}0 \times 10^{-6}\ \cancel{\text{C}})}{(0{,}10\ \cancel{\text{m}})^2}$$

$F_{32} = 5{,}4\ \text{N}$

$\vec{F}_{31}$ is towards the right (repulsive) and $\vec{F}_{32}$ is towards the left (attractive). Take the direction towards the right as positive.



$F_{net} = F_{31} + F_{32} = 1{,}6\ \text{N} + (–5{,}4\ \text{N}) = -3{,}8\ \text{N}$

$\vec{F}_{net} = 3{,}8$ N towards the left

6 $F = Eq = 3\ 500\ \text{N}\cdot\cancel{\text{C}^{-1}} \times 1{,}6 \times 10^{-19}\ \cancel{\text{C}} = 1{,}0 \times 10^{-22}\ \text{N}$

Direction is given as the direction that a positive particle would move, so the electron will experience a force due west.

7 E_1 due to –8,0 μC charge: $E_1 = k\frac{Q}{r^2} = (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{C}^{-2}})\frac{8{,}0 \times 10^{-6}\ \cancel{\text{C}}}{(1{,}5 \times 10^{-2}\ \cancel{\text{m}})^2}$

$= 3{,}2 \times 10^8\ \text{N}\cdot\text{C}^{-1}$

E_2 due to +6,0 μC charge: $E_2 = k\frac{Q}{r^2} = (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{C}^{-2}})\frac{6{,}0 \times 10^{-6}\ \cancel{\text{C}}}{(1{,}5 \times 10^{-2}\ \cancel{\text{m}})^2}$

$= 2{,}4 \times 10^8\ \text{N}\cdot\text{C}^{-1}$

The field is away from the positive charge and towards the negative charge, so both electric fields point in the same direction. The net electric field is:

$\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 = 3{,}2 \times 10^8\ \text{N}\cdot\text{C}^{-1} + 2{,}4 \times 10^8\ \text{N}\cdot\text{C}^{-1}$

$= 5{,}6 \times 10^8\ \text{N}\cdot\text{C}^{-1}$ in the direction of the –8 μC charge

8 a) $\vec{E} = k\frac{Q}{r^2} = (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\cancel{\text{C}^{-2}})\frac{5{,}0 \times 10^{-9}\ \cancel{\text{C}}}{(0{,}30\ \cancel{\text{m}})^2}$

$= 500\ \text{N}\cdot\text{C}^{-1}$ to the right (repulsive)

b) $\vec{E} = k\frac{Q}{r^2} = (9{,}0 \times 10^9\ \text{N}\cdot\cancel{\text{m}^2}\cdot\text{C}^{-2})\frac{3{,}0 \times 10^{-9}\ \cancel{\text{C}}}{(0{,}15\ \cancel{\text{m}})^2}$

$= 1\ 200\ \text{N}\cdot\text{C}^{-1}$ to the left (repulsive)

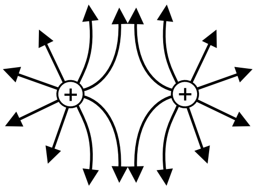
c) Take the direction towards the right as positive.

$\vec{E}_{net} = +500\ \text{N}\cdot\text{C}^{-1} + (-1\ 200\ \text{N}\cdot\text{C}^{-1})$

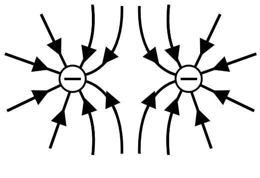
$= –700\ \text{N}\cdot\text{C}^{-1}$ or $700\ \text{N}\cdot\text{C}^{-1}$ to the left

d) $\vec{F} = q\vec{E} = 1{,}6 \times 10^{-19}\ \cancel{\text{C}} \times 700\ \text{N}\cdot\cancel{\text{C}^{-1}} = 1{,}1 \times 10^{-16}$ N to the right

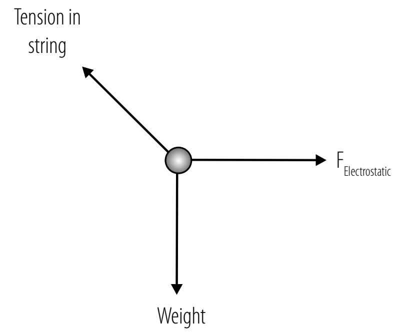
9 a)



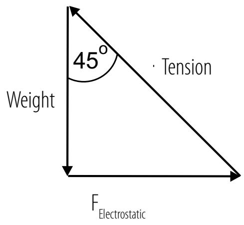
or



b)



c)

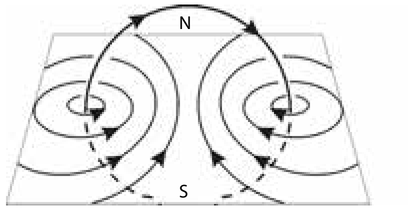


Calculate weight: $\vec{W} = m\vec{g} = 0{,}90 \times 10^{-3}$ kg $\times$ 9,8 m·s^{-2}
$= 8{,}8 \times 10^{-3}$ N down

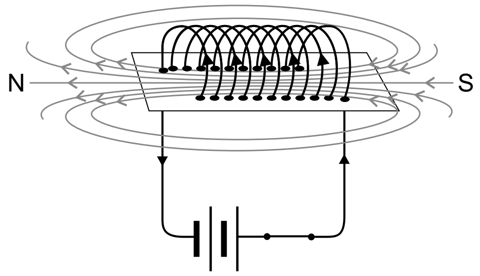
Determine $\vec{F}$: $\tan 45° = \frac{F}{W} \Rightarrow F = 8{,}8 \times 10^{-3}$ N $\times$ 1
$= 8{,}8 \times 10^{-3}$ N away from X (repulsion)

d) $k = 9{,}0 \times 10^{9}$ N·m^2·C^{-2}; $F = 8{,}8 \times 10^{-3}$ N; $r = 40$ mm $= 40 \times 10^{-3}$ m;
$Q_X = Q_Y = ?$
$F = k\frac{Q_1Q_2}{r^2}$
$\therefore Q_XQ_Y = \frac{(8{,}8 \times 10^{-3}\ \cancel{\text{N}})(40 \times 10^{-3}\ \cancel{\text{m})^2}}{(9{,}0 \times 10^{9}\ \cancel{\text{N}}\cdot\cancel{\text{m}^2}\cdot\text{C}^{-2})}$
$Q_x = Q_Y = \sqrt{1{,}56 \times 10^{-15}\ \text{C}^2} = 4{,}0 \times 10^{-8}$ C

10



11



12 a) There is a change in flux linkage, and so an emf is induced.

b) Faraday's Law of Electromagnetic Induction: The induced emf in any closed circuit is equal to the rate of change of the magnetic flux through the circuit.

c) The motion is parallel to the magnetic field and there is no change in magnetic flux.

d) When the magnet leaves the coil, there is again a change in magnetic flux, but now the emf is in the reverse (negative) direction, because the current has to flow the other way. The peak emf is greater because the magnet is moving faster as it accelerates due to gravity. The induced emf is proportional to the rate at which the magnetic flux changes.

Also, faster movement means it takes less time to complete the section. This is the reason CD represents a shorter time interval than AB.

13 a) electromagnetic induction

b) Faraday's Law of electromagnetic induction states that an induced emf in any closed circuit is equal to the rate of change of the magnetic flux through the circuit.

c) $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ where ε = the induced emf; N is the number of turns in the solenoid; $\Delta\Phi$ is the change in magnetic flux and Δt is the time taken for the flux to change.

d) the strength of the magnetic field – a stronger magnet induces a larger voltage
the number of turns on the solenoid – a greater number of turns induces a larger voltage
the speed at which the magnet moves relative to the solenoid – faster movement induces a larger voltage.

14 a) $\Phi = BA\cos\theta = 0{,}50\ \text{T} \times 10 \times 10^{-4}\ \text{m}^2 \times 1 = 5{,}0 \times 10^{-4}\ \text{Wb}$

b) $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = (-1\ 800)\ \frac{-5{,}0 \times 10^{-4}\ \text{Wb}}{0{,}20\ \text{s}} = 4{,}5\ \text{V}$

c) $\varepsilon = IR \therefore I = \frac{\varepsilon}{R} = \frac{4{,}5\ \text{V}}{30\ \Omega} = 0{,}15\ \text{A}$

15 a) Area of the coil $= 0{,}050\ \text{m} \times 0{,}050\ \text{m} = 2{,}5 \times 10^{-3}\ \text{m}^2$
$\Phi = BA\cos\theta = 0{,}60\ \text{T} \times 2{,}5 \times 10^{-3}\ \text{m}^2 \times 1 = 1{,}5 \times 10^{-3}\ \text{Wb}$
$\Delta\Phi = 0 - 1{,}5 \times 10^{-3}\ \text{Wb} = -1{,}5 \times 10^{-3}\ \text{Wb}$

b) $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = (-100)\frac{-1{,}5 \times 10^{-3}\ \text{Wb}}{0{,}10\ \text{s}} = 1{,}5\ \text{V}$

c) $I = \frac{\varepsilon}{R} = \frac{1{,}5\ \text{V}}{100\ \Omega} = 0{,}015\ \text{A}$ or $1{,}5 \times 10^{-2}$ A or 15 mA

d) $P = \frac{E}{\Delta t} \therefore E = P\Delta t = I^2R\Delta t$
$= (0{,}015\ \text{A})^2 \times 100\ \Omega \times 0{,}10\ \text{s} = 2{,}3 \times 10^{-3}\ \text{W}$

16 a) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{3{,}0} + \frac{1}{4{,}0} = \frac{3{,}0 + 4{,}0}{12}$
$\therefore R_p = \frac{12}{7{,}0} = 1{,}7\ \Omega$
or $R_p = \frac{4 \times 3}{4 + 3} = 1{,}7\ \Omega$
$\therefore R_T = 1{,}7\ \Omega + 2{,}0\ \Omega = 3{,}7\ \Omega$

b) $I_T = \frac{V_T}{R_T} = \frac{1{,}5\ \text{V}}{3{,}7\ \Omega} = 0{,}41\ \text{A}$

c) First calculate the voltage across the 2 Ω resistor:
$V_{2\Omega} = IR_{2\Omega} = 0{,}41\ \text{A} \times 2{,}0\ \Omega = 0{,}82\ \text{V}$
The voltage across the parallel resistors = 1,5 – 0,82 = 0,68 V

d) $I_{4\Omega} = \frac{V_{4\Omega}}{R_{4\Omega}} = \frac{0{,}68\ \text{V}}{4\ \Omega} = 0{,}17\ \text{A}$

17 a) $R_P = \frac{6{,}0 \times 12}{6{,}0 + 12} = 4{,}0\ \Omega$
$\therefore R_T = 4{,}0\ \Omega + 5{,}0\ \Omega + 10\ \Omega = 19\ \Omega$

b) $I_T = \frac{V_T}{R_T} = \frac{12\ \text{V}}{19\ \Omega} = 0{,}63\ \text{A}$

c) $V_P = I_TR_P = 0{,}63\ \text{A} \times 4{,}0\ \Omega = 2{,}5\ \text{V}$

d) $I_{12\Omega} = \frac{V_P}{R_{12\Omega}} = \frac{2{,}5\ \text{V}}{12\ \Omega} = 0{,}21\ \text{A}$

e) $P_{5\Omega} = I_T^{\ 2}R_{5\Omega} = (0{,}63\ \text{A})^2 \times 5\ \Omega = 2{,}0\ \text{W}$

18 If the bulbs have the same brightness, they must have the same power. The current through Y is smaller than through X, because current is split when it reaches the parallel combination. The resistance of Y must be larger than that of X. ($P = I^2R$, so for the same P, $I^2 \propto \frac{1}{R}$)

19 a) $P = I^2R = (5{,}0\ \text{A})^2 \times 48\ \Omega = 1\ 200\ \text{W}$

b) $V = IR = 5{,}0\ \text{A} \times 48\ \Omega = 240\ \text{V}$

c) 1 200 W = 1,2 kW × 5 hours = 6,0 kWh × 78c
= 468c per day ×
6 days = 2 808c = R28.08

LB p. 252 »

Activity 5 Prescribed project for formal assessment

G

Investigate endothermic and exothermic reactions

Reactions with water

1 **Lithium with water:**

Safe handling of alkali metals:
The Group 1 metals, lithium, sodium and potassium, are extremely flammable and corrosive. You should handle them with great caution. You and the learners must wear safety goggles. When handling the metals you should wear protective gloves. The troughs should have safety screens around them. Learners should be at least 2 m away from the apparatus while the reaction is in progress.

You will need: tweezers, filter paper, ceramic tile, scalpel or sharp knife to cut the metal, large water trough(s), detergent, small cubes (3 mm max) of lithium

Method

Prepare the apparatus and chemicals in advance: cut small pieces of the metals and store in oil; fill water troughs; collect other apparatus needed. Remove a piece of the lithium from the oil with the tweezers. Place the metal on a tile and, using a scalpel or sharp knife, cut small pieces of lithium, about the size of a 3 mm cube. Return the large piece to its bottle immediately. Make sure that the pieces of metal do not lie around on the tile for too long as they might catch alight spontaneously.

Reaction with water

- Half-fill the trough with water. Add a drop of detergent to stop the metals sticking to the side.
- Place safety screens around the trough.
- Remove a small piece of lithium from the bottle with the tweezers. Place it on a filter paper and close the bottle. Use the filter paper to wipe off the oil.
- Drop the piece of metal onto the water surface in a trough with the tweezers.
- The lithium should float and fizz as it gives off hydrogen. The temperature of the water should rise.

2 **Sulfuric acid with water:**

Concentrated H_2SO_4 is extremely corrosive and toxic. Do not allow learners to work with it. When diluting concentrated sulfuric acid, always add the acid to the water. Add small amounts of acid at a time; shake if in a volumetric flask; stir if in a beaker; and leave to cool first if necessary before adding more acid. The dissolution process of sulfuric acid is very exothermic. Prepare chemicals in advance to allow for cooling time of the solutions.
Follow the method in the Learner's Book

3 **Dissolution of various salts in water**
Exothermic dissolution processes: $CaCl_2$ in water
Endothermic dissolution processes: KNO_3, KBr, NH_4NO_3, $Na_2S_2O_3$ and a Cal-C-Vita tablet in water.
Follow the method in the Learner's Book

Acid-carbonate reactions

Both reactions are endothermic.
Follow the method in the Learner's Book

Potassium permanganate with glycerol

This is a dangerous experiment. We suggest that you demonstrate this experiment. Potassium permanganate is a strong oxidant and should be stored separately from flammable organic chemicals.

Crush the $KMnO_4$ crystals in a pestle and mortar beforehand. Put a few drops of glycerine on a few fine crystals of potassium permanganate in a glass beaker. Use very small quantities of reactants. The reaction is exothermic.

Copper(II) sulfate reactions

Anhydrous copper(II) sulfate with water

The white anhydrous $CuSO_4$ turns to blue $CuSO_4{\cdot}5H_2O$. The reaction is exothermic. This reaction can be used as a test for water.
Follow the method in the Learner's Book

Copper(II) sulfate with magnesium

The displacement reaction between Mg ribbon and $CuSO_4{\cdot}5H_2O$ is exothermic. The blue colour of the solution disappears and brown Cu precipitates. The balanced equation for the reaction is:

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$$

Be careful as this reaction can be vigorous. The displacement reaction between Mg powder and $CuSO_4{\cdot}5H_2O$ is far more violent than with the Mg pieces. The reaction is exothermic.

Discuss the steps for a practical investigation with the class and refer them to the information in the introduction on page 12. Read the safety instructions and explain the laboratory procedures to the class.

The learner's scientific report should include the following steps:

- Identify an answerable question and formulate a hypothesis to guide your investigation.
  For example, which chemical reactions are exothermic and which ones are endothermic? (Reactions that heat up – or release heat – are exothermic, and reactions that cool down – or take in heat – are endothermic.)
- Design an experiment to test your hypothesis.
  For example, pour water into a test tube to a third of its volume; measure the temperature of the water; add half a spatula of potassium nitrate to the water in the test tube; stir with the thermometer to dissolve; measure the temperature change.
- Present your results in an appropriate table, graph, diagram or equation.
  Learners record all the temperature changes in degrees Celsius in a suitable table.
- Check if your hypothesis was correct; if not, repeat the experiment or change your hypothesis.

Learners should make a list of endothermic reactions and exothermic reactions. They should also use the magnitude of the change in temperature to differentiate between reactions that are only slightly endothermic and exothermic and those that show a large change in temperature.

- Write a conclusion for your investigation.

Answers to questions that must be included in the learners' reports:

1 The physical property of temperature is used to classify the reactions. (1)

2 Endothermic reactions take in heat from the surroundings and the reaction mixture cools down. Examples are the dissolution of KNO_3, KBr, NH_4NO_3, $Na_2S_2O_3$, and a Cal-C-Vita tablet in water. Exothermic reactions release heat and the reaction mixture become hot. Examples are the dilution of sulfuric acid in water and the reaction of lithium with water. (4)

3 Example: $KNO_3(s) \rightarrow K^+(aq) + NO^{3-}(aq)$ is an endothermic process. The bonds between the K^+ ions and the NO_3^- ions in the solid KNO_3 are stronger than the ion–dipole forces in the solution.
$H_2SO_4(\ell) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$ is an exothermic reaction. The bonds in the H_2SO_4 molecules are weaker than the ion–dipole forces in the solution. (4)

4. enthalpy change = [enthalpy of products] – [enthalpy of reactants]
$\Delta H = H_{products} - H_{reactants}$
ΔH for an endothermic reaction is positive
ΔH for an exothermic reaction is negative (3)

LB p. 256 »

Activity 6 Application exercises

Determine the energy changes in the preparation of ammonia

1 Bonds broken: $1 \times N \equiv N$ bond
$3 \times H - H$ bonds

2 Total energy needed to break bonds: $N \equiv N$: $1 \times 946 = 946$ kJ·mol^{-1}
$H - H$: $3 \times 436 = 1\,308$ kJ·mol^{-1}
Total $= 2\,254$ kJ·mol^{-1}

3 The process is endothermic.

4 Bonds formed: $6 \times N - H$ bonds

5 Total energy released when product is formed: $6 \times 390 = 2\,340$ kJ·mol^{-1}

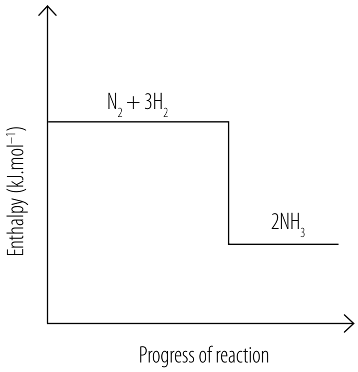
6 The reaction is exothermic.

7 The energy needed to break bonds = 2 254 kJ·mol^{-1}
The energy released to form bonds = 2 340 kJ·mol^{-1}
Net energy released during reaction = 86 kJ·mol^{-1} (ΔH = –86 kJ·mol^{-1})

8 The reaction is exothermic. Energy is released during the reaction.

9

Enthalpy profile for the preparation of NH_3



Test yourself 4 (LB p. 258)

1 a) Bond energy is the energy released when a chemical bond forms between two atoms.
  b) An exothermic reaction releases heat to the surroundings.
  c) An endothermic reaction takes up heat from the surroundings.
  d) Enthalpy is the amount of heat change taking place during a chemical reaction at constant pressure.
  e) Activation energy is the amount of energy required for a reaction to start.

LB p. 258

Activity 7 Teacher demonstration Ⓒ

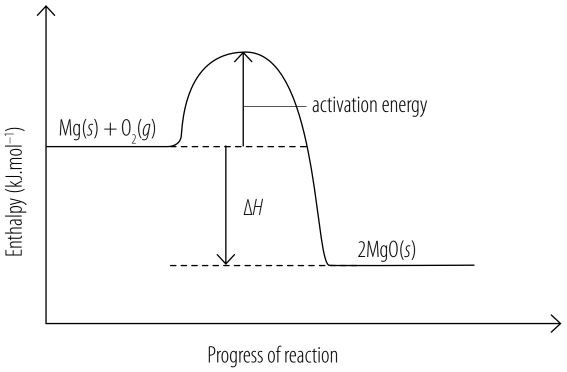
Investigate the concept of activation energy

Your will need: about 4 cm length of magnesium ribbon, pair of tongs, Bunsen burner

Explain to learners that the reaction between magnesium and oxygen in the air is non-spontaneous. Hold the magnesium ribbon in the flame of a Bunsen burner with a pair of tongs until it catches alight. Remove from the flame. The reaction is now spontaneous and the magnesium burns with a brilliant white flame. Explain to learners that the heat of the flame provides the activation energy for the reaction to start, after which the reaction is exothermic and spontaneous.

Answers to questions:

1 The reaction is exothermic because a lot of heat and light is released.
2 No, the reaction is non-spontaneous.
3 The heat from the flame provides the activation energy for the reaction to occur spontaneously.
4 **Energy profile for the burning of magnesium in air**



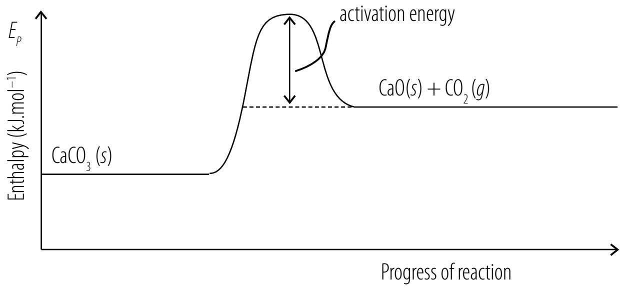
LB p. 259

Activity 8 Application exercises Ⓘ

Consider the energies in decomposition and synthesis reactions

1 a) The reaction is endothermic, because heat is required to decompose the calcium carbonate.

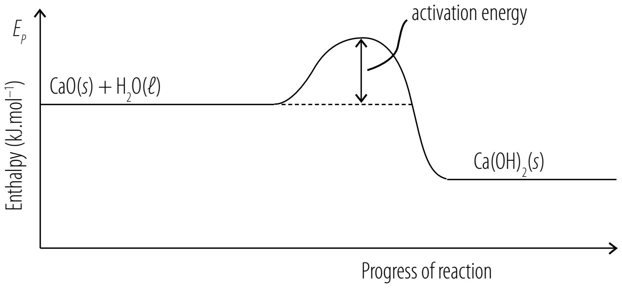
b)



2 a) The reaction is exothermic, because heat is released during the reaction.

b) The bonds in the product ($Ca(OH)_2$) must be stronger than in the reactants (CaO and H_2O). In an exothermic reaction, the amount of energy required to break the bonds in the reactants is less than the amount of energy released when the bonds in the product form. The greater the amount of energy involved in making or breaking bonds, the stronger the bonds are.

c)



Unit 3 Types of reactions: Acid-base

TERM 3, MODULE 4

Test yourself 5 (LB p. 261)

1 Acids: $HCOOH$; NH_4^+; HCO_4^-
Bases: CuO; HCO_3^-; CO_3^{2-}; OH^-; Cl^-

2 A Brønsted acid is a proton donor.
A Brønsted base is a proton acceptor.

Test yourself 6 (LB p. 262)

1 a) $HNO_3(aq) + H_2O(\ell) \rightarrow NO_3^-(aq) + H_3O^+(aq)$
acid 1 base 2 conj. base 1 conj. acid 2

b) $NH_4^+(aq) + F^-(aq) \rightarrow NH_3(aq) + HF(aq)$
acid 1 base 2 conj. base 1 conj. acid 2

c) $HCO_3^-(aq) + H_2O(\ell) \rightarrow H_2CO_3(aq) + OH^-(aq)$
base 1 acid 2 conj. acid 1 conj. base 2

d) $HPO_4^{2-}(aq) + H_2O(\ell) \rightarrow PO_4^{3-}(aq) + H_3O^+(aq)$
acid 1 base 2 conj. base 1 conj. acid 2

Test yourself 7 (LB p. 266)

1 a) $2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(\ell)$
b) $H_2SO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + H_2(g)$

c) $2HNO_3(aq) + Na_2CO_3(s) \rightarrow 2NaNO_3(aq) + H_2O(\ell) + CO_2(g)$
d) $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$
e) $HCl(aq) + NaHCO_3(s) \rightarrow NaCl(aq) + H_2O(\ell) + CO_2(g)$

2 a) Zinc chloride ($ZnCl_2$)
b) Calcium acetate or calcium ethanoate ($Ca(CH_3COO)_2$)
c) Copper(II) sulphate ($CuSO_4$)
d) Sodium nitrate ($NaNO_3$)

3 a) $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$
b) base 1: OH^- conjugate acid: H_2O
acid 2: H^+ conjugate base: H_2O

LB p. 267

Activity 9 Experiment

Neutralise sodium hydroxide with oxalic acid through titration

A5 $c = \frac{m}{MV} = \frac{15{,}7\ \cancel{g}}{126{,}0\ \cancel{g}\cdot mol^{-1} \times 0{,}25\ dm^3} = 0{,}50\ mol\cdot dm^{-3}$

B4 $2NaOH(aq) + (COOH)_2(aq) \rightarrow Na_2(COO)_2(aq) + 2H_2O(\ell)$

B5 Refer back to page 185 of the Learner's Book to do the calculation.

$$\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$$

$$\frac{1\ mol}{2\ mol} = \frac{0{,}50\ mol\cdot dm^{-3} \times 14{,}5\ cm^3}{c_b \times 25{,}0\ cm^3}$$

$$\therefore c_b = \frac{2\ \cancel{mol} \times 0{,}50\ mol\cdot dm^{-3} \times 14{,}5\ \cancel{cm^3}}{1\ \cancel{mol} \times 25{,}0\ \cancel{cm^3}} = 0{,}58\ mol\cdot dm^{-3}$$

C3 This is an extension question. Refer back to page 194 of the Learner's Book to do the calculation.

Calculate theoretical yield:
$1\ mol\ (COOH)_2\cdot 2H_2O \rightarrow 1\ mol\ Na_2(COO)_2$
$n((COOH)_2\cdot 2H_2O) = cV = 0{,}50\ mol\cdot \cancel{dm^{-3}} \times 0{,}0145\ \cancel{dm^3} = 0{,}00725\ mol$
$0{,}00725\ mol\ (COOH)_2\cdot 2H_2O \rightarrow 0{,}00725\ mol\ Na_2(COO)_2$
similarly, $2\ mol\ NaOH \rightarrow 1\ mol\ Na_2(COO)_2$
$n(NaOH) = cV = 0{,}58\ mol\cdot \cancel{dm^{-3}} \times 0{,}025\ \cancel{dm^3} = 0{,}0145\ mol$
$0{,}0145\ mol\ NaOH \rightarrow 0{,}00725\ mol\ Na_2(COO)_2$
mass $Na_2(COO)_2 = nM = 0{,}00725\ \cancel{mol} \times 126{,}00\ g\cdot \cancel{mol^{-1}}$
$= 0{,}91\ g\ Na_2(COO)_2$

Calculating percentage yield:

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$
$$= \frac{\text{actual yield (mass of } Na_2(COO)_2)}{0{,}91\ g} \times 100\%$$

LB p. 269

Activity 10 Recommended experiment for informal assessment

Investigate indicators

A Acids: lemon juice, vinegar, soda water; all foodstuffs and sauces that contain lemon juice, vinegar and tomato products; swimming pool acid.
Bases: toothpaste, soap, oven cleaner, household cleaner, shampoo, baking soda (all household cleaners and soaps are bases: drain cleaner, caustic soda, all purpose cleaner, sugar soap, brass and silver cleaners, bleach, washing powder), sodium bicarbonate.
Tap water is usually alkaline.

B Learners make their own pH indicators as described.

C Indicator colours

Indicator	Acid	Neutral	Alkaline
Litmus	Red	Purple	Blue
Methyl orange	Red	Orange	Yellow
Bromothymol blue	Yellow	Green	Blue
Phenolphthalein	Colourless	Colourless	Pink (red)
Universal indicator	Red	Yellow/Green	Blue/Violet
Red fruit, onion, cabbage extract	Red/Pink	Purple	Green/Yellow
Yellow onion skins	Yellow	Yellow	Orange
Spinach	Colourless	Green	Yellow

Checklist for teacher's assessment of individual in a group during learner experiment

Task skills	Yes	No	Comments
Uses innovative and new materials			
Stays focused on experiment			
Understands experimental method			
Uses time efficiently			
Uses apparatus and equipment correctly			
Helpful/ valuable member of group			
Answers simple questions during experiment			
Records results correctly in suitable table			
Writes a well structured conclusion			

LB p. 270 »

Activity 11 Experiment

G

Prepare sodium chloride

The experiment is straight forward. Use the table to make up 1 mol·dm^{-3} solutions.

Substance	Mass of salt to be made up to 100 ml	Mass of salt to be made up to 250 ml	Mass of salt to be made up to 500 ml	Mass of salt made up to 1 ℓ
NaOH	4,00 g	10,00 g	20,00 g	40,00 g

Substance	Volume conc. acid to make up to 100 ml	Volume conc. acid to make up to 250 ml	Volume conc. acid to make up to 500 ml	Volume conc. acid to make up to 1 ℓ
HCl 37,2%; 12,1 M	8,3 ml	20,7 ml	41,3 ml	82,6 ml

The creation of both of these solutions is a highly exothermic process. Add the acid or base slowly to the water, and wait for it to dissolve and cool down a little before adding the next amount.

LB p. 272

Activity 12 Research project

I

Investigate the use of limestone in toilets

The Blair toilet is a pit toilet that was designed in the 1970s in Zimbabwe. Its design makes use of air currents to get rid of odours. The interior of the toilet is dark, and waste is directed into a deep pit, from which the only escape is a ventilation pipe (or chimney) from the bottom of the pit to above the roof of the surrounding structure. At the top of the chimney there is a fine wire grate to prevent flies from entering and, more importantly, to trap flies that have hatched in the faecal matter, and are attracted to the light at the top of the chimney, so preventing them from flying out and spreading disease. The toilet is surrounded by a structure with a door strategically placed to direct prevailing winds towards the chimney to disperse odours. Gases produced by the decomposing waste are redirected to the outside via the chimney. The result is odourless and hygienic. (Adapted from Wikipedia)

Covering the deposit in a pit latrine with limestone prevents smells and discourages some fly species which may be attracted to it as a place to feed or reproduce. Lime has traditionally been used in an outdoor latrine because:

- it reduces the odours or smells
- it reduces the problem of flies in the latrine
- it absorbs some portion of the liquid (urine) and picks up the moisture from the air that helps with decomposition.

Wood ash from a woodstove or fire can also be used to sprinkle in the latrine.

Kitchen vegetable waste (not meat) and dry leaves can be added to promote the composting action of the latrine.

LB p. 273

Activity 13 Extension activity

I

Consider the causes of tooth decay

1 a) Dental caries is the decay and crumbling of teeth.
   b) Dental plaque is the sticky film on teeth in which bacteria proliferate.
   c) Enamel is the hard glossy natural coating of teeth.
2 The pH of a solution decreases when it becomes more acidic.
3 When you eat, the bacteria present in your mouth partially break down food (especially sugars and starches) to form acids.
4 Acid attacks the tooth enamel and can, over time, form a hole in the tooth.
5
   - You can eat foods containing less sugar.
   - You can eat sweets less frequently.
   - You can eat sweet foods only at mealtimes.
6
   - Fluoride toothpaste contains fluoride, which hardens tooth enamel.
   - Fluoride toothpaste is slightly alkaline and neutralises the acids.
   - Brushing removes food particles and plaque from the teeth.

Learner's Book page 274

Units 2–3 Summative assessment: Chemical change (Acid-base)

TERM 3, MODULE 4

1 a) bond (dissociation) energy
b) activation energy
c) indicator
d) Brønsted acid
e) ampholyte

2 a) A Brønsted base is a *proton donor*.
b) When an acid reacts with a metal carbonate, the products are a salt, water and *carbon dioxide.*
c) An acid will colour litmus red and has a pH *below* 7.
d) *Only chloride* salts form when hydrochloric acid reacts with a base.
e) Water can react *as either* an acid or a base.

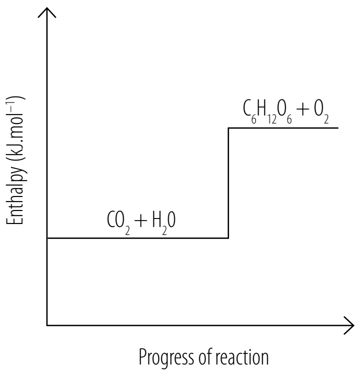
3 When free atoms bond together to form the product molecules, energy is *released* and the reaction is *exothermic*. An endothermic reaction has a *positive* value for ΔH. In the reaction between ethanol and oxygen, more energy is released during bond formation than is required to break the bonds in the reactants. This is an example of *combustion* and an example of an *exothermic* reaction.

4 a) i) C ii) D
b) A
c) C

5 a) The energy changes that occur in a system at atmospheric pressure.
b) ΔH
c) $\Delta H = H_{\text{products}} - H_{\text{reactants}}$
d) endothermic reactions

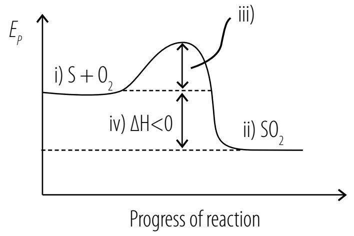
6 Energy can be neither created nor destroyed. Energy is only transferred between the reacting chemicals and their surroundings.

7 a) endothermic
b) green pigment chlorophyll; sunlight
c) glucose and oxygen
d)

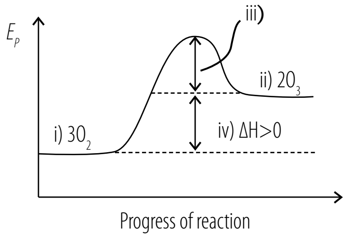


8 a) During endothermic reactions, energy is taken in; ΔH for the reaction is positive; the formation of ozone is an endothermic process. During exothermic reactions, energy is released; ΔH for the reaction is negative; the formation of sulfur dioxide is an exothermic process.

b)



Exothermic reaction
$S(s) + O_2(g) \rightarrow SO_2(g)$



Endothermic reaction
$3O_2(g) \rightarrow 2O_3(g)$

The activation energy for the formation of SO_2 is heat, and for the formation of O_3, is ultraviolet light from the sun.

9 a) $n = \frac{m}{M} = \frac{0{,}90\,\cancel{g}}{126{,}0\,\cancel{g}\,\text{mol}^{-1}} = 0{,}0070\ \text{mol}$

b) From the balanced equation we see that $n(\text{NaOH})$ used = 0,014 mol

$c = \frac{n}{V} = \frac{0{,}014\ \text{mol}}{0{,}050\ \text{dm}^3} = 0{,}29\ \text{mol·dm}^{-3}$

10 a) An acid is a proton donor.

b) An ampholyte is a compound that can donate or accept a proton, depending on the reaction it is in. HSO_4^- is the ampholyte, because it can donate and accept a H^+ ion to form H_2SO_4 or SO_4^{2-}.

c) $\underset{\text{acid 1}}{HSO_4^-} + \underset{\text{base 2}}{H_2O} \rightarrow \underset{\text{conj. acid 2}}{H_3O^+} + \underset{\text{conj. base 1}}{SO_4^{2-}}$

d) i) $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$

ii) $H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(\ell)$

iii) $H_2SO_4(aq) + Na_2CO_3(s) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(\ell)$

11 An indicator is an organic molecule that has a different colour at different pH values. Examples of indicators are litmus, bromothymol blue, methyl orange and phenolphthalein.

Unit 3 (continued) Types of reactions: Redox reactions

TERM 4, MODULE 4

Test yourself 8 (LB p. 283)

1 The oxidation numbers of sulfur in these compounds:

a)	SO_2	+4
b)	Na_2SO_4	+6
c)	H_2S	−2
d)	sulfur powder	0
e)	HSO_4^-	+6
f)	$Na_2S_2O_3$	+2
g)	H_2SO_3	+4
h)	SO_3	+6

2 The oxidation numbers of nitrogen in these compounds:

a)	N_2O	+1
b)	NO_2	+4
c)	NO	+2
d)	NH_4OH	−3
e)	N_2	0
f)	NH_3	−3
g)	$NaNO_3$	+5
h)	N_2O_4	+4
i)	NH_4^+	−3

LB p. 283 »

Activity 14 Recommended experiment for informal assessment

G C

Investigate redox reactions

Safety

- Learners and the teacher should always wear safety goggles during all chemistry experiments.
- Avoid skin contact with chemicals.
- Wash hands after handling chemicals.
- Handle glass apparatus with care. Report breakages immediately and treat and monitor skin cuts.
- Take care when using a Bunsen burner. Always handle hot apparatus with a pair of tongs.
- The Group 1 metals, lithium, sodium and potassium, are extremely flammable and corrosive. They should form part of a teacher's demonstration only. Learners should not experiment with them.
- Hydrogen gas is explosive and flammable. When hydrogen is produced during a reaction, all open flames must be extinguished and the room must be well ventilated.
- All lead salts are toxic: avoid skin contact; wash hands after the experiment. Never dispose of chemical waste down the drain. Contact the local authority for guidance regarding safe disposal of chemical waste.

- Iron powder can cause severe irritation in eyes, because the iron oxidises rapidly in the saline environment. Wear eye protection throughout.
- Mercury is a very toxic substance. It can be inhaled, ingested and absorbed through the skin. Never allow learners to handle mercury.

Part A

The curriculum requires you/your learners to do at least one synthesis, one decomposition and one displacement reaction for informal assessment. The Learner's Book contains a number of reactions that can be performed, depending on the equipment and chemicals that you have available in your science laboratory. Please read and follow all the safety instructions well.

Experiment 1: Synthesis reactions
Reactions with oxygen

You will need:

- samples of metals: Li, K, Na, Ca, Mg, Fe
- samples of non-metals: C, S and H (You can include white phosphorus if you have it in stock and know how to use it safely.)
  Note: White phosphorus is extremely hazardous to work with. It is kept in small quantities and under water, because it is extremely flammable and will ignite spontaneously when exposed to air, producing toxic fumes. Phosphorus reacts violently with some metals, halogens and oxidants, causing a fire and possibly, an explosion. Reaction with bases produces toxic phosphine gas. Phosphorus burns the skin and is very toxic when inhaled. Always wear full protection when working with phosphorus: wear safety goggles, gloves and protective clothing covering all exposed skin. Cut very small pieces of the non-metal, handle with a pair of tweezers and use immediately. Dispose of phosphorous compounds safely by contacting a local waste disposal company.
- gas jars filled with oxygen and sealed with cover slips; deflagrating spoons; Bunsen burner

The reaction for magnesium ribbon with oxygen was discussed on page D95 of this Teacher's Guide.

Prepare the gas jars:

1 Spread a little Vaseline or petroleum jelly around the top edges of the gas jars.
2 Fill the gas jars with oxygen and seal them by sliding a cover slip onto the mouth of each gas jar. The Vaseline will form a seal and prevent the gas from leaking out.

Prepare the substances for testing:

1 Cut and prepare small pieces of the metals and non-metals for testing.
2 The Group 1 metals, lithium, sodium and potassium, are extremely flammable and corrosive. You should handle them with great caution. Instructions on how to handle alkali metals were discussed on page D91 of this Teacher's Guide.
3 Use new clean steel wool for the reaction of iron with oxygen. Make sure the steel wool is not rusted.
4 Use charcoal powder for carbon.

5 Use flowers of sulfur (powdered sulfur).
6 Prepare hydrogen by reacting zinc metal with dilute hydrochloric acid. Collect the gas in an upside down test-tube by the downward displacement of air.

Do the experiments:

1 Place a small piece of one of the metals or non-metals in the deflagrating spoon.
2 Heat the spoon and its contents over a Bunsen burner until the substance is red hot or ignites.
3 Lower the spoon into the jar filled with oxygen.
4 Remove the spoon as soon as the reaction is completed and cover with the cover slip.
5 Reaction of hydrogen with oxygen in the air: turn the test tube the right way up. Hold a burning wooden splint at the mouth. The hydrogen will ignite with a blue flame to form water droplets at the top edge of the test tube.

Learners must complete the table:

Element	Flame colour	Product (oxides)	Equation
Lithium	White	White powder	$4Li + O_2 \rightarrow 2Li_2O$
Sodium	Yellow	White powder	$4Na + O_2 \rightarrow 2Na_2O$
Potassium	Purple	White powder	$4K + O_2 \rightarrow 2K_2O$
Calcium	Brick red	White powder	$2Ca + O_2 \rightarrow 2CaO$
Magnesium	Bright white	White powder	$2Mg + O_2 \rightarrow 2MgO$
Iron	Yellow glow and yellow sparks	Black powder	$3Fe + 2O_2 \rightarrow Fe_3O_4$
Copper	Red glow	Black powder	$2Cu + O_2 \rightarrow 2CuO$
Carbon	Yellow	Colourless gas	$C + O_2 \rightarrow CO_2$
Sulfur	Yellow	Dense white fumes	$P_4 + 5O_2 \rightarrow 2P_2O_5$
Hydrogen	Blue	Water	$2H_2 + O_2 \rightarrow 2H_2O$

Reaction between sulfur and iron

Safety
Make sure the laboratory is well-ventilated. It is possible that the sulfur vapours could escape and catch alight. If this happens, extinguish the flame by firmly placing a damp cloth over the mouth of the test-tube.

6 $Fe(s) + S(s) \rightarrow FeS(s)$
7 When the reaction mixture is heated, the sulfur melts and reacts with the iron in an exothermic reaction. The original elements combine to form a new product, iron(II) sulfide, that has different properties from the reactants.

Experiment 2: Decomposition reactions
Mercury is extremely poisonous and the decomposition of HgO should only be done as a demonstration (in a fume cupboard) by the teacher.

Safety
You must make sure you take adequate safety precautions when you work with mercury. Mercury is a highly toxic substance, even more so than

arsenic and cadmium. It can be inhaled, ingested and absorbed through the skin. Do not allow your learners to handle mercury.

- Always use protective gloves when handling mercury and do experiments in a fume cupboard or well ventilated room. Take care not to inhale mercury fumes.
- Do not use mercury where it could come into contact with a hot surface and vaporise.
- Contact a professional chemical disposal company to dispose of mercury waste. Never wash it down the drain!
- Never wear gold or silver jewellery when working with mercury – it forms an amalgam with these metals and irreversibly damages jewellery.

Only HgO liberates oxygen easily. In the process, droplets of mercury form higher up in the test tube where the sides are colder.

$$2HgO \rightarrow 2Hg + O_2$$

Lead(IV) oxide (PbO_2) liberates small amounts of oxygen as it changes to yellow lead(II) oxide (PbO).

$$2PbO_2 \rightarrow 2PbO + O_2$$

The CuO and MgO do not liberate oxygen, but can undergo a temporary colour change as they are being heated.

Decomposition of ammonium dichromate

Safety

Chromium and its compounds are known carcinogens. Chromium will irritate the mucous membranes. Perform experiment in a well-ventilated area, and avoid skin contact and inhalation of the materials. Wear gloves and safety goggles when handling ammonium dichromate.

4 $(NH_4)_2Cr_2O_7(s) \rightarrow N_2(g) + Cr_2O_3(s) + 4H_2O(g)$

5 The magnesium ribbon burns with a brilliant white flame and sets the $(NH_4)_2Cr_2O_7$ alight. The reaction is exothermic and looks like a tiny volcanic eruption. Green chromium(III) oxide fills the tile.

6 The magnesium flame supplies the activation energy for the decomposition, which is an exothermic reaction.

Experiment 3: Displacement of metals

5

	Mg	Zn	Cu	Fe
$CuSO_4(aq)$	Reaction	Reaction		Reaction
$ZnSO_4(aq)$	Reaction		No reaction	No reaction
$FeCl_2(aq)$	Reaction	Reaction	No reaction	
$MgSO_4(aq)$		No reaction	No reaction	No reaction

6 Decreasing activity: Mg, Zn, Fe, Cu

7 $Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$
$Mg(s) + ZnSO_4(aq) \rightarrow MgSO_4(aq) + Zn(s)$
$Mg(s) + FeCl_2(aq) \rightarrow MgCl_2(aq) + Fe(s)$
$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
$Zn(s) + FeCl_2(aq) \rightarrow ZnCl_2(aq) + Fe(s)$
$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

Displacement of halogens

Safety
Tetrachloromethane and trichloromethane are toxic and prolonged exposure can cause cancer; they are dangerous to the environment.

5

	KCl*(aq)*	KBr*(aq)*	KI*(aq)*
$Cl_2(aq)$		Reaction – solvent turns yellow	Reaction – solvent turns pink

Safety
If bromine water is available, you can do the displacement reactions as a demonstration. Remember that bromine is carcinogenic and poisonous. Do the experiment in a fume cupboard.

6 $Cl_2(aq) + 2KBr(aq) \rightarrow 2KCl(aq) + Br_2(\ell)$
$Cl_2(aq) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(s)$

7 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.

Part B

Additional safety notes

- Hydrogen sulfide is a poisonous gas that smells like rotten eggs. It irritates the eyes, nose and throat and higher concentrations will cause headaches, nausea and dizziness. Do the experiments in a well-ventilated room or in a fume cupboard. Prepare only enough H_2S to complete the experiment.
- $KMnO_4$ is a strong oxidiser and must be stored away from oxidisable substances. It stains skin, clothing and glassware; remove stains with lemon juice, oxalic acid or a weak solution of H_2O_2.

1 **Reducing action of hydrogen sulfide (H_2S)**

Learners are not expected to balance redox reactions from the half-reaction list in Grade 11, but here are the balanced equations for your information:

Preparation of H_2S:

$2HCl(aq) + FeS(s) \rightarrow H_2S(g) + FeCl_2(aq)$

Reaction with iron(III) chloride:

$2FeCl_3(aq) + H_2S(g) + HCl(aq) \rightarrow 2FeCl_2(aq) + S(s) + 3HCl(aq)$

The greenish-brown Fe^{3+} ion is reduced to the green Fe^{2+} ion. The solution turns milky as solid sulfur is formed.

Reaction with potassium permanganate:

$2KMnO_4(aq) + 5H_2S(g) + 6HCl(aq) \rightarrow 2KCl(aq) + 2MnCl_2(aq) + 5S(s) + 8H_2O(\ell)$

The purple MnO_4^- ion is reduced to the colourless Mn^{2+} ion and the solid sulfur gives the solution a milky effect.

$(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O)$

Reaction with potassium dichromate:

$K_2Cr_2O_7(aq) + 3H_2S(g) + 8HCl(aq) \rightarrow 2KCl(aq) + 2CrCl_3(aq) + 2S(s) + 7H_2O(\ell)$

The orange $Cr_2O_7^{2-}$ ion is reduced to the green Cr^{3+} ion.
($Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$)
The solution turns milky green.

2 **Oxidising action of potassium permanganate ($KMnO_4$)**
The reaction between H_2S and $KMnO_4$ in the previous experiment illustrates the oxidising ability of $KMnO_4$. Here we will look at the reaction between $KMnO_4$ and SO_2.
Preparation of SO_2:

$Na_2SO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(\ell) + SO_2(g)$

SO_2 can also be prepared by the reaction between copper metal and concentrated sulfuric acid. Place a small amount of copper filings in a test tube. Cover with concentrated H_2SO_4 and heat very carefully. Move the test tube constantly through the flame to prevent the acid from boiling and splashing out of the test tube.

$Cu(s) + 2H_2SO_4(\ell) \rightarrow CuSO_4(aq) + 2H_2O(\ell) + SO_2(g)$

You can either use a side-arm test tube and bubble the gas through the $KMnO_4$ solution, or dip a filter paper in $KMnO_4$ solution and hold it at the mouth of the test tube. The $KMnO_4$ will discolour.
The reaction between $KMnO_4$ and SO_2 is:

$2KMnO_4(aq) + 5SO_2(g) + 2H_2O(\ell) \rightarrow K_2SO_4(aq) + 2MnSO_4(aq) + 2H_2SO_4(aq)$

Note that no free sulfur forms and the resultant solution is colourless and clear.

Checklist for teacher's assessment of individual in a group during learner experiment/ teacher demonstration

Task skills	Yes	No	Comments
Stays focused on experiment/ demonstration			
Understands experimental method			
Follows method in orderly manner/ observes carefully what the teacher does			
Uses apparatus and equipment correctly			
Helpful/ assists teacher/ valuable member of group			
Answers simple questions during experiment/ demonstration			
Records results correctly in suitable table			
Writes balanced chemical equations correctly with phase symbols included			
Identifies reaction types correctly			
Answers questions correctly			

LB p. 288

Activity 15 Extension activity

P

Investigate redox reactions in everyday life

1 a) Fats and oils are found in all living cells in varying amounts. They are the carriers of flavourants and seasonings. Unsaturated fatty acids turn rancid when they are oxidised in the presence of oxygen and certain catalysts. Heptyl aldehyde is the main constituent of rancid foods.

b) The rate of fat oxidation depends on:
   - the degree of unsaturation (percentage double and triple bonds)
   - the presence of oxygen
   - storage temperature
   - the presence of catalysts, such as lipase, high and low energy radiation, metal contaminants, and animal and plant pigments, such as myoglobin, haemoglobin, chlorophyll and carotenoids.

c) Oxidation can be divided into three steps:
   i) Induction reaction: active radicals are formed by the action of oxygen and catalysts on fat.
   ii) Propulsion reaction: active radicals react with oxygen to form peroxy radicals. Acids, aldehydes, alcohols and ketones form. These chemicals are responsible for the rancid taste of old fats and oils. (Saturated fats are resistant to reactions with free radicals.)
   iii) Termination reaction: radicals react with each other to form stable products.

d) Keep foods in a refrigerator.
   Store foods in airtight containers
   Fill food packets with nitrogen.
   Add anti-oxidants.

e) Anti-oxidants are natural or artificial reducing agents which prevent the oxidation of fats. Most often they are substituted phenols, aromatic amines or sulfur compounds. They can perform any of the following functions:
   - react with oxygen
   - block induction reactions
   - neutralise oxidation products
   - react with free radicals
   - inhibit catalysts.

   It is important that anti-oxidants do not form toxic by-products, have no flavour and do not cause discolouration of the product. Natural plant fats and oils contain small amounts of natural anti-oxidants such as tocopherols (vitamin E), tannins, lecithin and ascorbic acid (vitamin C). Animal fats and oils become rancid more quickly because they do not have these natural anti-oxidants. Natural anti-oxidants are lost during purification processes and must be added after processing. Examples of anti-oxidants are BHA (butylated hydroxy anisole), NHG (nordihydroguairetic acid), BHT (butylated hydroxy toluene)and antibacterial agents such as sodium sulfite. Anti-oxidants are normally more reactive than the substrate and will be oxidised first. In Europe food additives are listed with an E number. Anti-oxidants have E-numbers between E310 and E321.

2 Photography

a) Photographic film has a light-sensitive coating that contains a silver halide such as silver bromide, AgBr, suspended in gelatine and applied to a plastic backing. When exposed to light, some AgBr molecules become activated. The number of AgBr molecules that become excited depends on the intensity of the light. The greatest number of excited AgBr molecules is where the light intensity is the greatest. These areas will eventually form the lighter areas on the photograph.

c) When the film is developed, the activated AgBr reacts with the developer in a redox reaction. The developer is a reducing agent such as the organic compound hydroquinone. Black metallic silver is formed. The developer reduces only the silver ions that were exposed to the light. During the fixing process the film is treated with photographer's hypo, which is a solution of sodium thiosulfate, $Na_2S_2O_7$. The hypo solution dissolves and washes away unexposed AgBr crystals. The negative that emerges has the greatest amount of metallic silver in the areas that were exposed to the most light.

d) The positive print is made from the negative by shining light through the negative onto light-sensitive photographic paper.

Unit 3 Summative assessment: Chemical change (Redox)

TERM 4, MODULE 4

1 a) redox/oxidation–reduction reaction
b) reduction
c) oxidation

2 A reducing agent is *oxidised* and *loses* electrons during a reaction. An oxidising agent is *reduced* and *gains* electrons during a reaction. Oxidation occurs when the atom *loses* electrons and when its oxidation number *increases*.

3 a) i) B ii) D
b) C
c) D

4 The oxidation number is an indication of an atom's relative richness in electrons and it signifies the number of charges the atom would have in a molecule if electrons were transferred completely.

5 a) iron in FeO: +2; $FeCl_3$: +3; Fe: 0; $FeBr_2$: +2
b) copper in Cu_2O: +1; $CuCl_2$: +2; Cu: 0; CuO: +2; CuCl: +1
c) carbon in C: 0; CO: +2; CO_2: +4; HCO_3^-: +4
d) Chlorine in Cl_2: 0; ClF_3: +3; Cl_2O: +1; ClO_3^-: +5; HCl: −2; HOCl: +1

6 a) $\overset{0}{Cu} \rightarrow \overset{+2}{CuSO_4}$ oxidation (increase in oxidation number of Cu)

$H_2\overset{+6}{S}O_4 \rightarrow \overset{+4}{S}O_2$ reduction (decrease in oxidation number of S)

Cu is the reducing agent
H_2SO_4 is the oxidising agent

b) $Cu \rightarrow Cu^{2+} + 2e^-$

7 a) oxidising agent: Cl_2
Reducing agent: Br^-
b) Oxidising agent: Cu^{2+}
Reducing agent: Zn
c) The blue colour of the solution disappears.
The zinc powder dissolves.
Reddish brown copper precipitates.
The temperature of the mixture increases.
d) Oxidising agent: H^+
Reducing agent: Mg
e) Spectator ion: Cl^-
f) Bubbles of H_2 gas form; the Mg dissolves.

MODULE 6: CHEMICAL SYSTEMS

Background information for Module 6

This module focuses on the lithosphere; the Earth's crust and upper mantle. It creates a suitable conclusion to an interesting and enriching journey through science. By now the learners should have developed into young adults, making this an ideal time to sharpen their social responsibilities towards their home planet, the Earth. The main focus of this module is to encourage learners to think independently, make up their minds about how they feel towards the environment, and to broaden their perspectives and sensitise them to current environmental issues. Encourage them to read, listen and talk about the exploitation of the Earth and the effects of pollution on human quality of life. Guide them to look further than monetary costs and to consider also the cost to the Earth and the future of the human race.

Chemical systems is allocated 5% of the annual curriculum, which translates into 8 hours. There are no recommended activities for formal or informal assessment.

LB p. 292 »

Activity 1 Revision exercise G

Recognise systems

A brick and a steel beam are not systems.

LB p. 299 »

Activity 2 Experiment G

Investigate the corrosion of iron

Background information on protection of iron and steel

When air, water or other surrounding substances attack metal, we say it has been corroded. The corrosion of iron and steel is called rusting. Rusting is a serious economic problem, and large sums of money are spent each year to protect or replace damaged iron and steel structures. Rust is a red-brown powder consisting mainly of hydrated iron(III) oxide ($Fe_2O_3 \cdot xH_2O$). For iron to rust, it requires the presence of water and oxygen, and rusting is aggravated by the presence of salt or seawater. Acid rain also increases the rate at which iron objects rust.

Some metals, such as aluminium and chromium, also corrode, but a very thin single layer of metal oxide forms that sticks to the surface of the metal. This layer seals the metal and protects it from further corrosion. In contrast, iron rust forms flakes that do not stick to the metal, but come off. In time, rusting can form holes right through a sheet of iron.

Humans have devised many different ways to protect the large variety of iron and steel products and structures used in our modern world, mainly by coating them with other materials.

- 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 and 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 and garden chairs.
- 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. Even if the zinc layer is badly scratched, the protection is still effective, because the zinc will corrode, but the steel will not. Zinc corrodes very slowly. Vehicle bodies are dipped into a bath 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.

Notes on experiments

- You and the learners should wear eye protection during experiments.
- Clean iron nails with a 1 mol·dm^{-3} solution of HCl to remove any rust and rinse well.
- Experiment 4: Coat an iron nail with Tippex instead of paint; cooking oil is the safest and cheapest oil to use; wrap nail in clingfilm to show how a plastic layer protects iron.

Answers

Experiment 1:

6 Rust is aided by water and oxygen. The nail in test tube 4, where all moisture was removed by the drying agent, and test tube 5, where all oxygen was removed, should take the longest to show rust. The nails in test tubes 2 and 3 should rust first.

7 Rust can be prevented from forming on iron by removing the moisture and oxygen from its surface.

Experiment 2:

6 and 7 All ionic substances will speed up the rusting process. Results will vary according to the concentration of the individual solutions.

Experiment 3:

6 The reactivity decreases in the following order: aluminium, zinc, iron, lead and copper. When a more reactive metal is connected to iron, this metal corrodes instead of iron. Aluminium and zinc will corrode instead of iron. Iron will corrode instead of lead and copper.
In beakers 1 and 3, the mass of the aluminium and zinc will decrease and that of the iron nails will increase.
In beakers 2 and 4, the mass of the copper and lead will increase and the mass of the iron nails will decrease.

Experiment 4:

6 The best results should be obtained from the nail wrapped with magnesium ribbon. The nails covered with Vaseline, oil and paint and the galvanised nail should also not rust. This depends on how uniform the covering is. The steel wool should rust faster than the nail, because of the larger exposed surface area.

LB p. 303

Activity 3 Research project

I P

Describe the extraction of metals

1 **Physical separating methods**

Metal ores often contain large amounts of gangue. To reduce the volume of material to be processed, the ore has to be concentrated by separating it from the gangue. Physical separation concentrates the minerals or materials by exploiting the differences in their physical characteristics, such as specific gravity, solubility or magnetic properties.

When we pan for gold, we use the high specific gravity of gold. A sample of sand is placed into a shallow pan partially filled with water. As the water is swirled around, the less dense sand washes over the rim of the pan, and bits of gold are left behind.

Iron ore also has a high specific gravity. Crushed iron ore is mixed with a silicon-water mix that has a specific gravity of 3,6. The denser iron ore settles to the bottom of the cyclone. (A cyclone is a machine that separates solids by making use of differences in their mass.) The gangue floats, and can be removed with the water mix.

Flotation is used to enrich phosphates and the ores of certain metals, such as copper and lead.The ore is crushed, mixed with water, and ground into a soup-like slurry. The slurry is transferred to flotation tanks, where it is mixed with detergents and oil. The oil adheres to the ore particles, but not to the sand and dirt. Air is blown through the mixture and rising air bubbles adhere to the oil-coated ore particles, bringing them to the surface, where they form froth. The detergents stabilise the bubbles long enough for the froth to be skimmed. Sand and dirt settle at the bottom of the tank, and are removed.

The magnetic property of ferromagnetic metals, such as iron and cobalt, is used to separate ores from gangue. Strong electromagnets are used for this process.

2 Heating (Roasting)

Metals in their combined forms always have positive oxidation numbers. The production of a free metal is always a reduction process. Sometimes it is necessary to convert the ore to another chemical state that is more suitable for reduction. Carbonates and sulfides are roasted to drive off the unwanted carbon or sulfur, leaving the oxides, which can be directly reduced.

Malachite, a common ore of copper, is primarily copper carbonate ($CuCO_3$). This mineral undergoes thermal decomposition in several stages between 250°C and 350°C, to CuO and CO_2. The carbon dioxide is expelled into the atmosphere, leaving copper oxide, which can be directly reduced to copper.

$$CuCO_3 \rightarrow CuO + CO_2$$

Galena (lead sulfide) is oxidised to a sulfite, which decomposes at high temperatures into lead oxide and sulfur dioxide gas.

$$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$$

The sulfur dioxide is expelled, and the lead oxide is reduced to lead.

Pyrite or iron disulfide can be converted to iron(III) oxide through roasting:

$$4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$$

3 Heating with carbon

Metals that are less reactive than carbon can be extracted by heating the metal oxide with carbon in a blast furnace. Metals such as iron, copper, tin, lead and zinc can be extracted by oxidation–reduction between their oxides and carbon.

The most commonly used reducing agent is carbon, as it is plentiful and inexpensive. When coal is heated strongly in the absence of air, volatile contaminants are driven off and coke is formed. Coke is composed almost entirely of carbon, and is used in blast furnaces. When the metal oxide is mixed with coke and heated strongly, the carbon reduces the metal oxide to form carbon dioxide and the metal.

The main reducing agent in a blast furnace is carbon monoxide (CO). There are three reactions that contribute to the formation of CO. The first two reactions are exothermic, and the furnace becomes intensely hot. In the third reaction, the hot, rising CO_2 reacts with more coke to form CO. This reaction is endothermic, and the temperature of the furnace drops slightly.

Reaction 1: $2C(s) + O_2(g) \rightarrow 2CO(g)$

Reaction 2: $C(s) + O_2(g) \rightarrow CO_2(g)$

Reaction 3: $CO_2(g) + C(s) \rightarrow 2CO(g)$

For example, the overall reaction for the reduction of iron(III) oxide to form iron is:

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

4 Electrolysis

It is only in the last 200 years that very reactive metals such as sodium and aluminium have been extracted by electrolysis.

Aluminium is the second most widely used metal, and is in high demand. The Hall-Heroult process uses electrolysis to extract aluminium from bauxite. In the first step, bauxite is treated with sodium hydroxide to produce pure aluminium oxide or alumina. The alumina is then dissolved in molten cryolite (Na_2AlF_6), that lowers the working temperature from about 2 000°C to 1 000 °C. In the electrolytic cell, the aluminium is reduced to pure metal, and the carbon electrodes react with the oxygen that is released, to form carbon dioxide gas. The process requires huge amounts of electricity.

LB p. 303 »

Activity 4 Practical investigation

I P

Investigate calcium carbonate

1 Chalk is the softest; limestone; marble is the hardest

2 Limestone is abundant, so that in most areas, people in ancient times could find enough limestone to meet their needs. Limestone is relatively soft and brittle, and can be cut into blocks and slabs, making it a suitable building material.

3 The actions of heat, water and acids on limestone:

- a) i) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
    - ii) The reaction is endothermic, because heat had to be supplied for the limestone to decompose.
- b) i) Limestone will not react with water and a slurry forms. Quicklime reacts with water and the reaction mixture becomes hot.
    - ii) The reaction is exothermic and heat is released to the surroundings.
- c) $CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(aq)$
- d) i) Slaked lime is slightly soluble in water.
    - ii) The limewater is alkaline and turns red litmus paper blue.
    - iii) We use limewater to test for carbon dioxide gas. Bubble the unknown gas through clear limewater. If a precipitate forms, the gas is probably carbon dioxide.
      $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(\ell)$
- e) i) A reaction occurs and large bubbles of carbon dioxide will form.
    - ii) $CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(aq) + H_2O(\ell) + CO_2(g)$

4 Farmers use slaked lime to improve the quality of the soil and to adjust the pH. In clay soil the soil particles are very small and pack tightly together. They trap and retain water molecules. Slaked lime breaks up the clay soil, making it less 'sticky', and neutralises the acids. Some soil types are too acidic to allow for plants to grow to their full potential. Slaked lime is a base and will neutralise excess acids in the soil.

5 Limestone uses:

Cement and concrete:

If limestone is mixed with clay before roasting in a rotary kiln, the mixture reacts to form cement. Cement is mixed with sand and water to make mortar, which is used to hold bricks together in a building. If gravel (small stones) is also added to the mixture, concrete is formed. When iron structures are added to the concrete, it is called reinforced concrete. Large amounts of cement, concrete and reinforced concrete are used in the building industry. Reinforced concrete is used in all large structures and foundations for large structures, such as multi-storey buildings, decking, roads and paths.

Glass:

The primary ingredient of glass is quartz sand (also called silica, SiO_2). Pure silica has a very high melting point (above 1 700 °C) and becomes rigid very quickly on cooling. This makes it hard to work with. When soda ash (Na_2CO_3) is mixed with the silica, the melting point is lowered to 700 – 850 °C. The glass formed in this way is relatively soluble in water. If limestone ($CaCO_3$) is also added, the glass becomes less soluble in water. This type of glass is known as soda-lime glass, and is the most common kind of glass.

Paper:

Limestone is used in many stages during the production of paper. In the production of pulp, sodium carbonate is treated with lime to produce caustic soda. It is used to dissolve non-cellulose wood elements, and as a bleaching agent for the pulp, and aids in the production of whiter paper. Limestone is valued for its high brightness and light-scattering characteristics. It is also used as an inexpensive filler and coating pigment in the manufacture of bright opaque paper.

LB p. 305

Activity 5 Experiment

Investigate oxy-cleaners

Oxy-cleaners or oxygen bleaches are oxidising agents that release oxygen when they are added to water. They are usually used for removing dirt and bleaching of stains. There are three types of oxy-cleaners – hydrogen peroxide (H_2O_2), sodium percarbonate ($2Na_2CO_3 \cdot 3H_2O_2$) and sodium perborate ($NaBO_3 \cdot H_2O$ and $NaBO_3 \cdot 3H_2O$). Hydrogen peroxide is a liquid, and sodium percarbonate and sodium perborate are powders. Sodium percarbonate is used in carpet, household and laundry cleaning products, and sodium perborate is used mostly in automatic dishwashing and laundry products as a hot water bleaching agent.

Pure sodium percarbonate contains about 13–14% oxygen and sodium perborate contains about 10–15% oxygen. Hydrogen peroxide dissolved in water also releases oxygen. A 3% hydrogen peroxide solution is used for general household purposes.

Add the same amount of different oxy-cleaners and H_2O_2 to 2ℓ bottles filled with water. Pull empty balloons over the mouths of the bottles. Collect the gas that is released in the balloons. Compare the amount of gas that is formed by comparing the sizes of the balloons. Test the gas for oxygen by deflating the balloons over a burning match.

Enrichment text: The history of gold in Southern Africa

In Mapungubwe, near Mussina in the Northern Province, local people used gold for trading with merchants from Arabia between 1000 and 1300 AD. At Thulumela, in the northern Kruger National Park, archaeologists discovered remnants of a civilisation from the 1400s to the 1500s that smelted and refined gold, copper and iron. Other areas with evidence of prehistoric mining activities are Lydenburg, Pilgrim's Rest and Soutpansberg.

Dr David Livingstone is known to have found traces of gold in Zimbabwe in the early 1840s. An English mineralogist, John Henry Davis, discovered gold on the farm Paardekraal (now Krugersdorp) in 1852, and in 1853 Pieter Marais discovered gold in the Jukskei River (near Johannesburg).

In 1866, a young German explorer and geologist, Karl Mauch, came to South Africa. In the following year, he discovered gold in the Tati River (Zimbabwe). Mauch speculated (correctly) that in ancient times, the southern parts of Africa had supported extensive gold mining and that it would do so again. Although he was correct in his prediction, he was wrong about the location of these goldfields. In December 1867, Henry Struben also discovered gold close to the fields discovered by Mauch. Not only did Struben find gold, but he also discovered the Zimbabwe ruins. Mauch and Struben's discoveries awakened world interest in the southern African gold deposits. In 1869, four experienced prospectors, Button, MacLachlan, Sutherland and Parsons, arrived in the Transvaal Republic in search of payable gold deposits. When Edward Button discovered payable gold on the farm Eersteling (Limpopo Province) in 1871, South Africa became a modern gold-producing country. However, this discovery was soon overshadowed by the discovery of gold in the Eastern Escarpment regions. The smaller gold mines closed down as gold miners went to try their luck at Pilgrim's Rest.

The first gold rush in South Africa took place in 1873 when gold was discovered, first on the farm Geelhoutboom (Mac Mac) near the town of Sabie, and shortly afterwards at Pilgrim's Rest in Mpumalanga. Gold diggers flocked to these areas, which became known as the New Caledonia Gold Fields. By the end of 1873, about 1 500 diggers worked 4 000 claims in this area. Alluvial gold was recovered from the streams and banks of the rivers by means of sluice-boxes, cradles and gold pans. Today the village of Pilgrim's Rest is a national icon and a Heritage Site.

In 1886 the Australian digger George Harrison opened up a reef that we now know as the Witwatersrand goldfields. The history of the development of Johannesburg, the rest of the Witwatersrand complex and the mining companies is an interesting period to research and explore.

LB p. 315 »

Activity 6 Application exercises

Consider gold

1 Gold is very unreactive and can occur in nature as a free element.
2 Mercury evaporates at room temperature to form very poisonous mercury vapours. Mercury poisoning can be acute or chronic. Acute poisoning results from a large quantity of soluble mercury salt being ingested. Chronic poisoning occurs when small amounts of mercury

are absorbed regularly. Chronic mercury poisoning affects the nervous system, resulting in hallucinations, trembling, nervousness and paralysis.

3 a) Cyanidation
  b) Oxidised. Gold in the ore changes to $NaAu(CN)_2$
  Oxidation number of Au in gold ore: 0
  Oxidation number of Au in $NaAu(CN)_2$: +1
  Oxidation number increases
  c) Zinc reduction or activated carbon adsorption, elution and electrowinning
  d) Calcination and smelting
  e) Gold is calcinated at high temperatures to purify the gold. The base metals are oxidised and combine with fluxes to form slag that can easily be removed from the gold.
  f) i) Cyanidation is a very effective process and it is possible to extract over 99% of gold from the ore. Mining companies stand to make more profit.
    ii) Cyanide can pollute water and become a threat to aquatic life.

4 Sulfur compounds in mine heaps can oxidise and dissolve in rain water to form acid mine drainage water that can pollute ground water and rivers. Left over cyanide and run-off can pollute water sources.

5 a) A *slurry* is a suspension of fine solid material in a liquid to form a thin liquid mixture.
  b) During *adsorption*, molecules from another substance attach to the surface of a medium.
  c) *Elution* is the removal of the adsorbed substance by washing.
  d) *Electrowinning* is the process of recovering a metal through electrolysis.
  e) A *flux* is a substance that is mixed with the metal to aid and promote fusion.
  f) *Refining* is the process of purifying a metal by removing other substances.

LB p. 320 »

Activity 7 Class debate

Debate the effects of the mining industry in South Africa

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 arguments 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:

- Mining makes up a large part of our economy
- Minerals and metals are exported to earn foreign capital
- The mining industry provides many jobs
- Raw materials are used to make many useful objects

Possible negative arguments:

- All mining activities have a negative impact on the environment
- Large amounts of water and chemicals are used
- Mines produce a lot of waste that can pollute the environment
- Mines occupy valuable land that could have been used for housing or agriculture
- Mining activities can damage the health of mine workers

LB p. 320 »

Activity 8 Practical investigation

Investigate the mining industry

Option A: Here is a summary of some of the mining industries.

	Why is this mining industry important in South Africa?	Where do the mining activities take place?	How is the mineral mined?	How is the mineral processed?	What is the mineral used for?
Iron	large reserves of iron ore; bulk is exported through the port of Saldanha Bay; foreign revenue; used for production of steel products	Sishen in the Northern Cape and Thabazimbi in Limpopo	opencast mines	crushed; screened; separated from gangue by specific gravity; blended; transported to steelworks or harbour	steel products
Coal	large reserves of coal; export earns foreign revenue; coal-fired power stations generate electricity	Mpumalanga, Limpopo, northern Kwazulu-Natal, northern Free State	opencast mines and underground mines	blended; transported to power stations or harbour	generation of electricity
Copper	copper needed for pipes, electric wiring and other products	Phalaborwa, Limpopo and Northern Cape	opencast mines and underground mines	crushed; screened; separated from gangue; extraction; electrowinning	copper pipes; electrical wiring

Option B: Here is a list of the elements mined or processed in South Africa.

Element	Physical properties	Uses
Carbon: diamonds (C)	hard	jewellery, industrial cutting tools
Carbon: coal (C)	softer than diamond	electricity generation
Aluminium (Al)	lightweight non-corroding metal	common metal, kitchenware, cans, foil, machinery, cars, planes, bikes
Titanium (Ti)	strongest light-weight metal, heat-resistant	aerospace, racing bikes, artificial joints, white paint
Chromium (Cr)	hard shiny metal	stainless steel (Fe-Cr-Ni), nichrome heaters, kitchenware, car trim, paints
Manganese (Mn)	hard metal	hard tough steel, earthmovers, rock crushers, plows, axes, batteries
Iron (Fe)	medium-hard metal, magnetic	steel alloys, metal structures, vehicles, magnets
Nickel (Ni)	medium-hard metal, magnetic	stainless steel (Fe-Cr-Ni), nichrome heaters, kitchenware, nicad batteries, coins
Copper (Cu)	coloured metal, conducts heat and electricity well	wires, cookware, brass (Cu-Zn), bronze (Cu-Sn), coins, pipes
Silver (Ag)	soft shiny metal, best conductor of electricity	jewellery, silverware, coins, dentistry, photo film
Tin (Sn)	non-corroding soft metal	solders, plated food cans, bronze (Cu-Sn), glass-making
Platinum (Pt)	non-corroding dense metal	jewellery, labware, spark plugs, catalysts, pollution control, petroleum cracking
Uranium (U)	radio-active, long-lived, dense	nuclear reactor fuel, nuclear weapons, counterweights
Gold (Au)	most malleable element, non-tarnishing coloured metal	jewellery, coins, ultra-thin gold leaf, electrical contacts
Vanadium (V)	hard metal	hard strong steel, structures, vehicles, springs, tools, aerospace
Zirconium (Zr)	non-corroding neutron- resistant metal	chemical pipelines, nuclear reactors, furnace bricks, abrasives
Antimony (Sb)	brittle metalloid	solders, lead hardener, batteries, semiconductors, photocells, bullets
Ruthenium (Ru)	non-corroding hard metal	electric contacts, pen tips, catalyst, hydrogen production, leaf switches
Rhodium (Rh)	non-corroding hard, shiny metal	labware, reflectors, electric contacts, thermocouples, catalyst, pollution control
Palladium (Pd)	non-corroding hard metal, absorbs hydrogen	labware, electric contacts, dentistry, catalyst, pollution control
Osmium (Os)	non-corroding high melting point hard metal, densest element (same as Ir)	electric contacts, pen tips, needles, fingerprint powder
Iridium (Ir)	non-corroding hard metal, densest element (same as Os)	labware, spark plugs, pen tips, needles

Source: taken from list in elements.wlonk.com

Summative assessment: Chemical systems

1 a) lithosphere
  b) roasting
  c) Witwatersrand basin
  d) sodium cyanide
  e) global warming
  f) ores

2 a) Gold is often alloyed with other metals to increase its *hardness*.
  b) During the Bronze Age, humans started *to alloy copper and tin to produce* bronze metal.
  c) In the flotation technique, the *sand and dirt* settle at the bottom of the tank. (The ores combine with air and float at the top.)
  d) The mineral deposits of a country are part of its natural *non*-renewable resources.
  e) The main impurity in gold is *silver*.
  f) The main pollution caused by gold mining is *water* pollution.

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

4 Stone Age, Bronze Age and Iron Age

5 a) The crust, the mantle and the core
  b) The lithosphere
  c) Magnesium, iron, aluminium, silicon and oxygen
  d) Magma
  e) Iron and nickel
  f) The Earth's magnetic field
  g) The crust

6 Metal compounds are known as minerals. Mineral deposits from which metals can be produced economically, are called ores.

7 a) crust
  b) mining: blasting, excavation and collecting
  c) size reduction (milling), separation by washing or floatation, sometimes roasting
  d) reduction
  e) carbon in the form of coke

8 a) Metals have positive oxidation states and must gain electrons to become free elements. Reduction is a gain of electrons.
  b) Carbon in the form of coke is used as a reducing agent.

9 a) Gold mining creates many job opportunities. Gold earns large sums of foreign currency for the country. This money can be used to finance many of our country's projects and expenses.
  Any other plausible reason is acceptable.
  b) Gold is used as money and in jewellery manufacture, and has many industrial applications.

10 a) Oil, coal and natural gas
  b) Fossil fuels are the remains of plants and animals that lived millions of year ago. It took all that time to form the fossil fuels. When we use up fossil fuels, there is no way to create a further supply.

c) There are abundant reserves of coal available in South Africa.
The technology to produce energy from coal is well established.
It is the cheapest way of producing electricity (if you ignore the cost to the environment).

d) Fossil fuel reserves are limited.
Pollution from fossil fuels is affecting the atmosphere (and should be a factor in the cost analysis).

e) Fossil fuels contain many contaminants. When the fossil fuels combust, so do the contaminants. The main pollutants are sulfur dioxide, nitrogen oxides, various organic compounds, heavy metal compounds, radioactive compounds and ash.
Sulfur dioxide and nitrogen oxides dissolve in rainwater to form acid rain that can damage buildings and plants.
Sulfur dioxide, nitrogen oxides and ash cause respiratory problems in humans.

11 The greenhouse effect is essential for all life on the Earth. It heats up the atmosphere and keeps the Earth at a temperature suitable for life. The balance between the energy received from the sun and the energy radiated back into space is delicate, and is determined by the concentration of the greenhouse gases. If the concentration of these gases increases, too much energy (heat) is absorbed and the ambient temperature of the atmosphere rises. This is called the enhanced greenhouse effect, or global warming.

12 Carbon dioxide levels are linked to the amount of photosynthesis that takes place. During the winter, the levels of sunlight are low. Many trees are dormant or lose their leaves. The level of photosynthesis decreases. During the night no photosynthesis is possible.

13 The icecaps consist of water molecules entrapped in a solid crystal lattice. If the icecaps melt, the water molecules will change phase and become liquid. The water will join the water of the oceans, increasing its total volume. A rise in sea-level is inevitable.

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 11 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

13 — atomic number
Al — symbol
27,0 — atomic mass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1,0																	2 **He** 4,0
7 **Li** 6,9	9 **Be** 9,0											5 **B** 10,8	6 **C** 12,0	7 **N** 14,0	8 **O** 16,0	9 **F** 19,0	10 **Ne** 20,2
11 **Na** 23,0	12 **Mg** 24,3											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

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

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 in this section and list them here for easy reference.

Grade
11

Study & Master

Physical Sciences

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.

The comprehensive Learner's Book:

- explains key concepts and scientific terms in accessible language and provides learners with a glossary of scientific terminology to aid understanding
- provides for frequent consolidation in the Summative assessments at the end of each module
- 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
- highlights examples, laws and formulae in boxes for easy reference.

The innovative Teacher's Guide includes:

- guidance on the teaching of each lesson of the year
- answers to all activities in the Learner's Book
- assessment guidelines
- photocopiable templates and resources for the teacher.

CIDA
EMPOWERMENT
FUND
PROUD PARTNERS

CAMBRIDGE
UNIVERSITY PRESS
www.cup.co.za

ISBN 978-1-107-60849-8
9 781107 608498