Living

Physics

TEACHER'S GUIDE

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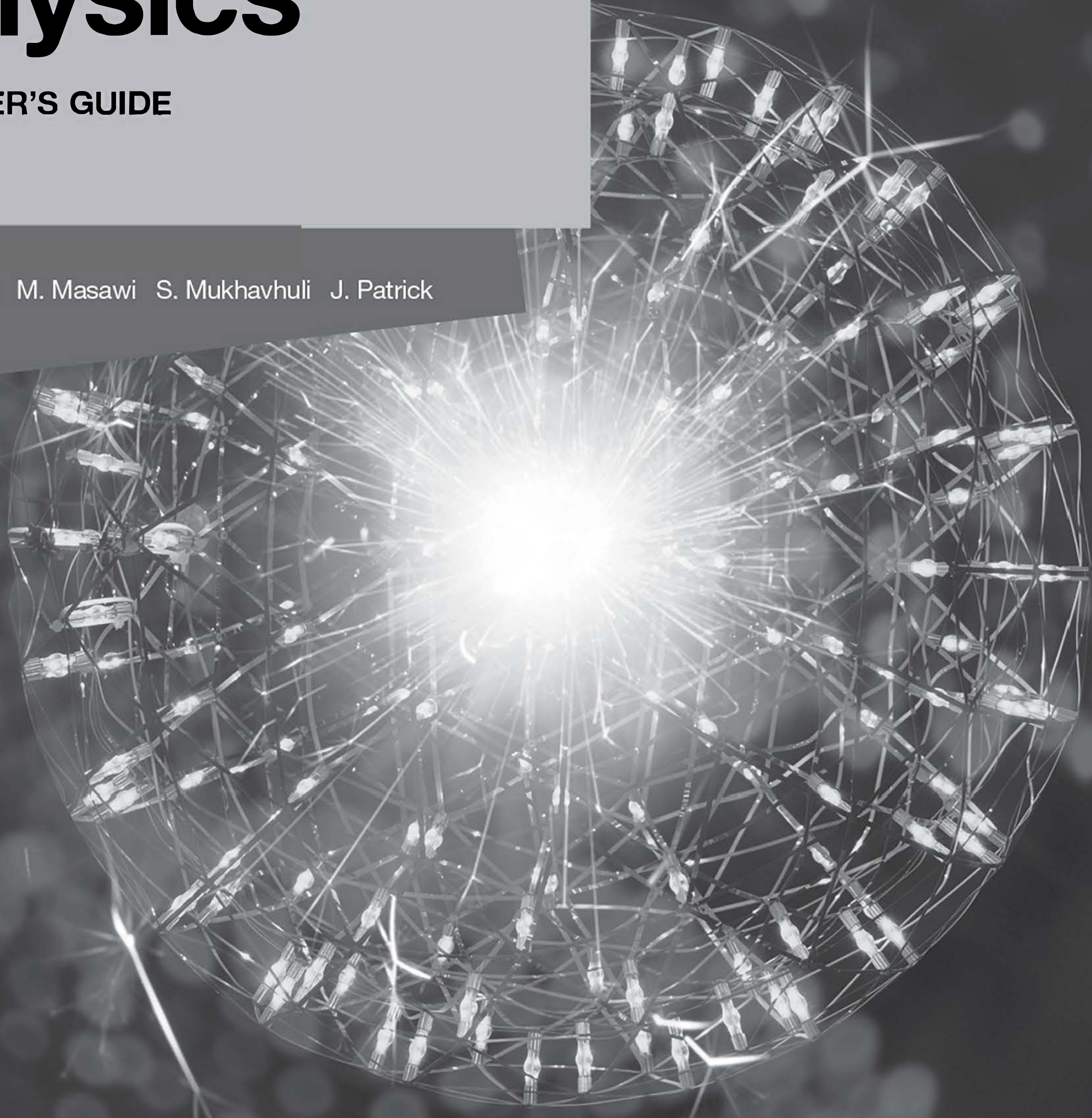

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any omissions or errors to be corrected in subsequent impressions.

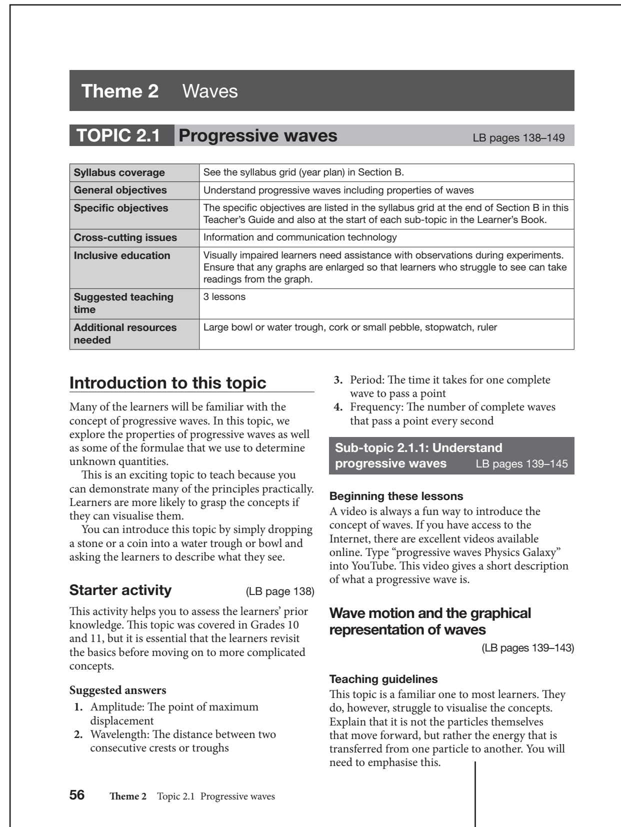
Contents

How to use this Teacher's Guide

Use this Teacher's Guide with the *Living Physics for Grade 12 Learner's Book*. These components follow the Ministry of Education's Senior Secondary Certificate Physics syllabus for (Advanced Subsidiary level Grade 12). This means they are up-to-date and relevant to current classroom environments and educational needs.

This Teacher's Guide is divided into four sections.

- **Section A** gives information about the new curriculum for AS-level (Grade 12), and how the Learner's Book and Teacher's Guide help you meet the objectives laid out in the syllabus.
- **Section B** contains a lesson plan template, a suggested year plan for teaching and guidelines on assessment (including examinations).
- **Section C** contains teaching guidelines for each topic and sub-topic in the Learner's Book.
- **Section D** contains additional resources that you might find useful. You may photocopy these resources to use in your classroom. There are many ways in which you can teach a subject. Each classroom is unique in the composition of its learners, the social and physical environment of your school, and the types of resources you have.



Theme 2 Waves

TOPIC 2.1 Progressive waves LB pages 138–149

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Understand progressive waves including properties of waves
Specific objectives	The specific objectives are listed in the syllabus grid at the end of Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with observations during experiments. Ensure that any graphs are enlarged so that learners who struggle to see can take readings from the graph.
Suggested teaching time	3 lessons
Additional resources needed	Large bowl or water trough, cork or small pebble, stopwatch, ruler

Introduction to this topic

Many of the learners will be familiar with the concept of progressive waves. In this topic, we explore the properties of progressive waves as well as some of the formulae that we use to determine unknown quantities.

This is an exciting topic to teach because you can demonstrate many of the principles practically. Learners are more likely to grasp the concepts if they can visualise them.

You can introduce this topic by simply dropping a stone or a coin into a water trough or bowl and asking the learners to describe what they see.

Starter activity (LB page 138)

This activity helps you to assess the learners' prior knowledge. This topic was covered in Grades 10 and 11, but it is essential that the learners revisit the basics before moving on to more complicated concepts.

Suggested answers

1. Amplitude: The point of maximum displacement
2. Wavelength: The distance between two consecutive crests or troughs
3. Period: The time it takes for one complete wave to pass a point
4. Frequency: The number of complete waves that pass a point every second

Sub-topic 2.1.1: Understand progressive waves LB pages 139–145

Beginning these lessons

A video is always a fun way to introduce the concept of waves. If you have access to the Internet, there are excellent videos available online. Type "progressive waves Physics Galaxy" into YouTube. This video gives a short description of what a progressive wave is.

Wave motion and the graphical representation of waves (LB pages 139–143)

Teaching guidelines

This topic is a familiar one to most learners. They do, however, struggle to visualise the concepts. Explain that it is not the particles themselves that move forward, but rather the energy that is transferred from one particle to another. You will need to emphasise this.

56 Theme 2 Topic 2.1 Progressive waves

Teaching tips for you, the teacher

The teaching guidelines

The teaching guidelines for each topic start with a table that provides links with cross-curricular issues (called cross-cutting issues in this series), time allocations and suggested resources.

The overview tables are followed by teaching guidelines that correspond to the Learner's Book pages. In these notes, you will find:

- answers to activities and experiments
- suggestions for informal assessment and remedial/extension activities.

Where possible, this Teacher's Guide will help you with ideas on how you can overcome obstacles to deliver the best possible lessons to your learners.

Bloom's taxonomy

The self-assessment questions at the end of each topic in the Learner's Book have been graded to reflect the types of questions outlined by Bloom's taxonomy. Although not shown in the Learner's Book, the answers given in this Teacher's Guide reflect the Bloom's level in brackets after the mark allocation. The symbols given there correspond to the Bloom's level in the table below.

Bloom's category	Abbr.
Knowledge	K
Understanding (of content)	U
Application	Ap
Analysis	An
Synthesis	S
Evaluation	E

Section A Teaching Physics at Advanced Subsidiary level

The main aim of the Physics syllabus is to provide the foundations required for future learning. As the world changes and becomes more technologically driven, Namibia will require a scientifically literate society to cope with the challenges faced by our communities.

The Physics curriculum promotes the following aims in the curriculum guide:

- Provide, through well-designed studies of theoretical and practical science, a worthwhile educational experience for all learners, regardless of whether they go on to study science beyond this level, and in particular, enable learners to acquire sufficient understanding and knowledge to:
  - » become confident citizens in a technological world, able to take or develop an informed interest in scientific matters
  - » recognise the usefulness and limitations of the scientific method, and appreciate its applicability in other disciplines and everyday life
  - » be suitably prepared for employment and/or further studies beyond the NSSC AS-level in Physics.
- Develop abilities and skills that:
  - » are relevant to the study and practise of Physics
  - » are useful in everyday life
  - » encourage efficient and safe practise
  - » encourage effective communication.
- Develop attitudes relevant to Physics such as concern for accuracy and precision, objectivity, integrity, enquiry, initiative, and inventiveness.
- Stimulate interest in, and care for, the environment.
- Promote an awareness that:
  - » scientific theories and methods have developed, and continue to do so, as a result of the cooperative activities of groups and individuals
  - » the study and practise of science is subject to social, economic, technological, ethical, and cultural influences and limitations
  - » the applications of science may be both beneficial and detrimental to the individual, community and environment
  - » science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal.

Teaching time

The NSSCO recommends that Physics be allocated 9 periods of 40 minutes each per 7-day cycle over the year. This allows learners sufficient time to consolidate the theory, practise their skills and apply their Physics knowledge.

Links to other subjects and cross-cutting issues

The topics covered in the Learner's Book and Teacher's Guide link to a number of cross-cutting issues including Environmental Education, HIV and AIDS, Information and Communication Technology (ICT), Road Safety, Population Education, Education for Human Rights and Democracy, and Special Needs Education.

Each cross-cutting issue is introduced at the start of a topic in the Learner's Book by a specific character. These characters and their issues are on page viii of the Learner's Book. The links to cross-cutting issues are also listed in the tables at the start of each topic in this Teacher's Guide and discussed in more detail throughout the book.

Methods suited to Physics

You play a huge role in nurturing a love for science. Physics is not just theory – practical activities, tasks and investigations are just as integral a part of the subject as content. It is important that learners feel enthusiastic and excited when they enter the classroom.

As teachers, it is important that we keep the lessons as learner-centred as possible. It is important that Physics is linked to the experiences of learners in Namibia. The more relatable a subject, the easier it is for the learners to make sense of the theory and appreciate the role science plays in our everyday lives.

Allocate as much time as possible to practical tasks. Practical investigations give learners the opportunity to see science in action and apply their knowledge. It also teaches the learners life skills like the ability to justify statements, draw conclusions and analyse data.

Physics is filled with confusing terminology and we should always pitch our lessons at the level of the learner. Introduce new words at the start of a topic and ensure that the whole class understands their meaning before moving on. Using language that is above their cognitive level will result in the learners becoming discouraged and losing interest.

Integration with other subjects is essential. Language and Mathematics, and even some Chemistry, form an integral part of the Physics curriculum and should be seen as part of learners' science education. Links should be made throughout the lesson and collaboration between teachers of different subjects can be a valuable tool in helping the learners achieve success across all facets of their schooling.

Learners that are actively engaged in lessons will learn faster, retain the information better and have a more enjoyable classroom experience.

The national curriculum

The national curriculum is based on the democratic principles of an equal opportunity being offered to all. Namibia has a diverse population made up of people of many cultures and languages. They should all receive the same opportunities to learn, develop and prosper in life. The diversity in your class will mean that learners have different learning styles and paces of learning. You may also find that your learners come from very different backgrounds. These factors will affect your planning and lessons.

Your teaching challenges lie in your ability to become familiar with:

- issues in learner-centred education
- issues of inclusion in a diverse community
- issues of barriers to learning – their challenges and possible solutions
- managing large classes
- informal assessment as a positive part of the learning process
- providing or developing resources that meet the requirements of the curriculum.

A guide to the Physics syllabus

Every subject has its own curriculum and syllabus.

We have clearly described the competencies that the learners must achieve. All these skills begin with a verb, or doing word, such as use, make, draw and discuss.

The skills and requisite knowledge are given in the syllabus as well as in this Teacher's Guide. This enables you to check that you are covering the requirements of the subject.

Inclusive education

Physics lends itself to the extensive promotion of inclusion. You can use these opportunities to instil in all learners a sense of inclusivity and caring towards others, as well as to build the self-esteem of learners with special needs.

Your learners are all different. Learner-centred education meets the challenge of learning by respecting the individual learning needs and styles of every learner. For this model to work, create a positive learning environment that guides learners towards their own achievement and success, both in the classroom and in life. To ensure a match between your teaching style and the needs of the learners, focus your attention on the learners' experiences, backgrounds, interests, talents and capabilities. These will determine the way in which you present and explore content, and will have a direct impact on the likelihood of success.

Using previous knowledge and experiences

"A learner brings to the school a wealth of knowledge and social experience gained continually from the family, the community, and through interaction with the environment."

Your role is to create opportunities for successful learning by affirming what learners know, giving them opportunities to express themselves, and using their talents and strengths to direct and inform learning. More powerful learning is possible when learners can make connections with what they already know and when it builds on their interests. In this way, you can adapt and modify the curriculum to suit the needs of the learners rather than the learners adapting to the demands of the curriculum.

"Learning in school should thus involve, build on, extend and challenge the learners' prior knowledge and experiences."

Interactive learning

Not all learners learn in the same way. Experienced teachers know instinctively that the old-fashioned chalk-and-talk way benefits only a small number of learners. By using a variety of teaching methods and presentation modes, science teaching will remain fresh and exciting for both you and your learners. It will also accommodate different learning styles. Engage the learners in the learning process by allowing them to carry out investigations and practical tasks. This gives them confidence with elementary scientific equipment and valuable skills necessary for his grade. The conceptual framework in the Grade 12 curriculum is centred on the learners' abilities to follow instructions. The content is organised in the scientific manner. In the learner-centred classroom, you create the opportunities for learner–teacher and learner–learner interactive learning. In this type of classroom, the different approaches to learning become apparent and guide you to identify what learners need to know, the pace at which they can learn and the support each learner requires.

Observe, listen and watch the levels of interaction, then use your knowledge and skills to guide learners, and build their knowledge, skills, positive attitudes and self-esteem. The greater the learners' self-esteem, the more successful they will become in any situation.

Different types of learning

Give opportunities for different types of learning. For example, learners construct knowledge through hearing (talking through a problem to find a solution or different solutions), listening (moving to a rhythm, singing or making music), seeing (looking at or creating visuals) and touch (building or using tactile means to feel their way). Allow the descriptions given in the syllabus to guide you when choosing your method.

Be flexible enough to encourage learners to construct their own meaning and create their own learning. However, always remain the guide, using your year plan and lesson plans as maps with clear objectives, but with various ways of achieving them. Have a planned route that you navigate sensitively so that the learners reach their destinations successfully in their own ways.

Constantly make decisions about where to stop and what to experience (content/knowledge), visualise possibilities (methodology and lesson delivery), avoid or deal with misconceptions, and make decisions on how to achieve your goal.

Participation, contribution and production

Participation, contribution and production are key words in the learning process. When they are applied, learning becomes possible. These principles enable each learner to satisfy her or his needs based on prior experience, knowledge and skills, as well as set their pace for learning.

It is the right of every learner to participate in and have access to all the educational programmes of mainstream schools. Inclusive education supports diversity amongst all learners, where diversity is regarded as a strength rather than a setback. This means that we have to remove all barriers to learning. In any class, and especially in larger classes, you will deal with many different learners who come from a wide range of backgrounds and abilities. Understanding these learners and their needs enables you to include their needs in their education in a beneficial way.

Namibia is a democratic society. "Democratic" means that decisions are made taking into account each member's contribution. For learners to become well-functioning adults, they should be accepted for who and what they are at this stage of their lives. Their potential should be recognised and developed to the best of their abilities. Democracy also implies that people are individuals with their own strengths and weaknesses, which may be different to other people's strengths and weaknesses.

Classroom organisation

As learners will work alone, in pairs, in groups and as a class, it is useful to have a flexible approach to classroom organisation. Make sure you can move tables and chairs easily and quickly to accommodate various teaching and learning strategies.

Plan where to stand, sit and move. Your use of classroom space is part of your teaching strategy.

For some lessons, you might be upfront and clearly visible, while for other lessons, learners might take the lead and you will play a facilitative role in the background. When learners present or give feedback to the class, make sure they face the whole class, and can be seen and heard by all.

It is useful to have a small resource corner where learners can help themselves to items of reusable clean waste, such as used cardboard, tins and plastic bottles, for the various things they need to create. Have enough space in the class for learners to display their projects.

Group and pair the learners quickly and efficiently. While it is sometimes useful to allow learners to choose their own groups, at other times it is best to place them in groups to ensure inclusivity so they learn to work in a range of groups and no learners feel rejected. Quick and fun ways to group learners include the following:

- Cut strips of scrap paper into various shapes. Place these in a bag or basket and ask learners to pull out a shape without looking. Put all the learners who chose triangles in one group, and so on.
- Use scraps of coloured paper to group learners according to the colour they choose.
- Ask learners to form a line according to their birth dates. The first five learners in the line form a group, the next five learners form another group, and so on.

Managing your class to support inclusive education

This is putting learner-centred education into practise.

Small group work

The advantage of working with a small group of learners is that you can group learners with similar prior knowledge or skills who will benefit from this way of teaching. Separate them from the rest of the class for about 15 minutes at a time.

Organise the rest of the class in a structured way so they are positively occupied while you are busy with the group needing your attention. For example, learners could do something they have done before, but can now add new information they have recently learnt. Make sure your instructions are clear and easy to follow, giving you the time and opportunity to work closely with the small group.

Rotating group work

Rotate the types of group work so that learners are not labelled in any way.

- The group that knows more about a topic and can move forward quickly should be able to do so. This gives you the opportunity to attend to the group needing extra input.
- Create groups with different abilities and needs. Mix learners from previous groups so there is no stigma attached to working in a particular group. This technique requires you to know each learner's prior knowledge and skills for whatever they are learning. Informal assessment gives you this knowledge.

Learners guiding learners

Most of the teaching focus is on you as the source of knowledge and skills. Sometimes, learners can be the source of knowledge and skills. A learner who has a family member or close friend with a skill that relates to the content has a great deal to share with their classmates. This builds the learner's confidence and self-esteem, vocabulary, and speaking skills. Learners usually enjoy learning from their peers.

Handling barriers to learning

Include learners who have barriers to learning or other individual needs in mainstream schools. The education system addresses the needs of learners with barriers to learning by using different teaching methods and materials where needed.

Learning support units, resource units and resource schools provide for learners who are so severely impaired that they cannot benefit from attending inclusive schools. Once they are ready, they can join inclusive schools.

You might find barriers to learning that you cannot deal with in your class. It is important that you assess learners with barriers carefully, understanding their levels of capabilities and whether you can help them. If the learners need special education in smaller groups, you should recommend that. Remedial education specialists and psychologists will recommend the best approach to their education.

If you have learners with less severe barriers to learning in your class, it is better to extend their learning at a different pace so they can reach the same outcomes as other learners. Their sense of achievement encourages them to reach for further goals. You might have different groups of learners in your class working at different paces and with different learning methods; this makes your approach and positive attitude important.

General tips to assist learners with learning barriers

- Learners who have difficulty organising themselves can be paired with learners who are more organised. These organised learners can offer support by writing down homework and modeling how to complete work on time.
- Keep an ongoing list of new words and terms, which will help learners familiarise themselves with words often used in science education. They can use a picture to assist their recall, as well as a definition.
- Help learners plan their tasks by developing short mind-maps that guide the process and help them feel less overwhelmed. Break down tasks into small parts, which will help learners accomplish the task.
- Place learners who battle to concentrate at the front of the class. If you see their minds wandering, touch their arms gently as you walk around the class, or involve them in the class by asking them questions.
- It helps learners with learning barriers to have a daily structure that they trust and are familiar with. Always be organised and consistent.
- Remember to give instructions clearly and simply. As far as possible, involve the learners with practical, hands-on activities.

Achievements and the real world

Remember that school education should equip learners for life as adults. It must develop knowledge, skills and attitudes to help them succeed in the increasingly complex and rapidly changing world of information and communication technology. Use your learners' experience and prior knowledge to build new knowledge and skills.

Appreciation

We give you applause and accolades for teaching Physics at this level, and ensuring that your learners can reach their potential, ready for all possibilities and success! Your work is contributing to the development of our learners, our nation and our beautiful Namibia. Thank you for teaching Physics. We hope you and your learners enjoy the lessons.

Section B Planning and assessment

This year plan is based on approximately 28 weeks in the year before the final examination starts. Use 25 weeks for teaching to allow sufficient time for formal/summative assessment.

How to use a lesson plan

This Teacher's Guide provides lesson plans to suggest one possible way of teaching the content covered in the Learner's Book. The plans are developed to meet the requirements set out in the Senior Secondary syllabus for Physics. On the next page is a template you can use for planning your lessons, together with notes on how to complete each part. A blank template is provided in the resources section at the end of this Teacher's Guide, which you may photocopy. You may use this template to make your own notes for lessons that suit your classroom environment. To guide you in planning your lessons, each lesson plan includes a guideline for the amount of time that a lesson should take. These times serve only as guidelines and may vary depending on the strength of your class and your available resources.

Subject: Physics	
Links to cross-cutting issues	This shows the integration of Environmental Education; HIV and AIDS, Population Education, Education for Human Rights and Democracy (EHRD), Information and Communication Technology (ICT), Road Safety or Special Needs Education, where appropriate.
Topic and sub-topic	This is the topic within the given syllabus that is being covered, for example, "Measurement techniques". The sub-topic shows the sub-section of that topic, such as "Precise measurements".
Time for lesson	How many periods or minutes are needed to cover the content
Basic competencies	These come from the syllabus and set out the new skills and concepts* covered in a topic that learners must master. Check their prior knowledge** and ensure that your learners can accomplish these competencies before moving on to the next body of work. Revisit these when you have completed a lesson, and ensure learners understand the concepts and skills that were covered.
Preparation	• Preparation involves reading through the lesson plan provided in this Teacher's Guide. • Different lessons may call for different types of preparation such as field trips or grouping learners for activities.
Resources	• The Learner's Book will be your primary resource and the relevant pages are listed here for easy reference. • If any other resources or knowledgeable persons are needed for the lesson, they will be mentioned here.
Guidelines	Make notes about the structure of the lesson, any difficult concepts that might require additional teaching or explaining, and the keywords that will assist you while you teach.

*New concept/skill: This refers to the new information that learners will encounter and is linked to their prior knowledge.
**Prior knowledge: Explains what learners need to know so that they can understand what they will be learning about.

Lesson plan guidelines

It is best that you consult the lesson plans well before starting a lesson. This will help you prepare for the lessons because you may need time to obtain additional resources that will enrich the learning experience. The lesson plans provide ideas on how to teach a given topic, providing you with insights that will assist your approach to a lesson, specifically in terms of how the work is covered in the Learner's Book.

Year plan

This is a summary of the learning content for Physics Grade 12 and suggested year plan.

General objectives: The general objectives from the syllabus are listed at the start of each sub-topic in the Learner's Book and also at the start of each topic in the Teacher's Guide.

Topic, sub-topic and specific objectives	Lessons	LB Pages	TG pages
Theme 1: General physics	**90**	**2–135**	**19–55**
Topic 1.1: Physical quantities and units	9	4–23	19–24
Sub-topic 1.1.1: Physical quantities and units • Recall that all physical quantities consist of a numerical magnitude and a unit • Make reasonable estimates of physical quantities included within the syllabus		5–6	19
Sub-topic 1.1.2: SI units • Recall and use the following SI base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol) • Express derived units as products or quotients of the SI base units and use the named units listed in this syllabus as appropriate • Use SI base units to check the homogeneity of physical equations • Use the following prefixes and their symbols to indicate decimal submultiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)		7–15	20–22
Sub-topic 1.1.3: Scalars and vectors • Distinguish between scalar and vector quantities » A scalar as a quantity which has a magnitude, but no direction » A vector as a quantity which has both magnitude and direction • State examples of scalar (e.g. mass) and vector (e.g. velocity) quantities • Add and subtract coplanar vectors (vectors in the same plane) • Represent a vector as two perpendicular components		16–20	22–23
Topic 1.2: Measurement techniques	9	24–45	25–29
Sub-topic 1.2.1: Measurements • Use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus. In particular, learners should be able to: » measure lengths using rulers, callipers and micrometers » measure weight and hence mass using balances » measure an angle using a protractor » measure time intervals using clocks, stopwatches and the calibrated time-base of a cathode-ray oscilloscope (c.r.o.) » measure temperature using a thermometer » use ammeters and voltmeters with appropriate scales » use a galvanometer in null methods » use a cathode-ray oscilloscope (c.r.o.) » use both analogue scales and digital displays » use calibration curves		25–35	25–27

Sub-topic 1.2.2: Errors and uncertainties • Explain the effects of systematic errors (including zero errors) and random errors in measurements • Distinguish between precision and accuracy » Precise measurements are all close to one another » An accurate measurement is close to the true value • Assess the uncertainty in a derived quantity by simple addition of absolute, fractional or percentage uncertainties (a rigorous statistical treatment is not required)		36–41	27–28
Topic 1.3: Kinematics	15	46–65	30–34
Sub-topic 1.3.1: Equations of motion • Define and use distance, displacement, speed, velocity and acceleration » Distance as a measure of how far an object travels along a particular path (without considering direction) » Displacement as a vector which has a magnitude equal to the shortest distance between the initial and final points and a direction from the initial to the final point » Speed as a rate of change of distance » Instantaneous velocity as a “rate of change of displacement” or speed in a given direction » Average velocity as the total displacement divided by the time taken » Acceleration as the rate of change of velocity • Use graphical methods to represent distance, displacement, speed, velocity and acceleration • Determine displacement from the area under a velocity–time graph • Determine velocity using the gradient of a displacement–time graph • Determine acceleration using the gradient of a velocity–time graph • Recall and use the equations of motion $v = u + \Delta t$; $a = \frac{v - u}{\Delta t}$; $s = \frac{v + u}{2 \times \Delta t}$ • Derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line • Solve problems using equations that represent uniformly accelerated (constant acceleration) motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance • Describe an experiment to determine the acceleration of free fall using a falling body • Describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction		47–62	30–34
Topic 1.4: Dynamics	18	66–85	35–40
Sub-topic: 1.4.1: Momentum and Newton’s laws of motion • State that mass is the property of a body that resists change in motion • Recall the relationship $F = ma$ and solve problems using it, appreciating that acceleration and resultant force are always in the same direction • Define and use linear momentum as the product of mass and velocity (recall $p = mv$) • Define and use force as rate of change of momentum • State and apply each of Newton’s laws of motion: » Newton’s first law (the law of inertia): an object at rest continues in a state of rest or if moving continues moving with constant velocity unless it is acted on by a resultant force » Newton’s second law: the resultant force exerted on a body is directly proportional to the rate of change of linear momentum of that body; and recall use $\Delta F = \frac{\Delta p}{\Delta t}$		67–74	35–37

» Newton's third law: when two bodies interact, they exert forces on each other, these forces have the same magnitude but are in opposite directions			
Sub-topic 1.4.2: Non-uniform motion • Describe and use the concept of weight as the effect of a gravitational field on a mass and recall that the weight of a body is equal to the product of its mass and the acceleration of free fall • Describe and explain qualitatively the motion of bodies falling in a uniform gravitational field with air resistance (including reference to terminal velocity) • Recall that acceleration is constant even when the motion is non-uniform		75–76	37–38
Sub-topic 1.4.3: Linear momentum and its conservation • Define impulse as $F\Delta t$ • Relate impulse to change in momentum ($F\Delta t = \Delta p$) • Use the relationship between impulse and change in momentum to calculate the force exerted, time for which the force is applied and change in momentum for a variety of situations involving the motion of an object in one dimension • Apply the concept of impulse to safety considerations in everyday life, e.g. airbags, seatbelts and arrestor beds • State the principle of conservation of momentum, that when bodies in a system interact, the total momentum remains constant (momentum is always conserved) provided that no external force acts on the system • Apply the principle of conservation of momentum to solve simple problems, including elastic and inelastic interactions between bodies in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required) » In elastic interactions, kinetic energy is conserved » In inelastic interactions, kinetic energy is not conserved • Recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation • Explain that, while momentum of a system is always conserved in interactions between bodies, some change in kinetic energy may take place		77–81	38–39
Topic 1.5: Forces, density and pressure	12	86–102	41–46
Sub-topic 1.5.1: Types of forces • Describe the force on a mass in a uniform gravitational field and on a charge in a uniform electric field • Explain the origin of the up-thrust acting on a body in a fluid (due to the difference in hydrostatic pressure) • Explain frictional forces and viscous forces including air resistance (no treatment of the coefficients of friction and viscosity is required) • Apply the concept that the weight of a body may be taken as acting at a single point known as its centre of gravity		87–88	42
Sub-topic 1.5.2: Turning effects of forces • Define moment as the product of force and perpendicular distance through the line of action from the pivot • Apply the moment of a force to everyday examples such as crowbar, wheelbarrow, pliers, scissors, tweezers or tongs • State that a couple is a pair of (equal but opposite) forces (acting along parallel but different lines) that tends to produce rotation only • Define and apply the torque of a couple (torque as the product of the magnitude of one of the forces and the distance of separation)		89–91	42–43

Sub-topic 1.5.3: Equilibrium of forces • State and apply the principle of moments • Recall and apply the principle that, when there is no resultant force and no resultant torque, a system is in equilibrium • Use a vector triangle to represent three coplanar forces in equilibrium		92–95	43–44
Sub-topic 1.5.4: Density and pressure • Define and use density (density as the mass per unit volume) • Define and use pressure (pressure as the perpendicular force per unit area) • Derive, from the definitions of pressure and density, the equation $\Delta p = \rho g \Delta h$ • Use the equation for hydrostatic pressure $\Delta p = \rho g \Delta h$		96–99	44–45
Topic 1.6: Work, energy and power	12	103–118	47–51
Sub-topic 1.6.1: Energy conversion and conservation • Give examples of energy in different forms, its conversion and conservation, and apply the principle of conservation of energy to simple examples (e.g. the kinetic energy changing to potential energy in a pendulum and the sum of the two is constant if air resistance is negligible)		104–106	47–48
Sub-topic 1.6.2: Work and efficiency • Explain the concept of work in terms of the product of a force and displacement in the direction of the force • Calculate the work done in a number of situations including the work done by a gas that is expanding against a constant external pressure: $W = p\Delta V$ • Recall and apply that the efficiency of a system is the ratio (which can be expressed as percentage) of useful energy output from the system to the total energy input • Discuss the implications of energy losses in practical devices and use the concept of efficiency to solve problems		107–109	48–49
Sub-topic 1.6.3: Potential energy and kinetic energy • Derive, from the equations of motion, the formula for kinetic energy $E_k = \frac{1}{2}mv^2$ • Recal and apply the formula $E_k = \frac{1}{2}mv^2$ • Distinguish between gravitational potential energy and elastic potential energy » Gravitational potential energy as energy of a mass due to its position in a gravitational field » Elastic potential energy as energy stored in an object as a result of reversible (elastic) deformation • Apply the relationship between force and potential energy in a uniform field to solve problems • Derive, from the defining equation $W = Fs$, the formula $\Delta E_p = mg\Delta h$ for gravitational potential energy changes near the Earth's surface • Recall and use the formula $\Delta E_p = mg\Delta h$ for gravitational potential energy changes near the Earth's surface		110–113	49–50
Sub-topic 1.6.4: Power • Define power as work done per unit time • Derive power as the product of force and velocity • Recall and use the relationships $P = \frac{W}{\Delta t}$ and $P = Fv$		114	50

Topic 1.7: Deformation of solids	15	119–135	52–55
Sub-topic 1.7.1: Stress and strain • Outline that deformation is caused by a force and that, in one dimension, the deformation can be tensile or compressive • Use the terms load, extension and compression • Explain and use the terms limit of proportionality, elastic limit, yield point and the spring constant (i.e. force per unit extension) • Obtain and draw force–extension, force–compression, and tensile/compressive stress–strain graphs • Recall and use Hooke's law ($F = kx$) • Define and use the terms stress, strain and the Young modulus: » Stress as the force per unit area of a material » Strain as extension per unit length » Young's modulus as the ratio of stress to strain • Describe an experiment to determine the Young modulus of a metal in the form of a wire		120–127	52–53
Sub-topic 1.7.2: Elastic and plastic behaviour • Distinguish between elastic and plastic deformation of a material » Elastic deformation being reversible when the stress is removed » Plastic deformation being permanent as a result of dislocations • Relate the area under the force-extension graph to the work done (the area under the force–extension graph = work done) • Determine the elastic potential (strain) energy in a deformed material from the area under the force-extension graph • Recall and use $E_p = \frac{1}{2}Fx = \frac{1}{2}kx^2$ for a material deformed within its limit of proportionality		128–132	54
Theme 2: Waves	**28**	**136–203**	**56–73**
Topic 2.1: Progressive waves	4	138–149	56–58
Sub-topic 2.1.1 Understand progressive waves • Describe what is meant by wave motion (propagation), an oscillation which transfers energy from one place to another without any net movement of the medium, as illustrated by vibration in ropes, springs and by experiments using water waves • Describe and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed • Derive, from the definitions of speed, frequency and wavelength, the wave equation $v = f\lambda$ • Recall and use the equations $v = f\lambda$ and $f = \frac{1}{T}$ • Describe that energy is transferred by a progressive wave • Recall and use the relationship intensity = $\frac{\text{power}}{\text{area}}$ and intensity $\propto$ (amplitude)^2		139–149	56–58
Topic 2.2: Transverse and longitudinal waves	4	150–157	59–60
Sub-topic 2.2.1 The difference between transverse and longitudinal waves • Compare transverse and longitudinal waves » For a transverse wave, the oscillations are perpendicular to the direction of travel of the energy of the wave » For a longitudinal wave, the oscillations are parallel to the direction of travel of the energy of the wave • Analyse and interpret graphical representations of transverse and longitudinal waves		151–157	59–60

Topic 2.3: Determination of frequency and wavelength of sound waves	4	158–167	61–63
Sub-topic 2.3.1 Determine frequency and wavelength of sound waves • Determine the frequency of sound using a calibrated cathode-ray or PC oscilloscope • Determine the wavelength of sound using stationary waves (e.g. use of sonometer, resonance tubes, tuning forks)		159–167	61–63
Topic 2.4: Doppler effect	3	168–176	64–66
Sub-topic 2.4.1 The Doppler effect • Explain that when a source (of waves) moves relative to a stationary observer, there is a change in observed frequency • Use the expression $f_o = \frac{f_s v}{(v \pm v_s)}$ for the observed frequency when a source of sound waves moves relative to a stationary observer • Explain that Doppler shift is observed with all waves, including sound and light		169–176	64–65
Topic 2.5: Electromagnetic spectrum	3	177–185	67–68
Sub-topic 2.5.1 The electromagnetic spectrum • State that all electromagnetic waves are transverse waves that travel with the same speed in free space • Recall the orders of magnitude of the wavelengths of the principal regions of the electromagnetic spectrum from radio waves to gamma rays		178–185	67–68
Topic 2.6: Superposition	10	186–203	69–73
Sub-topic 2.6.1: Stationary waves • Explain and use the principle of superposition in simple application • Describe experiments that demonstrate stationary waves using microwaves, stretched strings and air columns • Explain the formation of a stationary wave using a graphical method and identify nodes and antinodes		187–191	69–71
Sub-topic 2.6.2: Diffraction • Explain the meaning of the term diffraction • Describe experiments that demonstrate diffraction, including the qualitative effect of the gap width relative to the wavelength of the wave, for example diffraction of water waves in a ripple tank		192–193	71
Sub-topic 2.6.3: Interference and two-source interference • Define the terms interference and coherence » Coherence: when two waves both have the same frequency (and wavelength) and a constant phase difference » Interference: when two or more waves overlap/superpose, the resultant displacement is the sum of the displacements of each wave • Describe experiments that demonstrate two-source interference using water ripples, light (monochromatic light source e.g. laser) and microwaves • Discuss the conditions required if two-source interference fringes are to be observed • Recall and solve problems using the equation $\lambda = \frac{ax}{D}$ for double-slit interference using light		194–198	71–72

Sub-topic 2.6.4: Diffraction gratings • Recall and solve problems using the formula $d\sin\theta = n\lambda$ • Describe the use of a diffraction grating to determine the wavelength of light (the structure and use of the spectrometer are not included)		199–200	72
Theme 3: Electricity	29	**204–245**	**74–86**
Topic 3.1: Electric fields	5	206–214	74–77
Sub-topic 3.1.1: Concept of an electric field • Define and use electric field strength as force per unit positive charge (point charge) $\left(E = \frac{F}{Q}\right)$ • Explain the concept of an electric field as an example of a field of force (a region in which an electric charge experiences a force due to another charge) • Represent an electric field by means of field lines		207–209	74–75
Sub-topic 3.1.2: Uniform electric fields • Recall and use $E = \frac{\Delta V}{\Delta d}$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation • Calculate the forces on charges in uniform electric fields • Describe the effect of a uniform electric field on the motion of charged particles		210–212	75–76
Topic 3.2: Current electricity	15	215–229	78–82
Sub-topic 3.2.1: Electric current • Explain that electric current is a flow of charge carriers • Recall that the charge on charge carriers is quantised • Define the coulomb as the SI unit of electric charge, equal to the quantity of charge conveyed in one second by a current of one ampere • Recall and use $Q = I\Delta t$ • Derive and use, for a current-carrying conductor, the expression $I = Anvq$, where A is the cross sectional area, n is the number density of charge carriers (number of electrons per unit volume), v is drift velocity and q is the charge carried by the individual charge carrier		216–217	78–79
Sub-topic 3.2.2: Potential difference and power • Define potential difference and the volt • Potential difference (p.d) (V) as energy transferred (work done) per unit charge • The volt (the SI unit for of both potential difference and electromotive force) as the ratio of joule to coulomb • Recall and use $V = \frac{W}{Q}$ • Recall and use $P = VI$, $P = \frac{V^2}{R}$ and $P = I^2R$		218–219	79–80
Sub-topic 3.2.3: Resistance and resistivity • Define resistance of a conductor as the ratio of the potential difference across it to the current through it • Define the ohm (the SI unit for of electrical resistance) as the ratio of volt to ampere, transmitting a current of one ampere when subjected to a potential difference of one volt • Recall and use $V = IR$ • Sketch and discuss the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp • Explain that the resistance of a filament lamp increases as current increases because its temperature increases		220–226	80–81

• Explain that the resistance of a light-dependent resistor (LDR) decreases as the light intensity increases • Explain that the resistance of a thermistor decreases as temperature increases (negative temperature coefficient [NTC] thermistor only) • State and use Ohm's law • Define resistivity of a material as a product of the resistance and cross-sectional area per length of the specimen • Recall and use $\rho = \frac{RA}{l}$, where R is the resistance, ρ is the resistivity of the material, l is the length of the conductor and A is the cross-sectional area			
Topic 3.3: DC circuits	9	230–245	83–86
Sub-topic 3.3.1: Practical circuits • Recall and use appropriate circuit symbols • Draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus • Define electromotive force (e.m.f.) of a source as energy transferred per unit charge in driving charge round a complete circuit • Distinguish between e.m.f. and potential difference • Discuss the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power • Recall and use the equation $V = E - Ir$, where V is the p.d., E is the e.m.f, I is the current and r is the internal resistance		231–233	83–84
Sub-topic 3.3.2: Kirchhoff's laws • Recall Kirchhoff's first law and appreciate the link to conservation of charge • Recall Kirchhoff's second law and appreciate the link to conservation of energy • Derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series • Solve problems using the formula for the combined resistance of two or more resistors in series • Derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel • Solve problems using the formula for the combined resistance of two or more resistors in parallel • Apply Kirchhoff's laws to solve simple circuit problems		234–237	84–85
Sub-topic 3.3.3: Potential dividers • Explain the principle of a potential divider circuit as a source of variable p.d • Recall and use $V_{out} = V_{in}\frac{R_2}{(R_1 + R_2)}$ • Solve problems using the principle of the potentiometer as a means of comparing potential differences • Explain the use of thermistors (negative temperature coefficient [NTC] thermistors only), light-dependent resistors (LDR) in potential dividers to provide a potential difference that is dependent on the temperature and illumination respectively		238–241	85–86

Theme 4: Modern physics	9	**246–266**	**87–91**
Topic 4.1: Atoms, nuclei and radiation	5	248–260	87–89
Sub-topic 4.1.1 Atoms, nuclei and radiation • Describe and explain the simple structure of the nucleus • Recall that radioactive decay is the random and spontaneous emission of particles and/or electromagnetic radiation from an unstable nucleus • Recall the nature and properties of α, β and γ radiations (both β^- and β^+ are included) • Distinguish between proton number and nucleon number (mass number) and proton number (atomic number) and use standard nuclide notation ($_{AZ}X$) » Proton number (atomic number), denoted by Z » Nucleon number (mass number), denoted by A • State that an element can exist in various isotopic forms each with a different number of neutrons • Describe and explain the transformation of nuclei when they emit radiation • Appreciate that nucleon number, proton number and energy are all conserved in nuclear processes • Represent simple alpha and beta decay by equations of the form $^{234}_{92}U \rightarrow ^{230}_{90}Th + ^{4}_{2}\alpha$ $^{214}_{82}Pb \rightarrow ^{214}_{83}Bi + ^{0}_{-1}\beta$ • Deduce the mass number and proton number of the daughter and granddaughter products in a decay series • Recall that during beta decay that beta particles are emitted with a range of kinetic energies • Recognise the effects of a uniform electric field on the path of alpha and beta particles and gamma rays • Calculate the force on alpha and beta particles when passing through a uniform electric field $\left(\text{e.g using } F = EQ;\ E = \frac{\Delta V}{\Delta d}\right)$ • Use the unified atomic mass unit and/or the mass of an electron in calculations involving forces on alpha and beta particles (e.g. using $F = ma$ and equations of motion) • Deduce from the results of the α-particle scattering experiment the existence and small size of the nucleus • State that (electron) antineutrinos and (electron) neutrinos are produced during β^- and β^+ decay		249–260	87–89
Topic 4.2: Fundamental particles	4	261–266	90–91
Sub-topic 4.2.1 Fundamental particles • Appreciate that protons and neutrons are not fundamental particles since they consist of quarks • Describe a simple quark model of hadrons in terms of up, down and strange quarks and their respective antiquarks • Describe protons and neutrons in terms of a simple quark model • Appreciate that there is a weak interaction between quarks, giving rise to β decay • Describe β^- and β^+ decay in terms of a simple quark model • Appreciate that electrons and neutrinos are leptons		262–266	90–91

Assessment

The assessment will include, wherever appropriate, personal, social, environmental, economic and technological applications of Physics in modern society. Learners are required to demonstrate the assessment objectives in the context of the content and skills prescribed. Within each of the assessment objectives, the assessment must take account of the learners' ability to communicate clearly and logically, and apply conventions where appropriate.

The three assessment objectives in Physics are:

- A: Knowledge with understanding
- B: Handling information, application and solving problems
- C: Practical (experimental and investigative) skills and abilities

A. Knowledge with understanding

Learners should be able to demonstrate knowledge and understanding in relation to:

- A1: scientific phenomena, facts, laws, definitions, concepts and theories
- A2: scientific vocabulary, terminology and conventions, (including symbols, quantities, units)
- A3: scientific instruments and apparatus, including techniques of operation and aspects of safety
- A4: scientific quantities and their determination
- A5: scientific and technological applications with their social, economic and environmental implications.

The learning content defines what learners may be required to recall and explain. Questions testing assessment objectives will often begin with one of the following words: define, name, list, indicate, give examples, state, describe, compare, explain, distinguish, outline and give reasons.

B. Handling information, application and solving problems

Learners should be able to, in words or using other written forms of presentation (i.e. symbolic, graphical and numerical):

- B1: locate, select, organise and present information from a variety of sources
- B2: handle information, distinguishing the relevant from the extraneous
- B3: manipulate numerical and other data, and translate information from one form to another
- B4: analyse and evaluate information so as to identify patterns, report trends and draw inferences
- B5: construct arguments to support hypotheses or justify a course of action
- B6: evaluate information and hypotheses
- B7: apply knowledge, including principles, to new situations
- B8: reasoned explanations of phenomena, patterns and relationships.

C. Practical (experimental and investigative) skills and abilities

Learners should be able to:

- C1: collect, record and present observations, measurements and estimates
- C2: analyse and interpret data to reach conclusions
- C3: evaluate methods and quality of data to reach conclusions.

These skills cannot be precisely specified in the learning content because questions testing such skills are often based on information that is unfamiliar to the learner. In answering such questions, learners are required to use principles and concepts that are within the syllabus and apply them in a logical, deductive manner to a novel situation.

Scheme of assessment

At the end of Grade 12, the learners will write an external examination consisting of three papers.

- Paper 1: multiple-choice questions
- Paper 2: structured questions
- Paper 3: advanced practical skills

All learners should be entered for Papers 1, 2 and 3, which are compulsory papers.

	Description of paper	Time allocated	Total number of marks
Paper 1: Multiple choice questions (theory)	This paper consists of 40 multiple-choice items of the four-choice type. The questions will be based on the content described as specific objectives and will test abilities in assessment objectives A and B.	1 hour 15 minutes	40
Paper 2: Structured questions (theory)	This paper will consist of compulsory short-answer, structured and free-response questions. The questions will test skills and abilities in assessment objectives A and B. Learners will answer all questions on the question paper.	1 hour 15 minutes	60
Paper 3: Advanced practical skills	This paper requires learners to carry out practical work in timed conditions. Learners will be expected to collect, record and analyse data so that they can answer questions related to the activity. The paper will consist of two experiments drawn from different areas of Physics. Learners will answer all questions. Learners will answer on the question paper.	2 hours	40
			Total: 140

Learners will be graded from A–E depending on their abilities and achievement. Each paper is weighted differently.

- Paper 1: 31%
- Paper 2: 46%
- Paper 3: 23%

The assessment objectives are covered across the three papers. The grid below shows the approximate weightings of the three objectives per paper and the marks allocated to each.

	Weighting across all components	Marks in Paper 1	Marks in Paper 2	Marks in Paper 3
A: Knowledge with understanding	38.5% (not more than 20% recall)	20	30	0
B: Handling information, application and solving problems	38.5%	20	30	0
C: Practical (experimental and investigative skills and abilities)	23.0%	0	0	40
		40	**60**	**40**

Grade descriptions

The scheme of assessment is intended to encourage positive achievement by all learners. Grade descriptions are therefore provided for judgmental Grades A, C and E to give a general indication of the standards of achievement likely to have been shown by learners awarded particular grades. The description must be interpreted in relation to the content specified by the Physics syllabus, but is not designed to define that content. The grade awarded will depend in practise upon the extent to which the learner has met the assessment objective overall. Shortcomings in some aspects of the assessment may be balanced by better performance in others. Grade descriptions for science subjects will range from A to E.

At Grade A, the learner is expected to:

- show mastery of curriculum content
- demonstrate the ability to interpret relatively complex data with precision
- demonstrate the ability to discuss Physics topics with depth and breadth of understanding, bringing together ideas from various areas of the curriculum and from the learner's own experience
- communicate with clarity, by means of words, diagrams and other forms of presentation
- link his or her theoretical and practical studies in Physics with applications relating to society and to the environment
- show clear understanding of the scientific method, and be able to design, carry out and evaluate experiments with confidence and competence.

At Grade C, the learner is expected to:

- show reasonable competence of curriculum content
- demonstrate the ability to interpret relatively simple data with precision
- demonstrate the ability to discuss Physics topics with some success at bringing together ideas from different areas of the curriculum and the learner's experience
- communicate effectively, by words, diagrams and other forms of presentation
- show some ability to link his or her Physics studies with applications relating to society and the environment
- show reasonable understanding of the scientific method and be able to design, carry out and evaluate experiments with reasonable confidence and competence.

At Grade E, the learner is expected to:

- show a limited range of competence of curriculum content
- demonstrate the ability to interpret simple data with reasonable precision
- demonstrate some ability to discuss Physics topics
- communicate effectively, by words, diagrams and other forms of presentation
- show some ability to link his or her Physics studies with applications relating to society and the environment
- show reasonable understanding of the scientific method, and be able to design, carry out and evaluate simple experiments with some confidence and competence.

Informal assessment

It is important that the assessment objectives are tested throughout the year. Assessment, both formal and informal (diagnostic) should form part of your lesson plan. Each topic in the Learner's Book includes two different forms of assessment: informal assessment and self-assessment.

Informal (diagnostic) assessment

Informal assessment is used as a form of diagnostic assessment. The Teacher's Guide outlines which activities in the Learner's Book lend themselves to informal assessment. Diagnostic assessment is essential as it helps you identify any areas of weakness and allows you to gauge the learners' understanding and where additional help or practise is required.

Self-assessment

There is a self-assessment task at the end of each topic. These self-assessment questions give learners the opportunity to work independently and practise the type of questions that appear in the examination. Each question is allocated a specific number of marks and includes an abbreviation that relates to the type of cognitive skills required in answering the question. These skills are listed according to Bloom's taxonomy as seen in the table below.

Level	Bloom's category	Abbr.	Example verbs to use in questions
1	Knowledge	K	List, describe, write, state, name
2	Understanding (of content)	U	Explain, interpret, discuss, outline, compare, describe
3	Application	Ap	Solve, show, use, examine, classify
4	Analysis	An	Analyse, examine, investigate, contrast, identify, explain
5	Synthesis	S	Create, predict, plan, construct, formulate, propose
6	Evaluation	E	Judge, select, choose, discuss, verify

Section C Teaching guidelines

Theme 1 General Physics

TOPIC 1.1 Physical quantities and units

LB pages 4–23

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Show understanding of physical quantities included within the syllabus • Know the SI units for various physical quantities included within the syllabus • Know scalar and vector quantities including calculations and representations
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology (role of ICT in Science)
Inclusive education	Visually impaired learners need assistance when taking measurements. Ensure that they are paired with a learner that can work with very small measurements. Enlarge diagrams where possible and always provide enlarged graph paper for the learners to plot their graphs on.
Suggested teaching time	9 lessons
Additional resources needed	Graph paper, calculator, ruler, protractor

Introduction to this topic

Mathematics and Science are decidedly linked. In this topic, we will explore physical quantities and their units. This will require learners to use scientific notation.

Start the topic by revising how to use scientific notation on the calculator. Ensure all learners are comfortable with using their calculator.

Pair learners and start a competition. Ask learners to perform a number of mathematical functions. The pair that completes the functions the quickest is the winner.

Starter activity

(LB page 4)

This activity checks that the learners have a good grasp of the work taught in Grades 10 and 11. It acts as a form of diagnostic assessment and allows you to gauge the level of the learners in the class. It also helps you identify the learners that might struggle with future topics. Use this activity to explain the difference between °C and K.

Suggested answers

1.

Physical quantity	SI unit
Distance	m
Temperature	K
Weight	N
Potential difference	V
Frequency	Hz

2.

Symbol on diagram	Quantity	SI Unit
V (voltmeter)	potential difference	V (volt)
R (resistor)	resistance	Ω (ohm)
A (ammeter)	current	A (ampere)

Sub-topic 1.1.1: Physical quantities and units LB pages 5–6

Beginning these lessons

Physical quantities is a foundation topic. It is essential that learners have a good grasp of the topic to succeed in future topics.

Symbols are used in equations and formulae to represent physical quantities.

Start the lesson by introducing apparatus to the class and asking what the items are used to measure. Examples include a protractor, a balance, a ruler and a measuring cylinder. Ask learners to list the quantity being measured and the SI unit that the quantity is measured in.

Physical quantities (LB pages 5–6)

Teaching guidelines

Science is largely based on experimentation and observation. Estimation is a useful skill for learners to have. Use items around the classroom and ask the learners to estimate their mass or thickness. Try to keep the lessons fun and engaging by using different apparatus as much as possible.

Homework

Learners can complete Activity 1 at home if they do not finish it in class. Use this as an opportunity to teach the learners how to tabulate correctly. Focus on using appropriate headings and including the correct SI units.

Suggested answers

Activity 1: Identify physical quantities (LB page 6)

Quantity	Symbol	SI unit
Mass	m	kg
Distance	s	m
Velocity	v	$m{\cdot}s^{-1}$
Force	F	N

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects.

Go through the answers to Activity 1 with the learners in the next lesson. Learners can mark their own work. You may record their marks for informal assessment purposes.

Estimation (LB page 6)

Teaching guidelines

Estimating is a very necessary skill for a physicist to have. The ability to estimate will prepare learners for the practical examination that they will write at the end of Grade 12. Emphasise that estimation is not a guess, but rather a conclusion drawn from prior experience.

One way to introduce the concept of estimation is to fill a jar with sweets and ask the learners to estimate the number of sweets in the jar. The learner with the closest answer gets to keep the jar of sweets.

As a class, discuss the methods that the learners used to estimate the number of sweets in the jar.

Suggested answers

Experiment 1: Estimate and measure area (LB page 6)

This experiment gives learners the opportunity to practise their estimating skills. Allow the learners to work in groups and encourage them to use a variety of methods to estimate the values.

One method of measuring the area of the shoe involves comparing the size of their shoe with the length and width of the table. If they know the value of one, they can estimate the value of the other.

They could also draw around the shoe on graph paper and count the squares enclosed within the shoe. This will not give accurate results because some squares will not be completely within the outline of the shoe.

Question 6 asks learners to use the area of their desks to estimate the area of the classroom. The answers will vary depending on the size of the classroom. Ensure learners use the formula area = length × breadth to accurately calculate the area and that they have used the correct units: m^2.

Sub-topic 1.1.2: SI units LB pages 7–15

Beginning these lessons

It is important that as teachers we try to keep this section as fun and engaging as possible. Allow the learners 15 minutes in class to memorise Table 1.1.1 on page 7 of the Learner's Book. The learners must then close their books and try to recreate the table. The group that completes the table the quickest are the winners.

Base units and derived units

(LB pages 7–10)

Teaching guidelines

It is important that learners can distinguish between base units and derived units. Use the worked example on page 8 of the Learner's Book to guide the class on how to approach deriving units. Work step by step and allow the learners to practise examples in class.

Homework

Learners can copy Table 1.1.1 into their books for homework. Ensure that learners use superscripts when writing the exponents. Learners need to memorise which unit is used for which quantity.

Suggested answers

Activity 2: Derive units (LB page 9)

1. Learners will first have to rearrange the equation to make potential difference the subject:
   $V = \frac{P}{I}$
   The base units for power are $kg{\cdot}m^2{\cdot}s^{-3}$.
   The base unit for current is ampere (A).
   Since $V = \frac{P}{I}$, we can write the units for potential difference as $kg{\cdot}m^2{\cdot}s^{-3}{\cdot}A^{-1}$.
2. $R = \frac{V}{I}$
   Since V has the base units of $kg{\cdot}m^2{\cdot}s^{-3}{\cdot}A^{-1}$ and I is measured in A. We can write the units for R as:
   $\frac{kg{\cdot}m^2{\cdot}s^{-3}{\cdot}A^{-1}}{A}$
   $A = kg{\cdot}m^2{\cdot}s^{-3}{\cdot}A^{-2}$

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Go through the answers to Activity 2 with the learners in the next lesson. Learners can mark their own work. You may record their marks for informal assessment.

SI units and prefixes (LB pages 10–12)

Teaching guidelines

This topic relies on the learners' ability to memorise information. It is important that learners are familiar with the prefixes used in order to apply them to other topics. Learners should copy Table 1.1.3 into their books. Give them a few minutes to memorise the prefixes and their meanings. After a sufficient period of time, quiz the learners on what they remember.

Suggested answers

Activity 3: Identify derived units (LB page 11)

1. C
2. C
3. A
4. a) Nano
   b) M
   c) 10^{12}
   d) Micro
5. $a = \frac{\Delta v}{\Delta t} \frac{m{\cdot}s^{-1}}{s} = m{\cdot}s^{-2}$
6. $E_k = \frac{1}{2}mv^2$
   The base units are as follows:
   Mass = kg
   Velocity = $m{\cdot}s^{-1}$
   In this equation, the velocity is squared, so the base units for $v^2 = m^2{\cdot}s^{-2}$.
   If we make the two equations homogenous:
   $J = kg{\cdot}m^2{\cdot}s^{-2}$.

Recording data in tables and graphs (Revision) (LB pages 12–15)

Teaching guidelines

Tables and graphs are used extensively during practical work. It is essential that you give learners sufficient time to develop this skill. There are a number of rules that must be followed when drawing a table or graph.

Start the lesson by listing the rules and ensuring that all learners write them down in their books. Use the diagrams on page 13 of the Learner's Book to demonstrate what a good table and graph should look like. Compare these examples with poorly drawn graphs and tables.

Suggested answers

Activity 4: Draw a table and a graph

(LB page 15)

1.

Experiment	Current (mA)	Potential difference (V)
1	19.5	1.10
2	36.9	2.00
3	52.2	2.90
4	70.4	3.90
5	92.2	5.10

2. The graph should be a straight line sloping up to the right.
3. Current and potential difference are directly proportional.

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Learners can complete Activity 4 at home, which you can then mark in the next lesson. You can use these marks as a form of diagnostic assessment. This section is such an integral part of the scientific process that it is essential that all learners have these skills. The table and graph can be marked as follows:

- Headings and units provided ✓✓
- Values to the same number of significant figures ✓
- All values correctly recorded under the correct column ✓
- Correct scale used ✓
- Axes correctly labelled with units ✓✓
- Line of best fit drawn ✓✓
- Appropriate conclusion drawn ✓

Sub-topic 1.1.3: Scalars and vectors

LB pages 16–20

Beginning these lessons

Scalars and vectors were introduced in Grades 10 and 11. Introduce this sub-topic by listing a number of quantities, for example, time, velocity, speed, distance, force and energy, and ask the learners to group the quantities according to whether they are vectors and scalars.

Revise the definition of both terms and ensure that learners understand what is meant by the term "magnitude".

Scalar and vector quantities

(LB pages 16–17)

Teaching guidelines

Ensure that learners understand the implications of a quantity being a vector. This is a foundational concept and learners will really struggle with equations and graphs of motion if they cannot correctly identify vector quantities. Ask learners to copy into their books the table on page 16 of the Learner's Book listing the scalar and vector quantities for easy reference.

Adding vectors

(LB pages 17–20)

Teaching guidelines

This topic links with Mathematics. Learners need a strong foundation in trigonometry. Start the lesson by revising right-angled triangles and explaining what is meant by the terms opposite, adjacent and hypotenuse.

Use the diagram on page 18 of the Learner's Book showing a right-angled triangle as a reference.

This section requires lots of practise. Work through the worked example in class, but allow the learners to complete the activities independently.

Suggested answers

Activity 5: Use vectors (LB page 18)

1. **a)** 10 N to the right
   b) 1 N to the right

2. The x-component acts along the horizontal plane.
$F_x = F\cos\theta$
$F_x = 22\cos 28° = 19.42$ N
The y-component acts along the vertical plane.
$F_y = F\sin\theta$
$F_y = 22\sin 28° = 10.33$ N

Activity 6: Work with scalars and vectors (LB page 19)

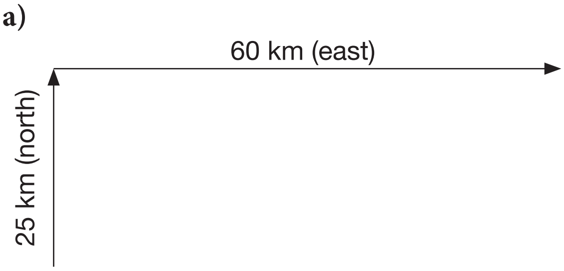
1. a) A scalar quantity has magnitude only, while a vector quantity has both magnitude and direction.
b) Any suitable example. Scalar quantity: time, distance, energy, speed; vector quantity: velocity, displacement, force, acceleration

2. a)

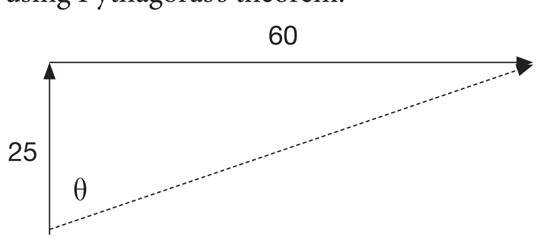
b) 10 N to the right

3. $F_x = F\cos\theta$
$F_x = 10\cos 30° = 8.66$ N
$F_y = F\sin\theta$
$F_y = 10\sin 30° = 5$ N

4. a)



b) total distance = 25 km + 60 km = 85 km (Distance is scalar, so direction does not need to be taken into account.)
c) The resultant displacement can be found using Pythagoras's theorem.



$c^2 = a^2 + b^2$
$c^2 = 25^2 + 60^2$
$c = \sqrt{4\,225}$
$c = 65$ km
$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$
$\theta = \tan^{-1}\frac{60}{25}$
$\theta = 67.38°$ The resultant displacement is 65km at 67.38° measured clockwise from north.

Activity 7: Research how scalars and vectors are used in real life (LB page 20)

Use the poster rubric on page 95 to assess the learners' reports.

Remedial activity

Many learners struggle to resolve a vector into its components. Write the following examples on the board and allow the learners to answer these questions for additional practice.

Find the x- and y-components of the following vectors:

1. A force of 18 N acting at an angle of 60° to the horizontal
2. A displacement of 12 km at an angle of 45°
3. A velocity of 23 $m{\cdot}s^{-1}$ at an angle of 37°

Suggested answers

1. $F_x = F\cos\theta$
$F_x = 18\cos 60° = 9$ N
$F_y = F\sin\theta$
$F_y = 18\sin 60° = 15.59$ N

2. $s_x = s\cos\theta$
$s_x = 12\cos 45° = 8.49$ m
$s_y = s\sin\theta$
$s_y = 12\sin 45° = 8.49$ m

3. $v_x = s\cos\theta$
$v_x = 23\cos 37° = 18.37$ $m{\cdot}s^{-1}$
$v_y = s\sin\theta$
$v_y = 23\sin 37° = 13.84$ $m{\cdot}s^{-1}$

Summary (LB page 21)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 22–23)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. A ✓ (1) [K]
3. B ✓ (1) [U]
4. B ✓ (1) [K]
5. D ✓ (1) [U]
[5]

6. a) A scalar quantity has magnitude only. ✓ (1) [K]

b) $F = ma$ (Newton's second law)
Using base units, the units for force are $kg{\cdot}m{\cdot}s^{-2}$. ✓
Since pressure = $\frac{\text{force}}{\text{area}}$, we can rewrite the units as $\frac{kg{\cdot}m{\cdot}s^{-2}}{m^2}$, ✓ which is equivalent to $kg{\cdot}m^{-1}{\cdot}s^{-2}$. ✓ (3) [Ap]
[4]

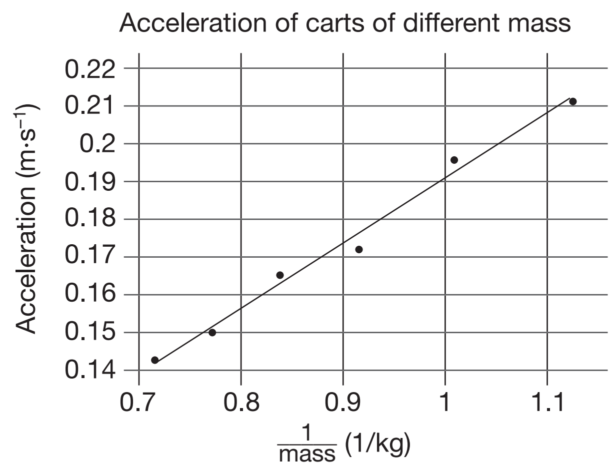
7. a) $c^2 = a^2 + b^2$
$c^2 = 100^2 + 120^2$ ✓
$c = \sqrt{24\,400}$ ✓
$c = 156.2$ N ✓
$\tan \theta = \frac{\text{opposite}}{\text{adjacent}}$
$\theta = \tan^{-1}\sqrt{\frac{100}{120}}$ ✓
$\theta = 39.8°$ ✓ The resultant force is 156.2 N acting at 39.8° to the 120 N force. (5) [Ap]

b) Choose to the left as positive.
$F_{res} = 120$ N + (–90 N) ✓ = 30 N left ✓
The horse moves out of the stable. (2) [Ap]
[7]

8. a) Mistakes include:
- ambiguous headings ✓
- no units were included ✓
- inconsistent significant figures. ✓ (3) [U]

b) The mass of the system is the independent variable. (1) [U]

c)



Axes labeled with variables and units ✓
Appropriate scale ✓
Plotting of values ✓
Line of best fit ✓ (4) [S]

d) Friction was not taken into account, which would affect the acceleration of the trolley. ✓ (1) [E]
[9]

9. a) Use a scale of 10 mm = 10 N.
$F = 11.54$ N ✓✓ (2) [An]
$T = 23.09$ N ✓✓ (2) [An]

b) $\tan 30° = \frac{F}{20}$ ✓
$F = 20 \tan 30° = 11.54$ N ✓✓ (3) [Ap]
$\cos 30° = \frac{20\text{ N}}{T}$ ✓
$T = \frac{20\text{ N}}{\cos 30°} = 23.09$ N ✓✓ (3) [Ap]
[10]

Total: 35

TOPIC 1.2 Measurement techniques

LB pages 24–45

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Know measuring instruments and apply them in physical quantities • Understand errors and uncertainties and the effects thereof in measurements
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology (role of ICT in science)
Inclusive education	Visually impaired learners will need assistance with observations during experiments. These learners will struggle to make smaller measurements like those using the callipers. Try to verbally explain how the apparatus works and ensure that any diagrams are enlarged.
Suggested teaching time	9 lessons
Additional resources needed	Calculator, ruler, Vernier callipers, mass balance, cathode-ray oscilloscope, measuring cylinder, measuring jug, thermometer, voltmeter, ammeter, bulb, connecting wires, battery

Introduction to this topic

This is a very practical section. The more the learners have the opportunity to interact with the apparatus, the better their understanding will be. Start the lesson by bringing to class as many types of apparatus as possible.

Write a number of quantities on the board, such as mass, volume, length and density, and ask the learners to identify the type of apparatus needed to measure each quantity.

Starter activity (LB page 24)

This activity introduces different types of apparatus to the class. It also lends itself to a class discussion about accuracy and precision. Try and bring a measuring cylinder and a jug to class so that the learners can see what is meant by the term calibrations. Use the measuring cylinder to measure out a specific volume of water and then pour it into the jug. Then compare the two volumes. Allow the learners to come to their own conclusions regarding the accuracy of these instruments.

Suggested answers

1. **a)** The measuring cylinder
   b) Learners may make an error reading the volume from the apparatus. Ensure that the error of parallax is taken into account. The graduations on a measuring cylinder usually have smaller divisions (e.g 0.2 ml) than a jug (e.g. 10 ml).
2. Thermometer

Sub-topic 1.2.1: Measurements

LB pages 25–35

Beginning these lessons

Allow the learners time to interact with the apparatus. Discuss the advantages and disadvantages of certain types of apparatus, for example, a ruler versus Vernier callipers. Use this as an opportunity to discuss errors they could make when taking measurements and what steps they can take to prevent these errors.

Measurement (LB pages 25–26)

Teaching guidelines

Learners need to be able to convert between units, for example, from millimetres to metres or from grams to kilograms. Link this section to Topic 1.1 in the Learner's Book.

Use the apparatus to measure the volume of a liquid or the mass of an object, and then ask the learners to convert these measurements into their base units.

Link this topic to Chemistry and how being able to measure accurately is vital for the preparation of chemicals.

Homework

Ask learners to record the temperature inside their homes for one week. The learners must then plot their readings as a line graph. Use this as an opportunity for learners to practise their tabulation and graph-drawing skills.

Suggested answers

Activity 1: Take measurements (LB page 26)

1. length = 0.102 m
   breadth = 0.065 m
   height = 0.042 m
2. $V = l \times b \times h = 0.102 \times 0.065 \times 0.042$
   $= 2.78 \times 10^{-4}$ m^3
3. 0.200 kg
4. density $= \frac{\text{mass}}{\text{volume}}$

   The base unit for mass is kg and for volume it is m^3. This means that the derived unit for density is kg·m^{-3}.

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects.

Go through the answers to Activity 1 with the learners in the next lesson. Learners can mark their own work. You may record their marks for informal assessment purposes.

Vernier callipers and micrometer screw gauge (LB page 27–29)

Teaching guidelines

The Vernier callipers and micrometer screw gauge were introduced in Grades 10 and 11, but some learners may still be unfamiliar with them. If you have access to these instruments, bring them to class and allow the learners to practise using them. Use them to measure items in the classroom like the diameter of an electric cable or the thickness of a ruler. If you do not have access to these instruments, you can use Figures 1.2.7 and 1.2.8 in the Learner's Book to explain how they work.

Suggested answers

Activity 2: Read Vernier callipers (LB page 27)

1. 34.60 mm; the first significant figures are taken as the main scale reading to the left of the Vernier zero, i.e. 34 mm. The remaining two digits are taken from the Vernier scale reading that lines up with any main scale reading, i.e. 60 on the Vernier scale. Note that the zero must be included because the scale can differentiate between 50ths of a millimetre. Therefore, the reading is 34.60 mm.
2. 40.00 mm; the 0 and the 10 on the Vernier scale both line up with main scale readings, therefore the reading is 40.00 cm.
3. 30.88 mm

Activity 3: Read micrometre screw gauges (LB page 29)

1. The last graduation visible to the left of the thimble is 7 mm and the thimble lines up with the main scale at 38 hundredths of a millimetre (0.38 mm); therefore the reading is 7.38 mm. The graduation mark below the main scale is just starting to appear from underneath the thimble. Hence 0.5 is not added to the reading taken above the main scale.
2. The main scale reading is 3 mm, while the reading on the drum is 0.46 mm; therefore, the reading is 3.46 mm.
3. The 0.5-mm division is visible below the main scale; therefore the reading is
   3.5 mm + 0.06 mm = 3.56 mm.

Mass and weight (LB pages 29–30)

Teaching guidelines

Mass and weight were covered extensively in Grades 10 and 11. Use the example in Activity 4 on page 30 of the Learner's Book to help the learners distinguish between mass and weight. Bring a scale to class and ask the learners to weigh themselves. Now ask the class to explain how their weight would change if they went to the Moon. Practise converting between mass and weight.

Suggested answers

Activity 4: Calculate mass and weight (LB page 30)

1. $W = mg$, which means that $m = \frac{W}{g}$.
   $m = \frac{124}{1.62} = 76.54$ kg
2. Mass stays constant, even when there is a change in gravitational acceleration.
   $W = mg$
   $W = 76.54 \times 9.81 = 750.12$ N
3. Yes

Measuring angles (LB pages 30–31)

Teaching guidelines

This section is closely linked to Mathematics. Ensure that all learners know how to use a protractor.

Learners should read through the steps on page 31 of the Learner's Book.

Suggested answers

Time intervals (LB pages 31–33)

Teaching guidelines

We can use a variety of instruments to measure time including analogue clocks, stopwatches and a cathode-ray oscilloscopes. The learners are familiar with the first two, but the cathode-ray oscilloscope will be unfamiliar to most.

An excellent video can be found on YouTube if you have access to the Internet. Type "Cathode ray oscilloscope, engineering made easy" into YouTube. If you do not have access to the Internet, use the diagram on page 30 of the Learner's Book to explain how a CRO works.

Suggested answers

Activity 5: Read an oscilloscope (LB page 33)

1. Each millisecond is equal to 10^{-3} s. This means that 0.25 ms is equal to 0.25×10^{-3} s.
2. There are six complete waves.
3. The screen shows three complete waves per centimetre. The time–base setting is 0.25×10^{-3} s per centimetre. Each wave will therefore take $\frac{0.25 \times 10^{-3}}{3}$ seconds to pass a point. Each wave will take 0.0083×10^{-3} s to pass a point.

Temperature (LB pages 33–34)

Teaching guidelines

Temperature is a measure of the average kinetic energy of a substance. The higher the temperature, the more kinetic energy the particles have.

Fill three beakers or bowls with water at different temperatures. Allow the learners to take the readings using a thermometer. Remind learners that temperature is always measured to one decimal place and that the decimal is either a 0 or a 5. Once the learners have taken a number of readings, ask them to convert the readings to kelvin.

Ammeters, voltmeters and galvanometers (LB pages 34–35)

Teaching guidelines

Electricity is an exciting topic for learners. Ask the learners to build a simple circuit using a battery, a bulb, connecting wires, an ammeter and a voltmeter. As a class, discuss why the ammeter is connected in series, but the voltmeter is connected in parallel.

Explain that we use a galvanometer to measure very small currents and potential differences. Use this as an opportunity to practise converting from milliamperes (mA) to amperes (A).

Sub-topic 1.2.2: Errors and uncertainties LB pages 36–41

Beginning these lessons

It is essential that learners can identify any experimental errors that they might make. Part of this is recognising which apparatus will give them the most precise measurement. Use a burette to measure 25 cm^3 of water. Pour the water into a measuring cylinder and compare readings. Now empty the measuring cylinder into a beaker and record the new reading. As a class, discuss why the volumes are different. Use this demonstration to introduce the term "uncertainty".

Experimental errors (LB pages 36–41)

Teaching guidelines

Bring the concept of experimental errors into any experiment done in class. Ask the learners to state any source of errors and how they could reduce the effects of these errors.

Practise categorising errors into systematic and random errors, and ensure that learners can distinguish between the two. This is not an isolated section, and you should refer back to the content every time learners do practical work in class.

Experimental errors play a role in all facets of science. Chemistry and biology in particular require very accurate measurements especially when working with very small volumes or masses.

Homework

Ask the learners to refer back to Activity 1 in Sub-topic 1.2.1. Ask the learners to list any source of random or systematic errors that Siphokazi could have made. Discuss these errors in class the next day.

Systematic errors could include forgetting to tare or zero the balance before taking the measurement or using a poorly calibrated balance. Random errors could include incorrectly measuring the block's dimensions or incorrectly converting from centimetres to metres.

Suggested answers

Activity 6: Measure volume (LB page 37)

1. The measuring cylinder
2. The measuring cylinder is the instrument that is calibrated the most precisely. The beaker and conical flask are less precisely calibrated.
3. Systematic errors could occur if you read the volume from a different angle each time.

Activity 7: Calculate absolute uncertainty (LB page 39)

Absolute uncertainty for:
- ruler = ±0.1 cm
- Vernier callipers = ±0.01 cm
- micrometer screw gauge = ±0.01 cm
- multimeter = ±0.06 V
- stopwatch = ±0.001 s

Activity 8: Calculate uncertainty (LB page 41)

1. volume = length × width × height
   $= (5.56 \times 3.12 \times 2.94)\ \text{m}^3 \pm (2.5 + 2.6 + 3.7)\%$
   $= 51.00\ \text{m}^3 \pm 8.8\%$
2. uncertainty in volume = volume × percentage uncertainty in volume
   $= 55.00\ \text{m}^3 \times 8.8\%$
   $= 4.84\ \text{m}^3$

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Allow the learners to work in pairs to complete Activity 8. Once the learners have completed the task, mark it in class and record their marks for diagnostic assessment.

Summary (LB page 42)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but it also helps them consolidate what they have learnt.

Self-assessment (LB pages 43–45)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. A ✓ (1) [K]
2. B ✓ (1) [U]
3. A ✓ (1) [U]
4. C ✓ (1) [K]
5. A ✓ (1) [K]

[5]

6. **a)** Stopwatch or analogue clock ✓ (1) [K]
   b) Random error: the learner did not push the stopwatch in time or did not use the formula correctly. ✓
   Systematic error: the ticker timer machine or stopwatch was not correctly calibrated. ✓ (2) [An]
   c) The experiment could be repeated a number of times and the average period recorded. ✓ (1) [U]
   d) $\frac{1}{T} = \frac{1}{s}$, therefore the base unit for frequency is s^{-1}. ✓ (1) [Ap]
   [5]
7. **a)** **i)** 170° ✓ (1) [Ap]
   ii) 10° ✓ (1) [Ap]
   b) The uncertainty of a protractor is its smallest division. A protractor has divisions equal to 0.5°. ✓
   $\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{quantity measured}} \times 100\%$
   $\text{percentage uncertainty} = \frac{0.5}{170}$ ✓
   100% ✓= 0.29% ✓ (3) [An]
   [5]
8. **a)** length: 7.0 cm + 0.05 cm
   = 7.05 cm ✓✓
   diameter: 0.2 cm + 0.04 cm
   = 0.24 cm ✓✓ (2) [Ap]
   b) $\frac{\text{uncertainty}}{0.24} \times 100 = 4.17\%$ ✓
   uncertainty = 0.01 cm ✓ (4) [Ap]
   [6]
9. **a)** Mass is determined by the amount of matter the object is made up of. ✓ An object's mass never changes. An object's weight is determined by the gravitational acceleration. ✓ It is a force. (2) [E]
   b) F is measured in newtons (N). Unit of mass = kg and the units of acceleration = $m{\cdot}s^{-2}$
   Newton's second law states that $F = ma$. ✓
   Therefore, $N = kg{\cdot}m{\cdot}s^{-2}$ ✓ (2) [Ap]
   [4]

Total: 25

TOPIC 1.3 Kinematics

LB pages 46–65

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Show understanding of physical quantities included within the syllabus • Know the SI units for various physical quantities included within the syllabus • Know scalar and vector quantities including calculations and representations • Know measuring instruments and apply them in physical quantities • Understand the concepts distance, displacement, speed, velocity and acceleration, including equations of motion
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Human rights; road safety
Inclusive education	Visually impaired learners will need assistance drawing vector diagrams and interpreting graphs. Use enlarged diagrams where possible and try to explain the concepts verbally, step by step.
Suggested teaching time	15 lessons
Additional resources needed	Ruler, calculator, graph paper, trolley kit or toy car, ticker-timer, ticker tape, mass pieces, stop watch, retort stand, clamp, measuring tape

Introduction to this topic

Introduce this theme by briefly discussing what is meant by the term "kinematics". Use trolleys or toy cars to demonstrate the concept of velocity and acceleration. Use a stopwatch to time the movement of a toy car along a table or track. Use a ramp to increase the velocity of the car. Ask the learners to predict the shape of the graph if the speed of the car is plotted per time and compare the shapes of the speed–time graphs if the toy car moves at a constant speed versus when it accelerates.

Starter activity

(LB page 46)

This activity revises the concepts taught in Grades 10 and 11. It asks the learners to interpret a velocity–time graph and draw conclusions from its shape. It acts as a form of diagnostic assessment because it allows you to gauge whether the learners understand the concept or not. It is essential that learners have a strong foundation in this section before moving on to more complicated aspects.

Suggested answers

1. Constant acceleration in the positive direction
2. $6\ m{\cdot}s^{-1}$ in the positive direction
3. The acceleration of the car is equal to the gradient of the graph.
   P → Q: Car accelerates in the positive direction at $0.9\ m{\cdot}s^{-2}$.
   R → S: Car slows down at a rate of $1.25\ m{\cdot}s^{-2}$.
4. The car turns around and accelerates in the opposite direction. It accelerates from rest until it reaches a velocity of $10\ m{\cdot}s^{-1}$ in the opposite direction.

Sub-topic 1.3.1: Equations of motion

LB pages 47–65

Beginning these lessons

Start these lessons by revising the units and symbols used for different quantities. Learners often struggle to interpret these types of questions. By highlighting the units used in a question, learners have a better idea of what the question is asking for. Ask learners to list these quantities in their books.

Distance, displacement, speed and acceleration (LB pages 47–50)

Teaching guidelines

This section introduces terminology that can be confusing for learners. Start the lesson by listing any new words that may be unfamiliar to learners. Use the key word boxes in the Learner's Book to guide you. Use trolleys or toy cars to demonstrate the difference between distance and displacement, and between speed and velocity.

Informal assessment

Allow the learners 10 minutes in class to summarise the different quantities used in this section. Learners can complete the table below, and it can be marked by their peers in the next lesson. You can then use these marks for diagnostic assessment. It is essential that learners have a good understanding of the concepts before moving on to equations of motion.

Quantity	Symbol	Unit	Vector/Scalar
Distance	s	$m{\cdot}s^{-1}$	Scalar
Displacement			
Speed			
Velocity			
Acceleration			

Equations of motion (LB pages 50–52)

Teaching guidelines

This section is based on mathematical concepts like changing the subject of the formula and solving equations to find unknown quantities. Teach the learners to answer questions by first listing the quantities they have and the quantity that they are looking for. This way, they can use the data sheet to easily identify which equation to use.

Homework

You can give learners Activity 1 to do for homework provided you have worked through the worked example on page 52 as a class. Learners should do Activity 1 independently to ensure that they understand the concepts taught in class.

Suggested answers

Activity 1: Calculate velocity (LB page 52)

1. **a)** $a = \frac{v - u}{\Delta t}$

   $1.25 = \frac{v - 17}{3}$

   $v = 18.7\,5\ m{\cdot}s^{-1}$ to the left

   b) No. His final speed is slower than that of the second car.
2. Must be measured in seconds. 2 min = 120 s

   $a = \frac{v - u}{\Delta t}$

   $a = \frac{34 - 7}{20}$

   $a = 1.35\ m{\cdot}s^{-2}$ in the positive direction
3. $v = u + a\Delta t$

   $0 = 2.2 + 2.5a$

   $-2.2 = 2.5a$

   $a = -0.88\ m{\cdot}s^{-2}$

   $s = ut + \frac{1}{2}a\Delta t^2$

   $2.2 \times 2.5 + \frac{1}{2}(-0.88)2.5^2$

   $s = 2.75$ m

Informal assessment

Learners can complete Activity 1 as homework and then you can mark it in class. These marks can act as diagnostic assessment of the learners' abilities. It will help you gauge where the learners' weaknesses lie.

Graphs of motion (LB page 52–57)

Teaching guidelines

Graphs of motion can prove a challenging section for many learners. Always start with simple graphs, in which all the points are plotted above the *x*-axis. Once the learners are more comfortable with the concept, you can introduce a change in direction. Allow the learners time to summarise the graphs of motion into their books. Use Figures 1.3.8 and 1.3.9 on pages 54 and 55 of the Learner's Book as a guide.

Suggested answers

Activity 2: Interpret graphs of motion (LB page 55)

1. **a)** The gradient of a velocity–time graph is equal to its acceleration. Car Y has a steeper gradient, so it must be accelerating at a faster rate than car X.

b) It is travelling at a constant velocity of 17.5 m·s^{-1} in the positive direction.

c) acceleration = gradient = $\frac{\Delta y}{\Delta x}$

acceleration = $\frac{17.5 - 0}{6 - 0}$ = 2.42 m·s^{-2}

d) distance = area under the graph

From 0–6 s:

area = $\frac{1}{2}$base × height

area = $\frac{1}{2}$ × 6 × 17.5 = 43.5 m

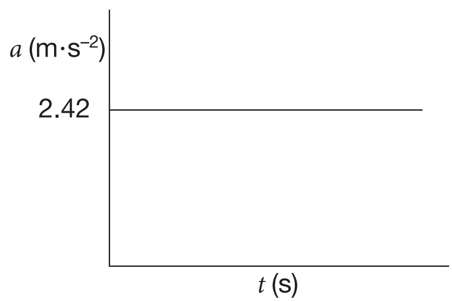
From 6–10 s:

area = length × breadth

area = 4 × 17.5 = 70 m

total distance = 43.5 + 70 = 113.5 m

e)



2. a) Truck: $s = ut + \frac{1}{2}a\Delta t^2$

$s = 40(10) + \frac{1}{2}(0)(10)^2$

$s = 400$ m

Police car: $s = ut + \frac{1}{2}a\Delta t^2$

$s = 15(10) + \frac{1}{2}(0)(10)^2$

$s = 150$ m

$\Delta s = 400 - 150 = 250$ m

b) acceleration = gradient = $\frac{\Delta y}{\Delta x}$

acceleration = $\frac{45 - 15}{25 - 10}$ = 2 m·s^{-2}

c) 40 m = 0.04 km

1 h = 3 600 s

speed in km·h^{-1} = 0.04 × 3 600

= 144 km·h^{-1}.

He did exceed the speed limit.

Activity 3: Understand kinematics (LB page 56)

1. A **2.** B **3.** B **4.** D

5. a) Acceleration is equal to the gradient of the graph.

gradient = $\frac{\Delta y}{\Delta x} = \frac{6 - 0}{10 - 0}$ = 0.6 m·s^{-2}

b) displacement = area under the graph

area = $\frac{1}{2}$ × base × height

area = $\frac{1}{2}$ × 6 × 10 = 30 m

Falling bodies (LB page 57–60)

Teaching guidelines

The best way to teach falling bodies is by using a practical approach. Use any object in the classroom like a ball, an eraser or a pencil. Hold the object up and allow it to fall. Ask the learners to describe the forces acting on it. As a class, discuss what happens to the velocity of the object as it falls. Ask learners to rewrite the equations of motion, but substituting "*g*" in for "*a*".

Experiment 1: Determine the value of gravitational acceleration using free fall (LB page 58)

This experiment is a fantastic way to prove the theory taught in the falling bodies section of the Learner's Book. Learners should attain answers fairly close to 9.81 m·s^{-2}.

If you do not have access to a ticker-timer, you can replicate the experiment using a ping pong ball, metre rule and a stopwatch. Measure the height from a window to the ground. Drop the ball from the window and start the stopwatch. Stop the stopwatch when the ball hits the ground. Use equations of motion to solve for *g*.

Suggested answers

1. A range of values will be attained (8.0–10.0).

2. No

3. Systematic errors could include a stretched tape measure or an incorrectly calibrated ticker-timer. Random errors could occur due to the person stopping the stopwatch too early or too late.

4. percentage uncertainty

$= \frac{\text{absolute uncertainty}}{\text{measured value}} \times 100\%$

Activity 4: Use equations for falling bodies (LB page 59)

1. a) 5 m·s^{-1} upwards

b) 9.8 m·s^{-2} downwards

c) Choose downwards as positive.

$v = u + g\Delta t$

$v = -5 + (9.81)(0.5)$

$v = -0.1$ m·s^{-1}

$v = 0.1$ m·s^{-1} upwards

The ball is still moving upwards during this time.

d) The object has a velocity of 0 m·s^{-1} at its maximum height.

Choose downwards as positive.

$v^2 = u^2 + 2gs$
$0 = (-5)^2 + 2(9.81)s$
$s = \frac{-25}{19.6} = -1.27$ m = 1.27 m upwards
$v = u + g\Delta t$
$0 = (-5) + 9.81t$
$t = 0.51$ s
time that the ball then took to reach the ground from its maximum height
= 5 – 0.51 = 4.49 s
$v = u + g\Delta t$
$v = 0 + (9.81)(4.49) = 44.05$ m·s^{-1}

e) Height of balloon = displacement of the object from the time it was dropped.
Taking downwards as the positive direction:
$v^2 = u^2 + 2gs$
$44.05^2 = (-5)^2 + 2 \times 9.81 \times s$
$s = 97.63$ m (height of balloon)
Alternatively, use the equation:
$s = u\Delta t + \frac{1}{2}g(\Delta t)^2$
where u is negative if down is the positive direction.

2. a) The only force acting on the ball is the force of gravity.

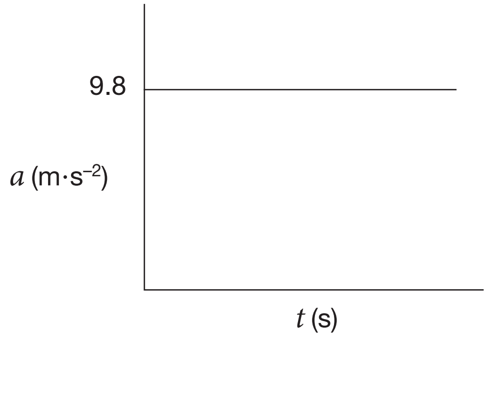
b) gradient $= \frac{\Delta y}{\Delta x} = \frac{4.9 - 0}{0.5 - 0}$
gradient = 9.8

c) area under graph = displacement (height reached by ball)
area $= \frac{1}{2}$base × height
area $= \frac{1}{2} \times 0.5 \times 4.9 = 1.23$ m

d) i) Choose downwards as positive.
$v = u + g\Delta t$
$v = 0 + (9.8)(1.7 - 0.5)$
$v = 11.76$ m·s^{-1} downwards

ii) $s = ut + \frac{1}{2}g\Delta t^2$
$s = (0)(1.2) + \frac{1}{2}(9.8)(1.2)^2$
$s = 7.06$ m (total height reached by ball)
height of balcony = 7.06 m – 1.23 m
= 5.83 m

e) If we choose downwards as positive:



Informal assessment

Go through the answers to Activity 3 with the learners in class in the next lesson. Learners can mark their own work. You may record their marks for informal assessment and use it to assess their understanding of the concept.

Projectile motion (LB pages 60–62)

Teaching guidelines

It is important that when teaching this concept, you use a practical approach. If you have access to the Internet, a simulation can be very helpful when introducing the idea of projectile motion. Type "PHET projectile" into your browser for a fun way to introduce the theory.

If you do not have access to the Internet, you can demonstrate this concept by throwing a ball of paper or a rubber ball into the air at an angle. Link this concept to components of forces, which was covered in Grades 10 and 11.

Homework

You can mark Activity 5 in class for informal assessment. The activity lends itself to peer assessment. The learners work in groups and discuss the answers amongst themselves before submitting their work. You can then mark the answers during lesson time.

Suggested answers

Activity 5: Calculate projectile motion (LB page 62)

1. $s = v\Delta t$
$s = 30.4 \times 3$
$s = 91.2$ m

2. $h = \frac{1}{2}g\Delta t^2$
$h = \frac{1}{2}(9.81)(3)^2$
$h = 44.15$ m

3. Choose up as positive.
$u_y = v\sin\theta$
$u_y = 30.4\sin 53° = 24.28$ m·s^{-1}
$v = u_y + g\Delta t$
$0 = 24.28 + (-9.81)\Delta t$
$t = 2.48$ s
$h = \frac{1}{2}g\Delta t^2$
$h = \frac{1}{2}(9.81)(2.48)^2$
$h = 30.05$ m
total height = 30.05 + 44.15 = 74.20 m

Remedial activity

Give learners who find it difficult to find the components of velocity the following examples to try at home.

Calculate the vertical and horizontal components of each of the following velocities:

1. 45 m·s^{-1} at an angle of 35°
2. 12 m·s^{-1} at an angle of 25°
3. 60 m·s^{-1} at an angle of 42°
4. 22 m·s^{-1} at an angle of 60°

Suggested answers

1. $v_y = v\sin\theta = 45\sin 35° = 25.8$ m·s^{-1}
   $v_y = v\cos\theta = 45\cos 35° = 36.8$ m·s^{-1}
2. $v_y = v\sin\theta = 12\sin 25° = 5.07$ m·s^{-11}
   $v_x = v\cos\theta = 12\cos 25° = 10.9$ m·s^{-1}
3. $v_y = v\sin\theta = 60\sin 42° = 40.15$ m·s^{-1}
   $v_x = v\cos\theta = 60\cos 42° = 44.6$ m·s^{-1}
4. $v_y = v\sin\theta = 22\sin 60° = 19.05$ m·s^{-1}
   $v_x = v\cos\theta = 22\cos 60° = 11$ m·s^{-1}

Summary (LB page 63)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

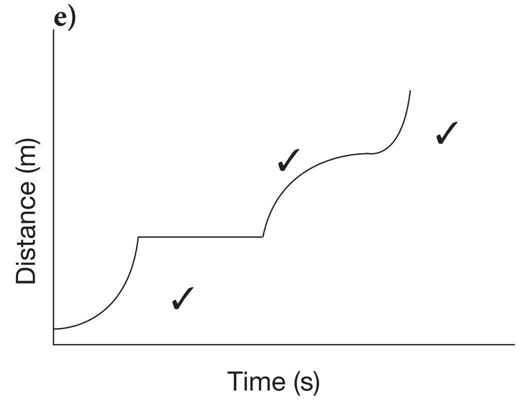
Self-assessment (LB pages 64–65)

Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. A ✓ (1) [U]
2. A ✓ (1) [K]
3. B ✓ (1) [Ap]
4. C ✓ (1) [Ap]
5. B ✓ (1) [U]
6. a) The rate of change of displacement ✓✓ (2) [K]
b) It slows to rest, ✓ turns around ✓ and accelerates. ✓ (3) [U]
c) displacement = area under the graph
displacement = $\frac{1}{2} \times b \times h + l \times b + \frac{1}{2} \times b \times h + (-\frac{1}{2} \times \mathrm{b} \times h)$
displacement = $(\frac{1}{2} \times 5 \times 4) + (7 \times 4) + (\frac{1}{2} \times 2 \times 4)$ ✓ + $(\frac{1}{2} \times 1 \times -2)$ ✓
displacement = 41 m ✓ (13) [Ap]
d) acceleration = gradient of the graph
deceleration = $\frac{\Delta y}{\Delta x}$ ✓ = $\frac{4-0}{5-0}$ ✓
= 0.8 m·s^{-2} in the positive direction ✓ (3) [Ap]
e)



(3) [S]

7. a) $y = \frac{1}{2}g\Delta t^2$
$t^2 = \frac{2y}{g} = \frac{2(45)}{9.81}$ ✓ = 9.18
$t = \sqrt{9.18} = 3$ s ✓ (2) [Ap]
b) $x = u\Delta t = 16(3)$
= 48 m ✓ (2) [Ap]
c) $v_y = -g\Delta t = -9.81(3) = 29.4$ m·s^{-1} ✓
$v = \sqrt{(v_x{}^2 + v_y{}^2)}$
$v = \sqrt{(16^2 + 29.4^2)}$ ✓
$v = 33.47$ m·s^{-1} ✓ (3) [Ap]
8. a) $v = u + g\Delta t$
$v = 26 + (-9.81)(2)$ ✓
$v = 6.4$ m·s^{-1} ✓ (2) [Ap]
b) $s = ut + \frac{1}{2}g\Delta t^2$
$s = 26(2) + \frac{1}{2}(-9.81)2^2$ ✓
$s = 32.4$ m ✓ (2) [Ap]
c) $s = ut + \frac{1}{2}a\Delta t^2$
$s = 6.4(60) + \frac{1}{2}(5)60^2$ ✓
$s = 9\,384$ m
total height reached by rocket
= 8 384 + 32.4 ✓ = 9 416.4 m ✓ (3) [Ap]
d) $v^2 = u^2 + 2gs$
$v^2 = 0 + 2(9.81)(9\,416.4)$ ✓
$v = 429.6$ m·s^{-1} ✓ (2) [Ap]

Total: 35

TOPIC 1.4 Dynamics

LB pages 66–85

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Understand momentum and Newton's laws of motion and its application • Understand non-uniform motion and its application • Understand linear momentum and its conservation
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Road safety
Inclusive education	Visually impaired learners may need assistance with observations during experiments. Ensure that the learners are given enlarged grids to draw graphs on and that diagrams are enlarged for ease of use.
Suggested teaching time	18 lessons
Additional resources needed	Trolley, string, meter rule, 5 × 50 g mass pieces, stopwatch, clamp

Introduction to this topic

Dynamics is a challenging, yet exciting topic for many learners. It involves in-depth discussions of many fundamental concepts like Newton's laws, momentum, mass and weight.

You can introduce this topic by revising the difference between mass and weight. Use a balance to measure the mass of an object. Discuss with the class whether the reading is the mass of the object or its weight. How would the reading change if the object was on the Moon? Discuss the effect that the weight of an object has on the force of gravity exerted on that object.

This topic is a calculation-based one and you can use this to emphasise to learners how Mathematics applies to real life. The simulations and experiments in the Learner's Book help learners visualise these concepts. Learners need to understand the content and be able to apply it, not just memorise the facts.

Starter activity

(LB page 66)

The aim of this activity is to ensure that learners understand the difference between vector and scalar quantities. This is an important concept to grasp because vectors involve direction and learners need to be able to determine when to choose a direction as positive.

Suggested answers

Quantity	Scalar/Vector	SI unit
Velocity	Vector	$m \cdot s^{-1}$
Acceleration	Vector	$m \cdot s^{-2}$
Distance	Scalar	m
Time	Scalar	s
Force	Vector	N
Mass	Scalar	kg

Sub-topic 1.4.1: Momentum and Newton's laws of motion

LB pages 67–74

Beginning these lessons

In this sub-topic, learners will need to state and distinguish between Newton's laws of motion. They will also need to calculate the momentum of a body and describe how the momentum of a body changes when its motion changes.

A good way to introduce this topic is by using a trolley system. If you do not have access to trolleys, you can use toy cars and a plank as an alternative. Demonstrate various situations of motion, for example, the trolley on a slope or traveling at constant velocity. With the learners, identify the forces acting on the trolley, and discuss the magnitude and effect of these different forces.

Newton's laws (LB pages 67–73)

Teaching guidelines

This sub-topic can be a difficult one for many learners, especially for those that struggle with Mathematics. Ensure that all learners can change the subject of a formula before beginning the topic. Most learners find it easier to manipulate an equation before they substitute in the values. Tell them to change the subject of the formula first and once they have done that, to fill in the values. Simulations like those found at https://phet.colorado.edu/ can be a valuable tool to help learners visualise the concepts.

Practise some examples, like those on pages 69–70 of the Learner's Book, as a class, before allowing the learners to complete the activities independently. Make sure that they write down all their steps and convert the quantities into the correct units.

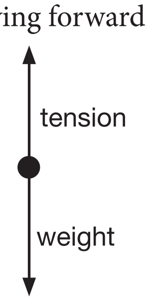
Homework

Learners can complete Activity 1 for homework if they do not finish it during class. Learners should use their time at home to consolidate their understanding of the work covered in this sub-topic. If you have access to the Internet, you could search for relevant additional exercises and give them as homework to learners.

Suggested answers

Activity 1: Use Newton's laws (LB page 71)

1. Newton's first law states that an object will resist any change to its motion. When a car collides, it suddenly comes to a stop. The passengers however, will continue to move forward. Seatbelts prevent the passengers from flying forward through the windscreen.
2. a)



b) $F = ma$ (Choose upwards as positive.)
$T - W = ma$
$T - 100(9.81) = 100(2)$
$T = 1\,081$ N upwards

3. a) $F = ma$ (Choose to the right as positive.)
$12 = (3 + 1)a$
$a = 3$ m·s^{-2} to the right

b) For the 3-kg block, choose to the right as positive.
$F = ma$
$12 - T = 3 \times 3$
$T = 12 - 9 = 3$ N to the right

c) According to Newton's second law, increasing the mass would decrease the acceleration of the system.

Experiment 1: Determine the relationship between mass and acceleration (LB page 71)

1. Dependent variable: time taken for trolley to travel the distance of the table; independent variable: mass of trolley
2. The force exerted on the trolley
3. A curve with a negative gradient
4. Acceleration is inversely proportional to the mass of the trolley.
5. The stopwatch could introduce a random error. You can reduce this error by repeating the experiment a number of times. Alternatively, you could use two stop-watches, at the same time to reduce the effect of this error.

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. You can mark Experiment 1 in class for informal assessment. The experiment is suitable for peer assessment. The learners can work in groups and discuss the answers amongst themselves before submitting their answers to you. You can then mark the answers during the lesson.

Momentum (LB pages 72–74)

Teaching guidelines

You can demonstrate the concept of momentum using the trolley system or the toy car that you used at the beginning of this sub-topic. It is important to emphasise that two factors affect momentum: the mass of the object and the change in its velocity.

Use the example of a bullet and steam roller. The bullet's change in the momentum is large because of the speed at which the bullet travels. The steam roller also experiences a large change in momentum; not because it is travelling quickly, but because of its large mass. Link this concept to the worked example on page 73 of the Learner's Book.

Suggested answers

Activity 2: Use momentum to solve problems (LB page 74)

1. a) $\Delta p = m(v - u)$ (Choose the original direction as positive.)
   $\Delta p = 0.150(-6 - 8) = -2.1$ kg·m·s^{-1}
   $= 2.1$ kg·m·s^{-1} in the negative direction
   b) The force that the ball exerts on the wall is in the positive direction. $F\Delta t = \Delta p$
   $F = \frac{\Delta p}{\Delta t} = \frac{2.1}{0.1} = 21$ N in the original direction
   c) 21 N in the rebound direction
   d) Newton's third law states that the force will be equal in magnitude, but will act in the opposite direction.
2. The arrestor bed is filled with sand and loose stones that apply a friction force that brings the truck to a halt. The change to the truck's momentum takes place over a longer time interval and is safer than if it had crashed. According to Newton's second law of motion, the force would be much larger if the truck had been brought to a stop in a crash in which the time interval would be very small.
3. a) 180 km·h^{-1} = 180 000 m·h^{-1}
   $\frac{180\ 000}{3\ 600} = 50$ m·s^{-1}
   b) $\Delta p = m\ (v - u)$
   $\Delta p = 500(0 - 50)$ kg·m·s^{-1}
   $\Delta p = -25\ 000$ kg·m·s^{-1} in the opposite direction
   c) $F\Delta t = \Delta p$
   $F = \frac{\Delta p}{\Delta t}$
   $F = \frac{-25\ 000}{20} = -1\ 250$ N
   $F = 1\ 250$ N in the opposite direction

Sub-topic 1.4.2: Non-uniform motion

LB pages 75–76

Beginning these lessons

In this sub-topic, learners distinguish between mass and weight. They will need to be able to describe the motion of a falling body and recall that acceleration due to gravity is a constant as long as air resistance is negligible.

You can introduce this section by demonstrating the principle of terminal velocity using a home-made parachute. To make the parachute, you will need:

- a piece of fabric cut into a square
- four pieces of string or thread
- a mass piece, pebble or small toy.

1. Tie a piece of string to each of the four corners of the fabric
2. Tie the other ends of the strings together.
3. Tie these ends to the object.
4. Roll up the parachute and throw it as high into the air as possible.

Ask the learners to identify the forces acting on the parachute. As a class, discuss how these forces change as the object falls. Use this to introduce the concept of terminal velocity.

Non-uniform motion (LB pages 75–76)

Teaching guidelines

Some learners may find it difficult to understand the difference between mass and weight. Emphasise that the mass of an object always stays the same, while its weight changes depending on the gravitational acceleration acting on it.

Ensure that you use the value 9.81 m·s^{-2} when working with gravitational acceleration. Remind learners that they will need to convert all masses into kilograms. To convert grams into kilograms, they simply need to multiply the mass in grams by 10^3.

Homework

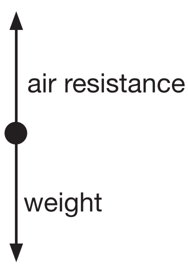
You can give the learners Activity 3 to do as homework. It gives learners the opportunity to practise the concepts covered in class.

Suggested answers

Activity 3: Understand non-uniform motion

(LB page 76)

1. a)



b) $w = mg$

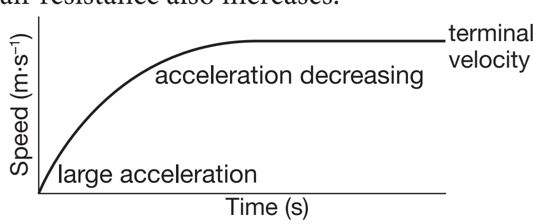
$w = 60 \times 9.81 = 588.6$ N downwards

c) Terminal velocity occurs when the air resistance experienced by a falling object is equal to its weight. The object falls at a constant velocity, called terminal velocity.

2. a) 9.81 $m{\cdot}s^{-2}$

b) As the ice falls, its velocity increases, so its air resistance also increases.

c)



Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Go through the answers to Activity 3 with the learners in class in the next lesson. Learners can mark their own work. You can use these marks for diagnostic assessment purposes.

Sub-topic 1.4.3: Linear momentum and its conservation LB pages 77–81

Beginning these lessons

In this sub-topic, leaners will need to change the subject of the conservation of momentum formula to calculate the velocity of an object.

This topic is very calculation-based, which you can use to demonstrate to learners that Mathematics has use in the real world. Learners will need to rearrange formulae and predict which formula can be applied to each situation.

Introduce the lesson using two marbles. Demonstrate the different types of collisions they will encounter using the marbles.

- Roll them towards each other.
- Roll one marble and allow it to crash into the second marble from behind.
- Make the marbles crash into each other and then come to a complete stop.

Have a class discussion about how the momentum of the marbles changes and relate these collisions to Newton's laws.

Impulse and the conservation of momentum (LB pages 77–81)

Teaching guidelines

Learners can really benefit from visual aids. You can use diagrams and models to help the learners picture different scenarios. Once they can distinguish between the different situations, they are far more likely to choose the correct formula.

The worked examples on pages 78–80 of the Learner's Book show the learners how to approach the different situations. Make sure that they write down all the information given in the question and use it to draw a diagram of the situation. Emphasise that learners must remember to choose a direction as positive.

Homework

Ask the learners to work through the worked examples at home. Ensure that they understand how the answer is calculated before attempting the activities.

You can check whether learners understood the concept at the beginning of the next lesson by writing a question on the board and asking them to work out the answer in pairs (with their books closed).

You could then ask for feedback on the steps they followed from some of the pairs of learners.

Suggested answers

Activity 4: Use impulse in calculations (LB page 77)

1. $F\Delta t = m\Delta v$
   $F = \frac{m\Delta v}{\Delta t}$
   $F = \frac{9\,500(0 - 4.5)}{3}$
   $F = -3\,375$ N
   $F = 3\,375$ N east
2. Seatbelts increase the time it takes for you to come to a complete stop. This means that your momentum changes over a longer period of time, which reduces the force of the impact that you feel.

Activity 5: Understand conservation of momentum (LB page 80)

1. **a)** Choose to the right as positive.
   $\Delta p = m(v - u) = 200(1.5 - 4)$
   $= -500 = 500$ kg·m·s^{-1} to the left
   b) $F\Delta t = \Delta p$
   $F = \frac{\Delta p}{\Delta t} = \frac{-500}{10} = -50 = 50$ N to the left
   c) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
   $(200 \times 4) + (100 \times 3)$
   $= (200 \times 1.5) + (100 \times v)$
   $1\,100 = 300 + 100v$
   $1\,100 - 300 = 100v$
   $v = 8$ m·s^{-1} to the right
2. Momentum is always conserved in a closed system, but kinetic energy is only conserved when a collision is elastic. In inelastic collisions, the kinetic energy is converted into heat or sound energy.
3. $m_1u_1 + m_2u_2 = (m_1 + m_2)v$
   $(0.025 \times 400) + (10 \times 0) = (0.025 + 10)v$
   $v = 0.998$ m·s^{-1} in the positive direction

Extension activity

The following is an extension activity that you can do to extend your learners. If learners have access to the Internet, they can use it to do their research.

Divide the learners into groups of four. Each group must conduct research on the life and work of Isaac Newton, and make a poster of their findings. Their research should include:

- his biography (when he was born, when he died, where he lived and his personal life)
- his research about momentum
- how we use his research in our everyday lives.

Each group then presents their poster to the rest of the class.

Remedial activity

Give learners who have trouble changing the subject of a formula the following questions to practise at home. In each question, make time (Δt) the subject of the formula.

1. $v = \frac{s}{\Delta t}$
2. $v = u + a\Delta t$
3. $F\Delta t = m\Delta v$

Suggested answers

1. $\Delta t = \frac{s}{v}$
2. $\Delta t = \frac{v - u}{a}$
3. $\Delta t = \frac{m\Delta v}{F}$

Summary (LB page 82)

Learners can use the summary for revision and self-study before they do the self-assessment exercises. This not only supports their study skills, but also helps to consolidate what they have learnt.

Self-assessment (LB pages 83– 85)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In both cases, it acts as a diagnostic assessment tool.

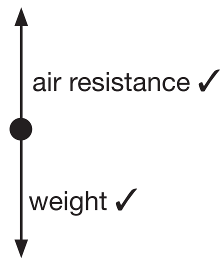
Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. A ✓ (1) [K]
2. C ✓ (1) [U]
3. C ✓ (1) [K]
4. C ✓ (1) [U]
5. B ✓ (1) [U]

[5]

6. a)



(2) [An]

b) $w = mg = 0.150 \times 9.81$ ✓ $= 1.47$ N ✓ (2) [Ap]

c) The weight of the apple remains constant, ✓ but the air resistance increases as the speed of the apple increases. ✓ (2) [U]

d) Choose downwards as positive.
$\Delta p = m(v - u)$ ✓ $= 0.150(2 - 0)$ ✓
$= 0.3$ kg·m·s^{-1} downwards ✓ (3) [Ap]
[9]

7. a) Choose to the left as positive.
$\Delta p = m(v - u) = 0.003\ (0 - 300)$ ✓
$= -0.9 = 0.9$ kg·m·s^{-1} to the right ✓ (2) [Ap]

b) $F\Delta t = \Delta p$
$F = \frac{\Delta p}{\Delta t} = \frac{-0.9}{0.4}$ ✓ $= -2.25$
$= 2.25$ N to the right ✓ (2) [Ap]
[4]

8. a) The principle of conservation of momentum states that when bodies in a system interact, the total momentum remains constant (momentum is always conserved) provided that no external force acts on the system. ✓ (1) [K]

b) Choose to the right as positive.
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$(0.1 \times 5) + (0.160 \times 0)$ ✓
$= (0.100 \times 1) + (0.160 \times v)$ ✓
$0.5 = 0.1 + 0.16v$
$v = 2.5$ m·s^{-1} to the right ✓ (3) [Ap]
[4]

9. a) The resultant force exerted on a body is directly proportional to the rate of change of linear momentum of that body. ✓✓ (2) [K]

b) Choose to the right as positive.
$F = ma$
$20 - 4 = (2 + 2)a$ ✓
$16 = 4a$
$a = 4$ m·s^{-2} to the right ✓ (2) [Ap]

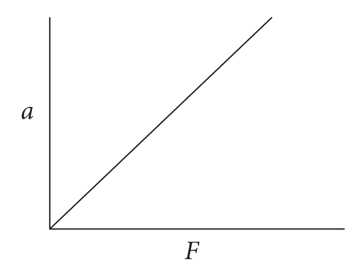
c) On block A:
$F = ma$
$T - 2$ ✓ $= 2(4)$ ✓
$T = 10$ N to the right ✓ (3) [An]

d) It would increase. ✓ (1) [S]
[8]

10. a) The mass of the trolley ✓ (1) [Ap]

b) The greater the force exerted on the trolley, the greater its acceleration. ✓✓ (2) [An]

c)



(2) [S]
[5]

11. a) $W = mg$
$W = 200 \times 9.81$ ✓ $= 1\,962$ N upwards ✓ (2) [U]

b) $F = ma$
$T - W = 200 \times 2$
$T - 1\,962 = 200 \times 2$ ✓
$T = 2\,362$ N upwards ✓ (2) [Ap]

c) Newton's second law (1) [K]
[5]

Total: 40

TOPIC 1.5 Force, density and pressure

LB pages 86–102

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Know different types of forces • Know and apply turning effects of forces • Understand equilibrium of forces • Understand density and pressure, and apply these in calculations
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with observations during experiments. Adjust the scale of the vector diagrams so that visually impaired learners can still apply the vector principles. All diagrams should be enlarged for learners and sufficient verbal explanations should be given.
Suggested teaching time	12 lessons
Additional resources needed	Calculator, glass prism or triangular-shaped pivot, wooden plank, blocks of different masses, protractor, balance, metre rule, measuring cylinder

Introduction to this topic

This topic covers forces, pressure and density. Most of the learners will be familiar with these concepts, but it is worth revising them before moving on to the calculations.

The sub-topics in this topic include many formulae, and it is important that learners are confident working with equations. Many of the questions in this topic will also be theory-based, so ensure that learners have a solid understanding of the content before moving on.

Teaching guidelines

It is important that learners can identify forces. Use several different examples like those in Activity 1 on page 88 of the Learner's Book to give them practise. Ensure that learners understand that force is a vector, so they need to give the direction in which the force acts.

Use practical examples like a spanner, a door and a seesaw to explain the turning effect of forces.

Build on the basic knowledge needed for this topic so that learners start with the easier calculations first. Do the worked examples on pages 90 and 91 of the Learner's Book as a class, before allowing the learners to work independently through the questions in Activities 2 and 3.

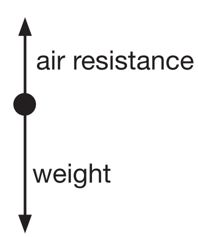
Starter activity

(LB page 86)

The aim of this activity is to check whether the learners remember what they learnt in Grades 10 and 11 about forces. It is essential that the learners can correctly name common forces and represent them using force diagrams.

Suggested answers

1.



2. The force of gravity acting on the boulder is greater than the air resistance, which is why the object accelerates downwards.

3. The denser boulder has more mass so its weight is greater. However air resistance, which depends on velocity and shape, is not greater because the gravitational acceleration is the same for both of them.

Sub-topic 1.5.1: Types of forces
LB pages 87–88

Beginning these lessons

This topic revises work done in Grades 10 and 11. Learners should be able to work independently through the topic, but it is a good idea to start the lesson by revising common forces. Identify objects in the classroom and then ask learners to identify the forces acting on them.

Types of forces (LB pages 87–88)

Teaching guidelines

Diagrams are a good way to introduce this topic. Emphasise that force is a vector, so the length and direction of the arrow represents the magnitude and direction of the force.

Identify the forces acting on different objects in the classroom. You could also roll a ball along the ground, slide a toy car down a slope or get a group of learners to play tug-of-war. Then ask learners to identify the forces acting on the systems.

As a class, discuss the effects the forces could have on the different objects and how a change in the magnitude of a force could affect motion.

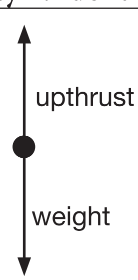
Homework

Ask learners to develop their own questions for their peers. Each learner needs to identify a moving object, such as a ball or a paper aeroplane, and their partner must identify and draw a force diagram to show all the forces that act on the object.

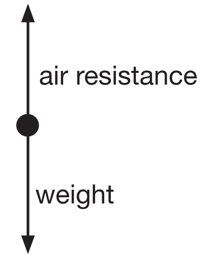
Suggested answers

Activity 1: Identify forces (LB page 88)

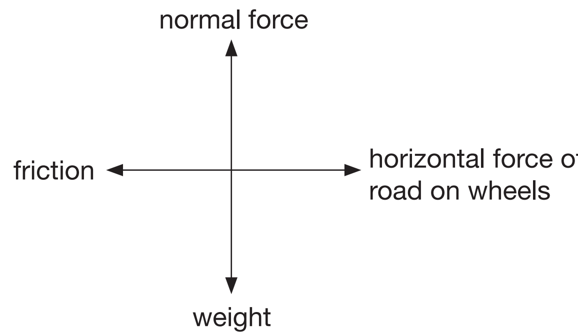
1. a)



b)



2.



3. The force of gravity

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Go through the answers for Activity 1 in class. Ensure the learners can identify all common forces. You can record the marks for this activity for informal assessment purposes.

Sub-topic 1.5.2: Turning effects of forces
LB pages 89–91

Beginning these lessons

Try to link the content of this topic to real life. For example, a door on a hinge and a pair of scissors are all examples of turning forces. Ask learners to draw their own conclusions about how the length of the turning arm affects the force produced.

Turning effect of forces and couples (LB pages 89–91)

Teaching guidelines

Start this topic by defining the moment of a force. If possible, bring different-sized spanners to school and give learners the opportunity to investigate for themselves which spanner requires the least amount of effort to undo a nut.

Much of this this topic is calculation-based, so it is essential that learners have a calculator they can use. Read through the questions in class and ensure that learners have enough time to work through the examples. Ask learners who are more mathematically competent to assist those who struggle. Ensure that learners know the meaning of the term "perpendicular".

Go through the worked examples on pages 90 and 91 of the Learner's Book as a class before allowing the learners to work in pairs to answer Activities 2 and 3.

Suggested answers

Activity 2: Calculate moments (LB page 90)

1. moment = $F \times d$
   moment = $12 \times 0.25 = 3$ N·m
2. The moment will increase because it is directly proportional to the perpendicular distance.

Activity 3: Calculate couples (LB page 91)

1. The forces must:
   - act in opposite directions
   - be equal in magnitude
   - be parallel.
   - acts along different lines of action.
2. a) The beam will rotate about its axis. It will rotate faster and faster.
   b) torque = $F \times d$
   torque = $\frac{20 \times 0.2}{2} = 2$ N·m

Sub-topic 1.5.3: Equilibrium of forces
LB pages 92–95

Beginning these lessons

In this sub-topic, learners explore the concept of equilibrium. Start the lesson by explaining what we mean when we say that a system is in equilibrium, and when we say that a system is in balance.

To demonstrate, use a ruler or a plank resting on a tin can. Add a rock or a mass piece to one end of the plank and then slowly add rocks to the other end until the plank is balanced. Ask the learners as a class to predict what they think will happen if the first rock is moved closer to the plank's turning point.

Principal of moments and coplanar forces in equilibrium (LB pages 92–95)

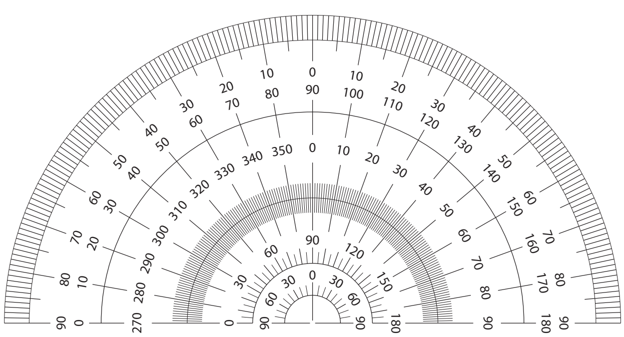
Teaching guidelines

Read through the questions in class with the learners and ensure they have enough time to work through the examples. You can give them additional examples to practise by changing the values given in Activity 4 on page 93 of the Learner's Book. If you change the distance of the object from the fulcrum, learners should get a different answer.

Make sure that learners can convert between different quantities, for example, between centimetres and metres. Learners who are mathematically competent can assist those who struggle.

Use more diagrams like those on pages 92 and 93 of the Learner's Book to help learners visualise the concepts.

Some learners may not have their own protractor or may have forgotten theirs at home. You can photocopy and enlarge the one below, and print it on thin paper. Keep a stock of these paper protractors in class for learners who do not have their own and need to draw vector diagrams.



Homework

Learners can complete the results and conclusion of Experiment 1 on pages 93 and 94 of the Learner's Book for homework. The process will teach them to draw their own conclusions from data they have collected. You can then discuss learners' conclusions in the next lesson as a class.

Suggested answers

Activity 4: Use the principle of moments

(LB page 93)

1. $F \times d$ (clockwise) = $F \times d$ (anticlockwise)
   $2 \times d = 3 \times 0.3$
   $d = 0.45$ m
2. $F \times d$ (clockwise) = $F \times d$ (anticlockwise)
   $27 \times 9.8 \times 2 = m \times 9.8 \times 1.8$
   $m = 30$ kg

Experiment 1: Verify the principle of moments

(LB page 93)

Results:

- Learners should draw a single table.
- All columns should include a heading and units.
- Ensure the correct units are used, for example, d should be measured in meters (m).
- Conclusion: $F \times d$ (clockwise) = $F \times d$ (anticlockwise)
- Accept sensible sources or error, for example, reading the metre rule from the wrong position and the balance not being tared properly.
- The uncertainty will depend on the instruments the learners used.

Activity 5: Use the triangle law of forces

(LB page 95)

- Ensure that the learners have drawn the diagram to scale.
- Learners must use a protractor.
- Accept a range of values within 0.5 N of 4.5 N at an angle of 15° ± 1° to the vertical.

Sub-topic 1.5.4: Density and pressure

LB pages 96–99

Beginning these lessons

In this topic, learners look at density and pressure in more detail. They are given the opportunity to work with the volume and area of three-dimensional shapes.

While pressure is not a new concept for learners, hydrostatic pressure is probably unfamiliar to most of them. Make sure that you define all new terms at the beginning of the lesson for learners.

You can introduce this topic by preparing a measuring cylinder containing liquids of different densities (which you can colour with food colouring), for example, lamp oil, rubbing alcohol, vegetable oil, water, dish soap, milk, syrup and honey.

It is a colourful way of introducing density, and a good way to start a class discussion on what determines the density of a substance.

Density and pressure, and the relationship between them

(LB pages 96–99)

Teaching guidelines

This topic can be confusing for some learners because they will need to be able to convert between units. To help them, encourage learners to highlight the units given in the question and identify the units required in the answer.

Make sure that all learners can use the scientific notation function on their calculator. Encourage learners to convert from centimetres to metres by simply multiplying by 10^{-2} and from millimetres to metres by multiplying by 10^{-3}. For example, 3 cm is equal to 3×10^{-2} m.

Homework

Ask learners to bring a simple three-dimensional object from home to class. This could be a tin, a brick or a cardboard cylinder. The class can then use the start of the lesson to determine the volume of their object using the appropriate formula.

Suggested answers

Activity 6: Calculate density (LB page 97)

$V = l \times b \times h = 0.04 \times 0.12 \times 0.03 = 0.000144 \text{ m}^3$

$\rho = \frac{m}{v} = \frac{0.12}{0.000144} = 833.33 \text{ kg·m}^{-3}$

Activity 7: Calculate density and pressure

(LB page 99)

1. a) $w = mg$
   $w = 60 \times 9.81$
   $w = 588.6$ N
   b) $P = \frac{F}{A}$
   $P = \frac{588.6}{0.003} = 1.96 \times 10^5$ Pa
   The ice will crack.
2. a) $P = \rho \times h \times g$
   $P = 100 \times 1\,000 \times 9.81 = 981\,000$ Pa
   The submarine will be safe.
   b) Less safe. In practice, submarines have a high margin of safety.

Extension activity

Copy the following question on the board and allow the learners to work in pairs in class. These marks can the form part of their informal assessment mark.

Question:

A polystyrene block has a mass of 12 g and a volume of 1 5cm^3.

a) Calculate the density of the block. (2)

b) The table below lists the densities of some liquids.

Substance	Density ($g{\cdot}cm^{-3}$)
Alcohol	0.791
Water	1.000
Oil	0.930
Gasoline	0.690

Identify in which of the liquids the block will sink. (2)

Answers:

a) $\rho = \frac{m}{V} = \frac{12}{15}$ ✓ $= 0.8\ g{\cdot}cm^{-3}$ ✓

b) The block will sink in alcohol ✓ and gasoline ✓ because it has a higher density than those liquids.

You can give this activity to learners who have completed their work before the rest of the class. In this activity, learners are required to determine the density of an irregularly shaped object, for example, a stone. The learners need to describe the method they used, showing all their calculations. Mark this activity using the rubric below.

Marks	0–1	2–3	4–5
Method	Required assistance to determine method.	An appropriate method was used, but it was not described in a logical manner.	Method was appropriate and well described.
Calculations	The incorrect formula was used.	The correct formula was used, but the substitution of values was incorrect.	The correct formula was used and the values correctly substituted.
Units	No units were included.	Units were included, but they were incorrect.	The correct units were included in the answer.

Total: 15

Remedial support activity

Give learners who struggle with formulae the opportunity to practise extra examples at home. Copy the following examples onto the board and ask learners to complete them for homework.

1. Determine the volume of a cube with sides 3 cm long.
2. Determine the density of a wooden cylinder that has a mass of 2 kg, a radius of 2 cm and a height of 10 cm. Give the answer in $g{\cdot}cm^{-3}$.
3. A block has density of 2.5 $g{\cdot}cm^{-1}$ and a volume of 12 cm^3. Determine its mass.

Suggested answers

1. $V = s^3 = 3^3 = 27\ cm^3$
2. $V = \pi r^2 h = 3.14 \times 2^2 \times 10 = 125.6\ cm^3$

   $\rho = \frac{m}{v} = \frac{2\,000}{125.6} = 15.92\ g{\cdot}cm^{-3}$ or $15\,920\ kg{\cdot}m^{-3}$
3. $\rho = \frac{m}{v}$

   $m = v \times \rho$

   $m = 2.5 \times 12$

   $m = 30$ g

Summary (LB page 100)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps consolidate what they have learnt.

Self-assessment (LB pages 101–102)

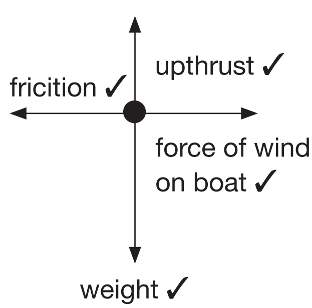
Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. C ✓ (1) [K]
3. C ✓ (1) [Ap]
4. B ✓ (1) [Ap]
5. C ✓ (1) [An]
[5]

6. a)



(4) [U]

b) $1.02\ g{\cdot}cm^{-3} = 1\ 020\ kg{\cdot}m^{-3}$ ✓
$\Delta p = \rho g \Delta h = 1\ 020 \times 9.81 \times 60$ ✓
$= 600\ 372$ Pa ✓ (3) [Ap]
[7]

7. a) $V = \pi r^2 h$ ✓ $= 3.14 \times (0.05)^2 \times 0.1$ ✓
$= 0.000785\ m^3$ ✓ (3) [Ap]

b) i) The force experienced by a mass in a gravitational field ✓✓ (1) [K]

ii) $\rho = \frac{m}{V}$
$\rho = \frac{400 \div 9.81}{0.000785}$ ✓
$= 51\ 942.32\ kg{\cdot}m^{-3}$ ✓ (2) [Ap]

iii) $P = \frac{F}{A} = \frac{F}{\pi r^2}$ ✓ $= \frac{400}{3.14 \times (0.05)^2}$ ✓
$= 50\ 955.41$ Pa ✓ (3) [Ap]

iv) It would be four times greater. ✓ Pressure is inversely proportional to r^2. ✓ This means that if r was halved, the pressure would be 2^2 times bigger. ✓ (3) [S]
[11]

8. a) The product of force and perpendicular distance through the line of action from the pivot ✓ (1) [K]

b) $F \times d$ (clockwise) $= F \times d$ (anticlockwise)
0.5×5 ✓ $= F \times 0.25$ ✓
$F = 10$ N ✓ (3) [Ap]

c) 0.5 m ✓ In order for the system to be in equilibrium, $F \times d$ (clockwise) $= F \times d$ (anticlockwise). ✓ If the force on one side doubles, the distance on the other side must also double to keep the moments on either side equal. ✓ (3) [U]
[6]

9. a) $\rho = \frac{m}{V}$ ✓ (1) [K]

b)
- Use a scale to determine the mass of the stone in kilograms. ✓
- Place 50 cm^3 of water in a 100-cm^3 measuring cylinder. ✓
- Place the stone in the measuring cylinder and note the new volume of water. ✓
- The difference between the two volumes of water is the volume of the stone in cm^3. ✓
- Convert the reading to m^3 by multiplying by 10^{-6}.
- Density is equal to the mass divided by the volume. ✓ (max 4) [S]

c) Higher ✓ (1) [An]
[6]

Total: 35

TOPIC 1.6 Work, energy and power

LB pages 103–118

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Understand energy conversions and its conservation • Understand work and its efficiency, including implications of energy loss • Understand the relationship between potential and kinetic energy • Understand power and its calculations
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning
Inclusive education	Visually impaired learners need assistance with observations during experiments. Learners with dyscalculia will struggle with the mathematical formulae used. Ensure that all problems are approached methodically and teach the learners a step by step method if applicable.
Suggested teaching time	12 lessons
Additional resources needed	Calculator, various electrical appliances for comparison in class, the Internet if possible for simulations

Introduction to this topic

Introduce this topic by briefly discussing what energy is. Most learners should be familiar with the concept of energy, but it would be useful if you revised the different types of energy with them. Use practical examples that can be found in the classroom like a fan or lightbulb.

Starter activity

(LB page 103)

This activity will help you assess whether learners are familiar with the different forms of energy. Use this activity to introduce the idea of energy conversion. Ensure that learners who are visually impaired sit next to a learner who can describe the images to them.

Suggested answers

1. Chemical energy to heat and light energy
2. Electrical energy to sound energy
3. Electrical energy to light energy

Sub-topic 1.6.1: Energy conversion and conservation

LB pages 104–106

Beginning these lessons

Start this lesson by stating the law of conservation of energy. Learners must be able to state this law word for word, but they also need to understand what it means.

Explain how energy can never disappear – it only changes from one form to another. Use energy conversions, like a heater turning electrical energy into heat energy or a radio turning electrical energy into sound energy, to explain how energy is transformed.

Energy forms, and energy conversion and conservation

(LB pages 104–106)

Teaching guidelines

To familiarise the learners with the different energy conversions, give them a class quiz. Give each learner five pieces of paper labelled "sound energy", "heat energy", "electrical energy", "chemical energy" and "potential energy". Name an everyday object that uses energy such as a hairdryer. The learners then hold up the two pieces of paper that relate to the energy conversion that takes place. In the case of the hairdryer, the learners would hold up the pieces of paper labelled "electrical energy" and "heat energy". You can link energy conversions to electrochemistry and batteries.

Homework

Ask learners to draw a mind map showing the different forms of energy. Ask them to link the different forms of energy by giving examples of appliances that convert one energy type to another.

Suggested answers

Activity 1: Identify energy conversions (LB page 106)

1. Electrical energy to heat and sound energy
2. Chemical energy to heat and light energy
3. Mechanical energy to electrical energy
   You can use Activity 1 as informal assessment. Give one mark for each correct form of energy. This activity can be peer-assessed in class and the marks recorded as diagnostic assessment.

Sub-topic 1.6.2: Work and efficiency

LB pages 107–109

Beginning these lessons

Start the lesson by briefly discussing what work is. Explain that various factors can affect whether work is done. Ensure that all learners are familiar with the formula and know the units that each of the quantities in the formula must be measured in.

Lift a book off the table and ask the learners if work is being done to lift the book. Now carry the book across the class. Is work still being done? Use this as an opportunity to explain the role direction plays in whether work is being done.

Work and efficiency (LB pages 107–109)

Teaching guidelines

Ensure that learners know and understand the definition of work and efficiency. Make sure that learners can convert between different units, for example, from centimetres to metres, by practising some examples in class.

Help learners understand that they can convert joules to kilojoules by simply multiplying by 10^3. For example, 3 kJ is equal to 3 × 10 J.

Homework

You can give the learners Activity 2 to do as homework and mark their answers in the following lesson. Pair learners who struggle with Mathematics with those who are more competent.

Suggested answers

Activity 2: Calculate work (LB page 108)

1. Because the crane lifts the box with a constant velocity, the upwards and downwards forces must be equal in magnitude.
   $F = mg = 500 \times 9.81 = 4\ 905$ N upwards
2. $W = F \times d$
   $W = 4\ 905 \times 25 = 122\ 500$ J
3. More work is done. For the box to accelerate upwards, the upward force must increase so that it is greater than the weight of the box. Work is directly proportional to the magnitude of the force exerted on it, which means the work done must increase.

Activity 3: Calculate efficiency (LB page 109)

1. $\text{efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$
   $\text{efficiency} = \dfrac{100}{150} \times 100\% = 66.67\%$
2. If a lightbulb is 87% efficient, 13% of the energy is converted into heat energy.
   $\dfrac{200}{13} \times 87 = 1\ 338.46$ J of energy is converted into light energy.

Extension activity

You can give the learners who finish their work in class before the others the following apparatus and ask them to design their own pulley.

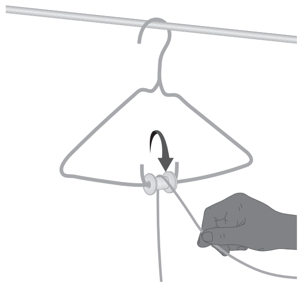
Materials:

- wire hanger
- pliers or strong scissors
- thread spool
- string or wire

Method:

1. Use the pliers or scissors to cut through the middle of the wire hanger.
2. Thread the two ends of the wire through the spool. Use the pliers to bend the open ends of the wire upwards as shown in the diagram. Be careful not to cut yourself on the wire.
3. Hang the wire hanger from a pole.

4. Thread the string over the spool.



5. Use your pulley to lift different objects like pencils, books and bricks. What happens if the object is too heavy for the pulley? How could you make your pulley more effective?

Sub-topic 1.6.3: Potential and kinetic energy LB pages 110–113

Beginning these lessons

The concepts of kinetic energy and potential energy should be familiar to most learners, but start the lesson by defining these two forms of energy for reinforcement. Ask the learners to describe a situation in which kinetic energy is converted to potential energy, and vice versa.

Use a ball to demonstrate the difference between potential energy and kinetic energy. Hold the ball above your head. Ask the learners to identify the type of energy that the ball has. Now drop the ball. Does the ball still have energy? Ask the learners to identify the type of energy it has. Link this to the conservation of energy discussed in Sub-topic 1.6.1 of the Learner's Book.

Kinetic energy and potential energy (LB page 110–113)

Teaching guidelines

This topic can be quite mathematical. Ensure that learners are familiar with the formulae for kinetic energy and potential energy, and can convert between the units in each formula. Pair those learners who struggle with Mathematics with those who are more confident.

Simulations like those found at https://phet.colorado.edu/ can help learners visualise the different situations. If you do not have access to the Internet, use diagrams instead. Encourage the learners to draw the situations.

Make sure you allow enough time in class for learners to practise examples similar to the questions in Activities 4 and 5 on pages 111 and 113 of the Learner's Book. If you have access to the Internet, you can use it to search for questions to give the learners.

Ensure that learners do not confuse gravitational potential energy with elastic potential energy. Use an elastic band or a spring to demonstrate elastic potential energy.

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. You can give the learners Activity 4 to do for homework and mark it in class the next day. Use it as a baseline to determine whether learners understand the concepts.

Suggested answers

Activity 4: Calculate kinetic energy (LB page 111)

1. $E_k = \frac{1}{2}mv^2$

   $E_k = \frac{1}{2} \times 300 \times 4^2 = 2\,400$ J
2. The kinetic energy will be four times greater. E_k is directly proportional to v^2. This means that if the velocity doubles, the kinetic energy will be 2^2 times greater.
3. $\Delta E_k = E_{kf} - E_{ki}$

   $\Delta E_k = 2\,400(4) - 2\,400$

   $\Delta E_k = 7\,200$ J

Activity 5: Understand kinetic and gravitational potential energy conversion (LB page 113)

1. a) $E_p = mgh$

   $E_p = 50 \times 9.81 \times 10 = 4\,905$ J

   b) i) Gravitational potential energy to kinetic energy

   ii) 4 905 J

   iii) $E_k = \frac{1}{2}mv^2$

   $4\,905 = \frac{1}{2} \times 50 \times v^2$

   $v^2 = 196$

   $v = 14.01$ m·s^{-1}

2. a) $E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2} \times 900 \times 3^3 = 4\ 050$ J

b) $E_p = mgh$

$E_p = 900 \times 75 \times 9.81 = 662\ 175$ J

c) $E_m = E_p + E_k$

$E_m = 662\ 175 + 4\ 050 = 666\ 225$ J

d) E_k at the bottom = mechanical energy

$E_k = \frac{1}{2}mv^2$

$666\ 225 = \frac{1}{2} \times 900 \times v^2$

$1\ 480.5 = v^2$

$v = 38.48$ m·s^{-1}

You can use Activity 5 as informal assessment. The questions cover a lot of the content and will allow you to gauge the learners' understanding. Ask the learners to complete the activity on a separate piece of paper, which they can then hand in to be marked according to the memo above. The marks are then recorded and included in their informal assessment mark.

Sub-topic 1.6.4: Power LB page 114

Beginning these lessons

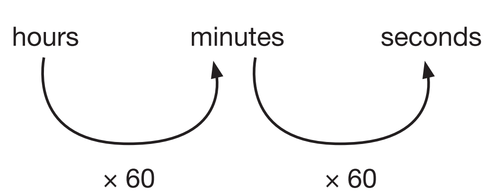
Start this lesson by discussing the different meanings of the word "power" with the learners. Bring some electrical appliances to class like a kettle or a lightbulb. Show the learners where the power rating is written and ask them what they think this means.

Power (LB page 114)

Teaching guidelines

This topic can be fairly mathematical. Ensure that learners are familiar with the formula for power and can convert between units. Pair learners who struggle with Mathematics with those who are more competent.

Remind learners that they should always convert time into seconds. You can use the diagram below to help them with this.



Homework

Ask learners to go home and compare the power ratings of different appliances. Ask them to think about how the power rating affects the efficiency of an appliance. State the advantages and disadvantages of an appliance with a higher power rating.

Remedial activity

Give learners who are having trouble with the mathematical aspects a copy of the questions below and ask them to answer them for homework. These questions focus on changing the subject of the formula, which is challenging for many learners.

1. We can calculate the kinetic energy of an object using the formula $E_k = \frac{1}{2}mv^2$. Rewrite the formula so that mass is the subject.
2. An object with a mass of 5 kg is at rest at the top of a hill. It has a gravitational potential energy of 23 000 J. Determine the height of the hill.

Suggested answers

1. $m = 2 \times \frac{E_k}{v^2}$
2. $E_p = mgh$

   $h = \frac{E_p}{mg}$

   $h = \frac{23\ 000}{5} \times 9.81 = 469.4$ m

Summary (LB pages 115–116)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but helps them consolidate what they have learnt.

Self-assessment (LB pages 117–118)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [Ap]
2. B ✓ (1) [Ap]
3. A ✓ (1) [K]

4. A ✓ (1) [S]

5. A ✓ (1) [U]

[5]

6. a) $\Delta V = A \times \Delta x$

$\Delta V = 0.01 \times 3.5$ ✓ $= 0.035\ m^3$

$W = p\Delta V$

$W = 1.5 \times 10^5 \times 0.035$ ✓ $= 5\ 250\ J$ ✓ (3) [Ap]

b) $P = \frac{W}{\Delta t}$ ✓ $= \frac{5\ 250}{0.2}$ ✓ $= 26\ 250\ W$ ✓ (3) [Ap]

c) It increases it. ✓✓ (2) [U]

[8]

7. a) The product of the magnitude of a force ✓ and the distance moved in the direction of the force ✓ (2) [K]

b) $W = \Delta E_p = mgh$ ✓

$W = 150 \times 9.81 \times 15$ ✓ $= 22\ 072.50\ J$ ✓ (3) [Ap]

c) efficiency $= \frac{22\ 072.50 ✓}{50\ 000 ✓} \times 100$

$= 44.15\%$ ✓ (3) [Ap]

d) Gravitational potential energy ✓ to kinetic energy ✓ (2) [U]

e) E_p at top $= E_k$ at the bottom ✓

$22\ 072.50 = \frac{1}{2}mv^2$

$22\ 072.50 = \frac{1}{2} \times 150 \times v^2$ ✓

$v = 17.16\ m{\cdot}s^{-1}$ ✓ (4) [Ap]

[14]

8. a) $E_p = mgh$

$20\ 000$ ✓ $= 65 \times 9.81 \times h$ ✓

$h = 31.40\ m$ ✓ (3) [Ap]

b) 20 000 J ✓ (1) [U]

c) Mechanical energy is conserved, so E_p at top $= E_k$ at the bottom. ✓

$20\ 000 = \frac{1}{2}mv^2$

$20\ 000 = \frac{1}{2} \times 65 \times v^2$ ✓

$v = 24.81\ m{\cdot}s^{-1}$ (2) [Ap]

d) Mechanical energy is not conserved if there are friction forces, and so not all the potential energy is converted into kinetic energy. (1)

[8]

Total: 35

TOPIC 1.7 Deformation of solids

LB pages 119–135

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Compare stress and strain, and apply these concepts in deformation of solids • Understand elastic and plastic behaviour
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Health and well-being; HIV and AIDS awareness
Inclusive education	Visually impaired learners need assistance with observations during experiments, especially when working with small instruments like micrometers. Use items like elastic bands, metal wire and a tin can to help these learners visualise the concepts.
Suggested teaching time	15 lessons
Additional resources needed	Clamp, spring, retort stand, metre rule, mass pieces, sticky tape, pointer, pulley, pointer, wire, micrometer screw gauge

Introduction to this topic

Most learners will be able to relate to this topic. They can apply the science they learn to the world around them. In this topic, we discuss materials and how they are affected when a force is applied to them.

Use items in the classroom, like metal wires, elastic bands and clay, to demonstrate the concepts of elasticity and how materials are deformed.

Starter activity (LB page 119)

A good way to approach this activity is with a class discussion. The activity encourages learners to think about the materials around them and why they were chosen to be used for that specific purpose. Encourage learners to share their views and to start thinking about how materials are affected by forces.

Suggested answers

- Iron is used to make steel.
- Steel can be used to make strong beams.
- Cement is mixed with sand, stones and water to make concrete.
- Although concrete can support heavy loads it is weak when it is stretched.
- Concrete is reinforced by placing steel rods inside it that are strong when under tension.
- Wood is light and strong but rots in water.

Sub-topic 1.7.1: Stress and strain

LB pages 120–127

Beginning these lessons

Introduce this sub-topic by describing different materials in the classroom like metal, wood, chalk and plastic. Ask the learners to explain why a material has been chosen for a particular use.

Apply a force to the materials: stretch them, crush them and throw them (if you can). Ask the learners to predict how these materials will behave. Use this to introduce the concepts of stress and strain.

Deformation of solids in one direction (LB pages 120–127)

Teaching guidelines

This sub-topic is new for most learners and it contains some terms that will be unfamiliar to them. Ask the learners to write down the definitions of key words at the back of their books for easy reference. Use the key word boxes in the Learner's Book as a reference for the words that the learners will need to know.

Allow learners enough time in class to practise examples. If you have access to the Internet, you can use it to find suitable practice questions to give the learners. Pair weaker learners with those who are good at Mathematics. This sub-topic also gives learners the opportunity to practise drawing and reading information from graphs. Learners need to plot their results for Experiment 1 on page 121 of the Learner's Book on a graph. Ensure all learners:

- use an appropriate scale
- use a sharp pencil
- can plot a line of best fit so that there are equal numbers of points on either side of the line.

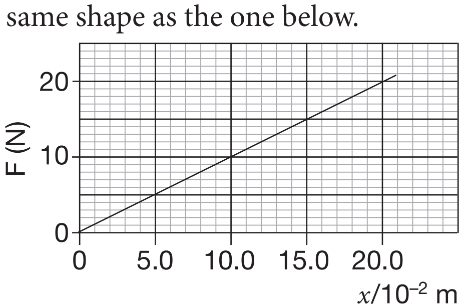
Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Learners can plot the graph for Experiment 1 for homework once they have obtained all the data in class. Learners should plot the graph independently and you can then mark it in class during the next lesson. The readings for each group will be different, but ensure that they have plotted the points correctly according to the data they obtained.

Suggested answers

Experiment 1: Determine the relationship between load and the extension of a spring (LB page 121)

1. The graph should be a diagonal straight line with a positive gradient. It should have the same shape as the one below.



2. Directly proportional; as one quantity increases, the other will also increase by the same amount.
3. Calibrations on a metre ruler are not as precise as other instruments for measuring length. Human error could play a role if the lengths were not measured accurately. The length could be measured incorrectly if the learner did not wait for the spring to be at rest before measuring its length.

Activity 1: Use Hooke's Law (LB page 123)

1. $F = kx$, therefore $k = \frac{F}{x}$
   $k = 0.140 \times \frac{9.81}{0.035} = 39.2$
2. **a)** $k = \frac{F}{x} = \frac{45}{0.0015} = 30\ 000$
   b) $F = kx$
   $F = 30\ 000 \times 0.0018 = 54$ N

Activity 2: Calculate stress (LB page 125)

1. $A = \pi r^2$ where $r = \frac{1}{2}d$ so $A = \frac{1}{4}\pi d^2$
   $A = \frac{1}{4} \times 3.14 \times (0.0025)^2 = 4.91 \times 10^6\ \text{m}^2$
   $\sigma = \frac{F}{A} = \frac{15}{4.91 \times 10^{-6}} = 3.055 \times 10^6$ Pa
2. **a)** $A = \frac{1}{4}\pi d^2$
   $A = \frac{1}{4} \times 3.14 \times (0.003)^2 = 7.065 \times 10^{-6}\ \text{m}^2$
   $\sigma = \frac{F}{A} = \frac{60}{7.065\ 10^{-6}} = 8.49 \times 10^6$ Pa
   b) $\varepsilon = \frac{e}{L} = \frac{3.2 - 3}{3} = 0.067$

Activity 3: Calculate Young's modulus (LB page 126)

1. Tensile stress is defined as the deformation force per unit area of a body or material. Tensile strain is defined as the ratio between the change in length of a material and its original length.
2. **a)** $\sigma = \frac{F}{A} = \frac{60}{1.3 \times 10^{-6}} = 4.615 \times 10^7$ Pa
   b) Young's modulus $= \frac{\sigma}{\varepsilon}$
   $\varepsilon = \frac{4.615 \times 10^7}{2.1 \times 10^{11}} = 2.198 \times 10^{-4}$
   c) $\varepsilon = \frac{e}{L}$
   $e = \varepsilon \times L = 2.198 \times 10^{-4} \times 1.6$
   $e = 3.52 \times 10^{-4}$ m

Experiment 2: Determine Young's modulus of a metal wire (LB page 127)

1. Set up apparatus for this experiment beforehand.
   - Safety precautions in case wire breaks: Wear goggles and stand away from the wire.
   - Alternative experiment: Find Young's modulus for an elastic band.

   Ensure the area is measured in m^2.
2. Learners must calculate Young's modulus using the formula $E = \frac{\sigma}{\varepsilon} = \frac{F}{A} \times \frac{L}{e}$.

All learners will have different readings. The answer is not as important as the method the learners used. Make sure the learners substituted the values in correctly and that all readings are measured in the correct units.

3. Sources of error could include measuring the distance moved by the load and measuring the diameter of the wire

Sub-topic 1.7.2: Elastic and plastic behaviour LB pages 128–132

Beginning these lessons

Introduce this sub-topic using an elastic band and a piece of thread. Ask a learner to stretch the two. Ask the class to describe what happens. Do the two materials behave differently? Use this as an opportunity to introduce new terms like "elasticity" and "fracture point".

Elastic and plastic deformation, and work (LB pages 128–132)

Teaching guidelines

Always ensure that learners understand the terms being used. Use the key word boxes in the Learner's Books as a guide.

Using diagrams and graphs is a good way to teach this topic. Graphs help learners visualise the concepts.

Allow enough time to practise examples in class. You can use the Internet if you have access to it to search for suitable practice questions.

Pair learners who struggle with those who are good at Mathematics. Work through the worked examples on page 131 before allowing the learners to complete the activities independently.

Homework

Learners can complete Activity 4 at home if they do not finish it in class. Learners use the strain and stress graphs to interpret the difference between a ductile material and a brittle material.

Suggested answers

Activity 4: Interpret stress–strain graphs (LB page 129)

1. The elastic region
2. It stretches, then returns to its original shape.
3. This is the fracture point. It breaks.
4. Graph (a) shows that a ductile material can be stretched a lot before breaking. Graph (b) shows that a brittle substance fractures suddenly after reaching its maximum stress.

Activity 5: Calculate work (LB page 132)

1. k = gradient of graph = $\frac{\Delta y}{\Delta x}$

   $k = \frac{10 - 0}{0.02 - 0} = 500\ \text{N·m}^{-1}$

2. $W = \Delta E_p = \frac{1}{2}kx^2$

   $W = \frac{1}{2} \times 500 \times (0.02)^2$

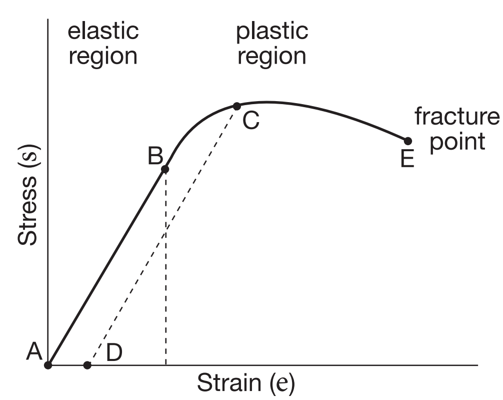
   $W = 0.1\ \text{J}$

Remedial activity

Give learners who are having trouble with the activities or concepts in this sub-topic a copy of the graph below and then ask them to identify:

- regions A–B and B–C
- point E.

Demonstrate these regions using an elastic band.



Suggested answers:

- A–B: elastic region
- B–C: plastic region
- E: fracture point

Summary (LB page 133)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them to consolidate what they have learnt.

Self-assessment (LB pages 134–135)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment opportunity.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. B ✓ (1) [Ap]
3. C ✓ (1) [Ap]
4. C ✓ (1) [K]
5. C ✓ (1) [Ap]

[5]

6. a) Tensile stress is defined as the deformation force per unit area of a body or material. ✓ (1) [K]

b) Tensile strain is defined as the ratio between the change in length of a material and its original length. ✓ (1) [K]

[2]

7. a) Elastic deformation occurs when a material is stretched or deformed, ✓ but once the force is removed, the material regains its original shape. ✓ [2] [U]

b) $L = ke$ ✓ [1] [S]

[3]

8. a) Young's modulus $E = \frac{\sigma}{\varepsilon}$

Therefore $\varepsilon = \frac{\sigma}{E} = \frac{2.20 \times 10^8}{1.20 \times 10^{11}}$

$= 1.833 \times 10^{-3}$ ✓

$\varepsilon = \frac{e}{L}$

Therefore $e = \varepsilon \times L = 1.833 \times 10^{-3} \times 1.75$ ✓

$= 3.21 \times 10^{-3}$ m ✓ (2) [Ap]

b) Young's modulus applies to elastic deformity only. ✓ (1) [K]

[3]

9. a) Hooke's Law states that for relatively small deformations of an object, the displacement or size of the deformation is directly proportional to the deforming force or load. ✓ (1) [K]

b) $k = \frac{F}{x} = \frac{0.2 \times 9.81}{0.12}$ ✓ $= 16.35$ ✓ (2) [Ap]

[4]

10. a) $0.5\text{mm}^2 = 0.5 \times 10^{-6}\ \text{m}^2$

$\sigma = \frac{F}{A} = \frac{10 \times 9.81}{0.5 \times 10^{-6}}$ ✓ $= 1.96 \times 10^8$ Pa ✓ (2) [Ap]

b) $\varepsilon = \frac{e}{L} = \frac{0.1 \times 10^{-2}}{100 \times 10^{-2}} = 1.00 \times 10^{-3}$

c) $E = \frac{\text{stress}}{\text{strain}} = \frac{1.96 \times 10^8}{1 \times 10^{-3}}$

$= 1.96 \times 10^{11}$ Pa (2) [Ap]

[6]

11. $A = \frac{1}{4}\pi d^2$

$A = \frac{1}{4} \times 3.14 \times (0.010)^2 = 7.85 \times 10^{-5}\ \text{m}^2$ ✓

$e = \frac{F \times L}{A \times E}$ ✓

$e = \frac{12 \times 0.5}{7.85 \times 10^{-5} \times 130 \times 10^9}$ ✓

$e = 5.88 \times 10^{-7}$ m ✓ (4) [Ap]

12. $E_p = \frac{1}{2}kx^2$ and $k = \frac{F}{x}$ ✓

Therefore, $E_p = \frac{1}{2}kx = \frac{1}{2} \times 12 \times 0.18$ ✓

$= 1.08$ J ✓ (3) [U]

13. a) $\varepsilon = \frac{F \times L}{A \times e}$

$\varepsilon = \frac{10 \times 2 ✓}{1.5 \times 10^{-7} \times 0.0011}$ ✓

$= 1.21 \times 10^{11}$ Pa ✓ (3) [Ap]

b) $E_p = \frac{1}{2}kx^2$

$E_p = 0.5 \times 9\,090.9 \times (0.004)^2$ ✓

$E_p = 0.073$ J ✓ (2) [Ap]

[5]

Total: 35

Theme 2 Waves

TOPIC 2.1 Progressive waves

LB pages 138–149

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Understand progressive waves including properties of waves
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with observations during experiments. Ensure that any graphs are enlarged so that learners who struggle to see can take readings from the graph.
Suggested teaching time	4 lessons
Additional resources needed	Large bowl or water trough, cork or small pebble, stopwatch, ruler

Introduction to this topic

Many of the learners will be familiar with the concept of progressive waves. In this topic, we explore the properties of progressive waves as well as some of the formulae that we use to determine unknown quantities.

This is an exciting topic to teach because you can demonstrate many of the principles practically. Learners are more likely to grasp the concepts if they can visualise them.

You can introduce this topic by simply dropping a stone or a coin into a water trough or bowl and asking the learners to describe what they see.

Starter activity (LB page 138)

This activity helps you to assess the learners' prior knowledge. This topic was covered in Grades 10 and 11, but it is essential that the learners revisit the basics before moving on to more complicated concepts.

Suggested answers

1. Amplitude: The maximum displacement of the particles from the equilibrium position
2. Wavelength: The distance between two consecutive crests or two consecutive troughs
3. Period: The time it takes for one complete wave or oscillation to pass a point
4. Frequency: The number of complete waves or oscillations that pass a point every second

Sub-topic 2.1.1: Understand progressive waves

LB pages 139–149

Beginning these lessons

A video is always a fun way to introduce the concept of waves. If you have access to the Internet, there are excellent videos available online. Type "progressive waves Physics Galaxy" into YouTube. This video gives a short description of what a progressive wave is.

Wave motion and the graphical representation of waves

(LB pages 139–143)

Teaching guidelines

This topic is a familiar one to most learners. They do, however, struggle to visualise the concepts. Explain that it is not the particles themselves that move forward, but rather the energy that is transferred from one particle to another. You will need to emphasise this.

You can use a slinky spring or a rope to demonstrate wave principles in class. Use the slinky to explain terminology like amplitude, wavelength and displacement. Use lots of diagrams in your explanations and allow time in class to discuss the concepts.

Homework

You can give learners Activity 1 to do for homework and mark it in class the next day. Or, you could ask learners to mark each other's work as you go through the answers. As this is not a new topic for learners, they should be able to complete this activity independently.

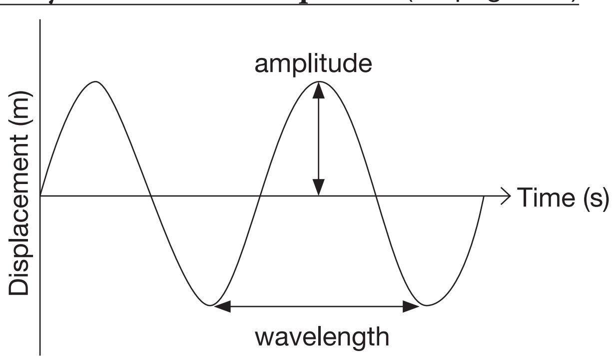
Suggested answers

Experiment 1: Investigate the relationship between energy, and the amplitude and period of the wave (LB page 142)

1. The amplitude increased as the height at which the cork was dropped increased.
2. It took less time for the waves to reach the edge of the bowl.
3. The more energy the cork had, the greater the amplitude and the shorter the period.

Activity 1: Use the wave equation (LB page 143)

1.



2. $T = \frac{1}{f}$ or $f = \frac{1}{T}$
3. 180°

The relationship between speed, frequency and wavelength, and the intensity of waves (LB pages 143–145)

Teaching guidelines

This topic is mathematical and the best way to teach it is by working through examples like those in Activity 2 on page 144. Ensure that learners can change the subject of the formula by working through the worked examples methodically, step by step.

Always be careful when using the terms "directly proportional" and "inversely proportional". Directly proportional does not simply mean that when one quantity increases the other quantity also increases. It means that that both quantities increase by the same proportion, for example, if one quantity doubles, the other quantity also doubles. If the quantity halves, the other quantity also halves.

Activity 2: Solve wave problems (LB page 144)

1. $v = f \times \lambda$
   $v = 20 \times 0.2 = 4\ \text{m·s}^{-1}$
2. a) $f = \frac{v}{\lambda}$
   $f = \frac{2.5}{0.2} = 12.5\ \text{Hz}$
   b) $T = \frac{1}{f} = \frac{1}{2} = 12.5 = 0.08\ \text{s}$
3. a) A vacuum is a space that has no matter in it.
   b) $v = f \times \lambda$, therefore $\lambda = \frac{v}{f}$
   $\lambda = \frac{3 \times 10^8}{4.2 \times 10^{14}} = 7.14 \times 10^{-7}\ \text{m}$
4. 0.8 m

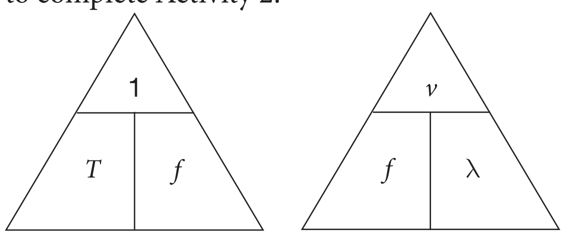
Informal assessment

Ask the learners to work through the worked examples at home. Then at the beginning of the next lesson, check if they have understood the concepts by writing only the question on the board.

Let them work out the answer in pairs with their books closed. You could then ask for feedback on the steps from some of the pairs. Ensure that they understand how the answer is calculated before attempting the activities.

Remedial activity

Some learners struggle with changing the subject of the formula. The following triangles may help them complete the activities. Allow these learners to copy the triangles into their book and use them to complete Activity 2.



Summary (LB page 146)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 147–149)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [K]
2. D ✓ (1) [K]
3. A ✓ (1) [Ap]
4. C ✓ (1) [Ap]

[4]

5. **a)** $\lambda = \frac{v}{f}$
   $\lambda = \frac{340}{500}$ ✓ $= 0.68$ m ✓ (2) [An]
   b) $v = f \times \lambda$
   $v = 0.08 \times 5$ ✓ $= 0.4\ \text{m·s}^{-1}$ ✓ (2) [An]
   [4]
6. For speed to stay constant when the wavelength doubles, the frequency would need to halve. ✓ Intensity is directly proportional to the frequency squared, so the intensity will be $\left(\frac{1}{2}\right)^2$, which means the intensity of wave 1 is one-quarter of the intensity of wave 2. ✓ [2] [S]
7. **a) i)** The distance between two consecutive crests or troughs ✓ (1) [K]
   ii) The number of complete waves that pass a point every second ✓ (1) [K]
   b) $v = f \times \lambda$ ✓ (1) [An]
   c) i) 0.2 m ✓ (1) [K]
   ii) $T = \frac{1}{f} = \frac{1}{2.5}$ ✓ $= 0.4$ s ✓ (2) [Ap]
   iii) $\lambda = \frac{v}{f} = \frac{0.25}{2.5}$ ✓ $= 0.1\ \text{m·s}^{-1}$ ✓ (2) [Ap]
   [8]
8. **a)** The waves transfer energy ✓ without transferring matter. ✓ (2) [K]
   b) $\lambda = \frac{v}{f} = \frac{320}{240}$ ✓ $= 1.33$ m ✓ (2) [An]
   c) i) $T = \frac{1}{f} = \frac{1}{240}$ ✓ $= 4.17 \times 10^{-3}$ s ✓ (2) [Ap]
   ii) 2.08×10^{-3} s ✓ (1) [S]
   [7]

Total: 25

TOPIC 2.2 Transverse and longitudinal waves LB pages 150–157

Syllabus coverage	See the syllabus grid (Year plan) in Section B.
General objectives	Know the differences between transverse and longitudinal waves
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning
Inclusive education	Visually impaired learners need assistance with observations during wave demonstrations. Use a slinky spring or rope to demonstrate the principles. All graphs should be enlarged for ease of use.
Suggested teaching time	4 lessons
Additional resources needed	Slinky spring or rope

Introduction to this topic

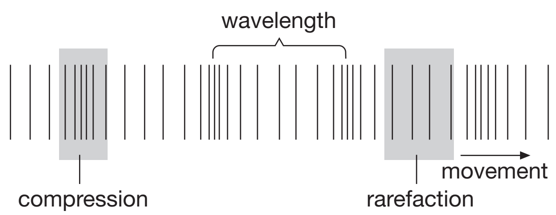
In this topic, we explore the differences and similarities between longitudinal and transverse waves. Learners need to be able to distinguish between them and identify them graphically.

You can introduce this topic using a slinky spring. Let a learner hold the slinky at one end. Move your arm up and down. Ask the learners to identify the type of wave produced. Now move the slinky backwards and forwards. Ask the learners to compare the motions and identify the type of wave produced.

Starter activity (LB page 150)

This activity reintroduces longitudinal waves to the learners. They need to be able to identify the components of the wave. The activity acts as a baseline for you to determine what they remember from Grades 10 and 11.

Suggested answers

1. **a)** 0.004 s
   b) The wavelength will need to halve for the speed to remain constant: $v = f \times \lambda$. If the frequency doubles, the wavelength will need to halve for the speed to stay constant.
2. 

Sub-topic 2.2.1: The difference between transverse and longitudinal waves LB pages 151–157

Beginning these lessons

Diagrams and simulations (if you have access to the Internet) are the best way to teach this sub-topic. Visualising the concepts makes it much easier for learners to retain the information.

Use ropes like those in Figure 2.2.7 in the Learner's Book to demonstrate wave principles. You can even make your own wave generator using a water trough or long tray and a ruler.

Transverse and longitudinal waves, and their graphical representation (LB pages 151–154)

Teaching guidelines

Terminology is an important aspect of this sub-topic. Learners can make their own glossary at the back of their books. Use the key word boxes like the one on page 151 of the Learner's Book to identify the important terms.

Homework

Learners can complete Activity 1 at home if they do not finish it in class. It is revision of work they did in Grades 10 and 11, so they should be able to complete it independently. The work can then be peer-assessed in class in the next lesson using the memorandum provided below.

Suggested answers

Activity 1: Distinguish between waves (LB page 152)

1. A longitudinal wave; the particles move parallel to the direction of propagation of the wave.
2. A: rarefaction; B: compression
3. For example, sound waves

Activity 2: Describe properties of progressive waves (LB page 153)

1. The particles themselves do not move towards the shore. It is the energy that is transferred towards the shore.
2. Transverse waves: The particles move (oscillate or vibrate) at right angles to the direction of propagation. Longitudinal waves: The particles move (oscillate or vibrate) parallel to the direction of propagation.
3. Diffraction

Informal assessment

Go through the answers to Activity 2 with the learners in the next lesson. Learners can mark their own work. You may record their marks for informal assessment.

Remedial activity

Simulations can be a fantastic way to help learners who are struggling to grasp the concepts. If you have access to the Internet, type "PHET wave on a string" into your browser.

This simulation allows learners to produce transverse waves. They can change the frequency, amplitude and wavelength of the wave. If you do not have access to the Internet, the learners can benefit from demonstrations using a rope or a slinky spring.

Summary (LB page 155)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps consolidate what they have learnt.

Self-assessment (LB pages 156–157)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

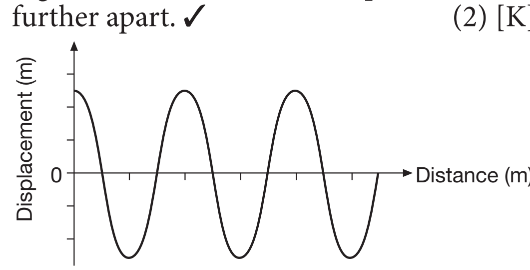
1. A ✓ (1) [K]
2. C ✓ (1) [K]
3. A ✓ (1) [An]
4. B ✓ (1) [K]
5. D ✓ (1) [U]

[5]

6. a) Transverse waves: The particles move (oscillate or vibrate) at right angles to the direction of propagation. ✓ (1) [K]
   b) Amplitude: The maximum displacement of a particle in a wave ✓ (1) [K]
   Wavelength: The distance between consecutive crests or troughs ✓ (1) [K]
   c) Water waves or electromagnetic waves ✓ (1) [K]

[4]

7. • Both are progressive waves. ✓
   • Both obey the wave equation. ✓
   • Both undergo refraction, reflection and diffraction. ✓ [3] [U]
8. a) Longitudinal waves: The particles move (oscillate or vibrate) parallel to the direction of propagation of the wave. ✓ (1) [K]
   b) Compression: The particles are closer together. ✓ Rarefaction: The particles are further apart. ✓ (2) [K]
   c)



✓✓ (2) [Ap]

[5]

9. a) Longitudinal ✓ (1) [K]
   b) $f = \frac{1}{T} = \frac{1}{0.02} = 50$ Hz
   $\lambda = \frac{v}{f} = \frac{340}{50}$ ✓ $= 6.8$ m ✓ (2) [Ap]

[3]

Total: 20

TOPIC 2.3 Determination of frequency and wavelength of sound waves

LB pages 158–167

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Know how to determine the frequency and wavelength of sound using a cathode-ray or PC oscilloscope
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and Communication Technology
Inclusive education	Visually impaired learners need assistance with the diagrams used in this topic. These diagrams can be explained in detail and their understanding should not be compromised. Help will be required for learners that are hearing impaired because they will struggle to hear the sound produced during the practical activities. They will need to be paired with a learner who can hear the change in tone.
Suggested teaching time	4 lessons
Additional resources needed	Cathode-ray oscilloscope if available, microphone, signal generator, loudspeaker, 1 000-cm^3 measuring cylinder, set of tuning forks in the frequency range 256 Hz to 512 Hz, resonance tube, Vernier callipers, metre stick or ruler, upright stand, clamp and wooden block

Introduction to this topic

Although learners are now familiar with the concept of wavelength and frequency, most of them will know nothing about the practical methods used to determine these quantities. If possible, bring an oscilloscope to the classroom. If you do not have one available, you can turn your cell phone into an oscilloscope by downloading an oscilloscope app from your app store. Apps are available for both android and Apple phones.

Starter activity

(LB page 158)

This activity acts as a baseline for you to determine whether the learners understood the previous topic. It is essential that learners are confident with this theory before moving on to more difficult concepts.

Suggested answers

1. Transverse waves: water waves and radio waves; longitudinal waves: sound waves
2. $f = \frac{v}{\lambda}$

   $f = \frac{2.5}{0.1}$

   $f = 25$ Hz
3. a) $f = \frac{v}{\lambda}$

   $f = \frac{3 \times 10^8}{0.035}$

   $f = 8.571 \times 10^9$ Hz

   b) $T = \frac{1}{f}$

   $T = \frac{1}{8.571 \times 10^9}$

   $T = 1.17 \times 10^{-10}$ s
4. The higher the frequency of the wave, the shorter the wavelength.

Sub-topic 2.3.1: Determine frequency and wavelength of sound waves

LB pages 159–167

Beginning these lessons

A tuning fork is an inexpensive piece of apparatus that can help learners visualise the concepts. If you do not have access to a tuning fork, you can use a metal pipe to create the same effect.

Fill a water trough or bowl with water. Knock the tuning fork or pipe against a hard surface. Then place the vibrating tip just above the surface of the water. Ask the learners to describe their observations to the class.

Determine the frequency of sound using a cathode-ray oscilloscope

(LB pages 159–162)

Teaching guidelines

This topic can be tricky to teach because learners feel there are many quantities involved and often find it difficult to visualise the concepts if they cannot perform the experiments themselves. Diagrams like those on pages 159 and 160 of the Learner's Book can help them understand how the apparatus are used and how the readings are attained.

Practise examples with the learners as a class. Use the worked example on page 152 to explain to the class how to use the time-base setting of a cathode-ray oscilloscope to determine the frequency and wavelength of a wave.

Homework

Learners can complete the experimental report for Experiment 1 at home if they do not finish it in class. The work can then be peer assessed in class during the next lesson using the memorandum provided. Place emphasis on the format rather than focusing on whether the answers are correct.

Suggested answers

Experiment 1: Determine the frequency of sound using a cathode-ray oscilloscope

(LB page 160)

You can do this experiment as a demonstration.

- Let the learners practise changing the time-base setting of the CRO.
- As a class, discuss how changing the time-base setting affects the wave formed on the oscilloscope trace.

Activity 1: Use readings from a CRO to determine frequency and period

(LB page 161)

1. **a)** There are two complete waves in 8.2 cm, so the wavelength of one wave is 4.1 cm.
   $T = 0.35 \times 4.1 = 1.44$ ms
   1.44 ms $= 1.44 \times 10^{-3}$ s
   b) $f = \frac{1}{T} = \frac{1}{1.44 \times 10^{-3}} = 694.4$ Hz
2. **a)** A single repetition of the wave wave covers 1 cm on the grid. Since it has a time-base setting of 0.5 ms·cm^{-1}, the period of the wave is 0.5 ms. This is equivalent to 0.5×10^{-3} s.
   b) $f = \frac{1}{T} = \frac{1}{0.0005} = 2\,000$ Hz
   c) The complete wave would cover two blocks on the grid. The wavelength would double.

Using a resonance tube to determine the wavelength of a sound wave

(LB pages 162–164)

Teaching guidelines

This sub-topic introduces new terminology. The concept of resonance will be new to most learners. A practical approach is the best way to explain resonance. Ask the learners to stay as quiet as possible. Start by using the tuning fork with the lowest frequency. Ask the learners to put up their hand when they hear resonance occurring.

You can find a short video explaining resonance on YouTube. If you have access to the Internet, type "How resonance works" into the search engine. You could use this video to introduce the concept.

Suggested answers

Experiment 2: Determine the wavelength of sound waves using a resonance tube

(LB page 163)

- Learners will calculate a range of values for the wavelength.
- Place emphasis on the format and method rather than on the final answer.
- Ensure the correct formulae have been used: $\lambda = 2(L_2 - L_1)$ and $v = f \times \lambda$, where f is the frequency of the tuning fork used.
- Ensure that wavelength is measured in metres.

Activity 2: Determine the wavelength of sound using resonance tubes

(LB page 164)

1. $\lambda = 4X$
2. **a)** $\lambda = 4L = 4 \times 0.5 = 2$ m
   b) $f = \frac{v}{4L} = \frac{340}{2} = 170$ Hz

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. You can use the experimental report for Experiment 2 on page 163 of the Learners' Book for continuous assessment. You can use the experiment rubric on page 93 of this Teacher's Guide.

Remedial activity

Simulations can be a fantastic way to help learners who struggle to grasp the concepts. If you have access to the Internet, type "cathode ray oscilloscope simulation" into your browser. This simulation allows learners to produce CRO traces from which they can find values to work with. It gives learners more opportunity to practise their calculations.

Summary (LB page 165)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 166–167)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. D ✓ (1) [U]
3. C ✓ (1) [Ap]
4. A ✓ (1) [U]
[4]

5.
- Measure the length of the air column (from the water level to the top of the tube) with the metre stick. This is L_1. ✓
- Find the point of a second (weaker) resonance with the same tuning fork. Again, slide the tube up and down until the note you hear is at its loudest. ✓
- Measure the length of the air column with the metre stick. This is L_2. ✓
- Calculate the wavelength of the sound produced by each tuning fork using the equation $\lambda = 2(L_2 - L_1)$. ✓ (4) [S]

6. a) $1\lambda = 4$ divisions
$4 \times 0.2 \text{ ms} = 0.8 \text{ ms} = 0.8 \times 10^{-3} \text{ s}$ ✓
$f = \frac{1}{T} = \frac{1}{0.8 \times 10^{-3}}$ ✓ $= 1\,250 \text{ Hz}$ ✓ (3) [Ap]

b) $v = f \times \lambda$
$v = 1\,250 \times 0.26$ ✓ $= 325 \text{ m·s}^{-1}$ ✓ (2) [Ap]
[5]

7. a) The number of complete waves ✓ that pass a point every second ✓ (2) [K]

b) $0.5 \times 10 = 5 \text{ cm}$ ✓
$2 \times 10^{-3} \text{ s} \times 5 = 0.01 \text{ s} = 200 \text{ s}$ ✓
$f = \frac{1}{T} = \frac{1}{0.01} = 100 \text{ Hz}$ ✓ (3) [Ap]

c) $v = f \times \lambda$
$v = 100 \times 0.34$ ✓ $= 34 \text{ m·s}^{-1}$ ✓
(2) [Ap]
[7]
Total: 20

TOPIC 2.4 Doppler effect

LB pages 168–176

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Understand the Doppler effect
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with observations during experiments. It is difficult to demonstrate the Doppler effect using sound effects to learners with poor hearing. Try to use words and diagrams to better explain it to them.
Suggested teaching time	3 lessons
Additional resources needed	Internet (if available)

Introduction to this topic

This topic introduces learners to the concept of the Doppler effect. We use the Doppler effect to explain changes in the frequency of sound waves when a sound moves towards or away from an observer.

This topic also includes the formula required to calculate the frequency of the sound heard by the observer.

The best way to introduce this topic is by using sound effects. Play a video from a Formula 1 race and ask learners to describe how the sound changes as the cars pass the commentator. Link this concept with the knowledge learners already have about the frequency and speed of waves.

Starter activity

(LB page 168)

This activity reinforces the work covered in the previous topic. Learners are required to use a CRO trace to calculate unknown quantities. It gives you the opportunity to assess whether the learners have fully grasped the work covered.

Suggested answers

1. a) $\lambda = 4$ cm
time-base setting $= 0.2 \times 10^{-3}$ ms·cm^{-1}
Therefore, $T = 4 \times 0.2 \times 10^{-3} = 0.8 \times 10^{-3}$ s
$f = \frac{1}{T} = \frac{1}{0.8} \times 10^{-3} = 1\ 250$ Hz

b) The waves are closer together. If the frequency doubles, the wavelength halves. The height of the wave remains the same because the amplitude is unchanged.

2. a) $\lambda = 4L = 4 \times 1.5 = 6$ m

b) $f = \frac{v}{4L} = \frac{300}{4(1.5)} = 50$ Hz

Sub-topic 2.4.1: The Doppler effect

LB pages 169–176

Beginning these lessons

A video is always a fun way to introduce the Doppler effect. If you have access to the Internet, there are excellent videos available online. Type "Doppler effect" into YouTube. This video gives a short description of what the Doppler effect is.

The Doppler effect and its effect on the frequency of sound waves

(LB pages 169–171)

Teaching guidelines

It is important that you make this sub-topic relatable for learners. Use the example of a racing car in a Formula 1 race as it moves past the spectators. Make the sounds! Reinforce the idea that the pitch of a sound is determined by its frequency. The greater the frequency of a sound, the higher its pitch. Use diagrams like those on pages 169 and 170 in the Learner's Book to show how the waves are first closer together and then further apart, and how this affects frequency.

Suggested answers

Activity 1: Describe frequency and pitch
(LB page 171)

1. B
2. Wavelength and frequency are inversely proportional. A long wavelength results in a low frequency and a wave with a short wavelength has a high frequency.
3. C and D; they have the same frequency. Pitch and frequency are related. The wave with the greatest frequency will have the highest pitch.

Mathematical expression for the Doppler effect (LB pages 171–172)

Teaching guidelines

This is a mathematical section of the sub-topic. Emphasise that learners must use a minus sign when the source of the sound approaches the observer and a positive sign when the source of the sound moves away.

Use diagrams like those on page 170 of the Learner's Book to help learners visualise the situation. Explain the difference between the frequency of the sound produced and the sound heard by the observer.

Activity 2: Understand the Doppler effect
(LB page 172)

1. Higher; the sound waves are closer together resulting in a higher frequency.
2. $f_o = \frac{f_s v}{(v - v_s)} = \frac{700 \times 340}{340 - 20} = 743.75$ Hz
3. $f_o = \frac{f_s v}{(v + v_s)} = \frac{700 \times 340}{340 + 20} = 661.11$ Hz

Doppler shift and electromagnetic radiation (LB page 173)

Teaching guidelines

Start this part of the sub-topic by revising the fact that different colours of light have different frequencies. Red light has a low frequency, while blue light has a high frequency. Link this to the Doppler effect.

The diagram on page 173 of the Learner's Book can be helpful when explaining the idea of Doppler shift and how a change in frequency changes the colour of light seen.

Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. Go through the answers to Activity 2 with the learners in class in the next lesson. Learners can mark their own work. You can record their marks for informal assessment. This activity gives you an idea of how well the learners understood the formula.

Summary (LB page 174)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 175–176)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [U]
2. A ✓ (1) [Ap]
3. A ✓ (1) [Ap]
4. A ✓ (1) [K]
5 A ✓ (1) [K]

[5]

6. a) The Doppler effect can be defined as the change in the observed frequency of a wave ✓ when the source or the detector moves relative to the transmitting medium. ✓ (2) [K]

b) $f_o = \frac{f_s v}{(v - v_s)}$

$250 ✓ = \frac{f_s \times 340}{(340 - 30)}$ ✓

$f_s = 227.94$ Hz ✓ (3) [Ap]

[5]

7. a) Away. ✓ Frequencies of light coming from the star are lower than if the star was not moving away from Earth. ✓ They have shifted towards the red end of the spectrum. (2) [E]

b) The higher the speed of the star (away from Earth), the more the frequency decreases. ✓✓ (2) [U]

[4]

8. a) $f_o = \frac{f_s v}{(v + v_s)} = \frac{100 \times 340}{340 + 60}$ ✓

= 85 Hz ✓ (2) [Ap]

b) $v = f\lambda$

$340 = 85 \times \lambda$ ✓

$\lambda = 4$ m ✓ (2) [Ap]

[4]

9. a) As it moves towards her, the frequency of the wave increases as the waves are pushed closer together. ✓ As it moves away from her, the frequency decreases as the waves move further apart. ✓ (2) [U]

b) $f_o = \frac{f_s v}{(v - v_s)} = \frac{300 \times 340}{340 - 28}$ ✓ = 326.92 Hz ✓

$f_o = \frac{f_s v}{(v + v_s)} = \frac{300 \times 340}{340 + 28}$ ✓

= 277.17 Hz ✓ (4) [Ap]

c) When the boat moves away from her ✓ (1) [U]

[7]

Total: 25

TOPIC 2.5 Electromagnetic spectrum

LB pages 177–185

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Understand the electromagnetic spectrum
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with the diagrams used in this topic. These diagrams can be explained in detail and their understanding should not be compromised.
Suggested teaching time	3 lessons
Additional resources needed	Diagram or a poster showing the electromagnetic spectrum, its frequencies and wavelength, if available

Introduction to this topic

In this topic, we look at the electromagnetic spectrum in detail. The different components of the spectrum are compared according to their frequency, wavelength and uses.

The best way to teach this topic is by using visual aids. Try using as much colour as possible and relate the different types of electromagnetic radiation to situations the learners are familiar with.

Starter activity (LB page 177)

This activity acts as a baseline for you to determine what the learners know regarding the electromagnetic spectrum. It is a good way to clear up any misconceptions from the start. It also introduces the different components of the spectrum.

Suggested answers

1. False
2. True
3. True
4. True
5. False
6. True
7. False
8. True
9. True
10. False

Sub-topic 2.5.1: The electromagnetic spectrum

LB pages 178–185

Beginning these lessons

You can introduce this lesson using a video or a diagram. If you have access to the Internet, type "electromagnetic spectrum" into YouTube. If you do not have access to the Internet, you can use a diagram like the one on page 180 of the Learner's Book that shows the wavelengths of the different components. Ensure the diagram is big enough for visually impaired learners to distinguish between the components.

The nature and features of electromagnetic waves (LB pages 178–179)

Teaching guidelines

You need to make these concepts relatable for the learners. Use real-life examples like cell phones and using microwaves for cooking to help the learners understand the applications.

This section is very content heavy, so you will need to give learners a way to help them remember the facts. Help the learners make up funny sentences where the first letter of each word in the sentence relates to a component of the spectrum.

Suggested answers

Activity 1: Describe properties of electromagnetic waves (LB page 179)

1. Electromagnetic radiation consists of streams of photons that travel at the speed of light (3×10^8 m·s^{-1} in a vacuum). It also has a wave nature. Electromagnetic waves consist of electric and magnetic fields that oscillate (vibrate) at right angles to each other and to the direction in which the wave is travelling.
2. 3×10^8 m·s^{-1}
3. $f = \frac{v}{\lambda}$

   $f = \frac{3 \times 10^8}{10^6} = 300$ Hz

The orders of magnitude of wave-lengths of the electromagnetic spectrum (LB pages 179–182)

Teaching guidelines

This section is also very theory heavy. Although it is important that learners can link frequency and wavelength, it is just as important that they memorise the order of the waves in the electromagnetic spectrum.

Allow the learners 15 minutes in class to memorise the order of the electromagnetic waves. Learners can use a mnemonic to help them remember the order. Each learner must make up a silly sentence in which the first letter of each word represents the first letter of each of the electromagnetic waves.

After the 15 minutes are up, do a quick classroom quiz. The winner is the learner who can correctly list the different types of waves the fastest.

Homework

Learners can complete Activity 2 at home if they do not finish it in class. The work can then be peer assessed in class the next day. Ask learners to come up with a sentence to help them remember the order of the electromagnetic spectrum.

Suggested answers

Activity 2: Determine the speed and wave-length of an electromagnetic wave (LB page 180)

1. $c = f \times \lambda$
   $3 \times 10^8 = 1 \times 10^{22} \times \lambda$
   $\lambda = 3 \times 10^{-14}$ m
2. $f = \frac{c}{\lambda}$
   $f = \frac{3 \times 10^8}{1 \times 10^{-7}} = 3 \times 10^{14}$ Hz

Activity 3: Determine the frequency and wavelength of electromagnetic waves (LB page 181)

1. They are inversely proportional: the higher the frequency, the shorter the wavelength.
2. $f = \frac{v}{\lambda} = \frac{3 \times 10^8}{1 \times 10^{-12}} = 3 \times 10^{20}$ Hz
3. Radio waves have a longer wavelength and lower frequency than gamma waves.

Informal assessment

Learners must design a poster that can be used in the classroom showing the different components of the electromagnetic spectrum. This poster should include:

- the names of the different components
- their frequencies and wavelengths
- their uses.

You can mark this poster according to the project rubric on page 95 of this Teacher's Guide. Add these marks to their informal assessment mark.

Summary (LB page 183)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 184–185)

Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In both cases, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [U]
2. B ✓ (1) [K]
3. B ✓ (1) [An]
4. A ✓ (1) [K]
5. A ✓ (1) [K]

[5]

6. a) Radio waves, microwaves, infrared, visible light, ultraviolet light, X-rays, gamma rays ✓✓ (2) [U]
   b) Magnetic resonance imaging, ✓ communication or microwave ovens (any two) ✓ (2) [K]

[4]

7. They are all transverse waves; ✓ they travel at 3×10^8 m·s^{-1} in a vacuum; ✓ they can be reflected, refracted and diffracted. ✓ (3) [K]
8. a) 100.2×10^6 Hz ✓ (1) [U]
   b) $\lambda = \frac{v}{f} = \frac{3 \times 10^8 ✓}{100.2 \times 10^6}$ ✓ = 2.99 m ✓ (3) [Ap]
   c) $\lambda = \frac{v}{f} = \frac{1}{100.2 \times 10^6}$ ✓ = 9.98 m × 10^{-9} ✓ (2) [Ap]

[6]

9. $f = \frac{c}{\lambda} = \frac{3 \times 10^8}{0.12}$ ✓ = 2.50×10^9 Hz ✓ (2) [Ap]

Total: 20

TOPIC 2.6 Superposition

LB pages 186–203

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Show an understanding of stationary waves • Develop an understanding of diffraction • Know two-source interference • Know diffraction gratings
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Learners with special needs
Inclusive education	Visually impaired learners need assistance with observations during experiments. Make sure that any standing wave patterns are enlarged so that these learners can differentiate between nodes and antinodes. Learners that have difficulty hearing will need to be assisted in Experiment 2.
Suggested teaching time	10 lessons
Additional resources needed	Microwave source, probe detector, metal reflector, meter to detect microwaves, 1 000-cm^3 measuring cylinder, resonance tubes, tuning fork in the range 256 Hz to 512 Hz, Vernier callipers, stand, metre rule, ripple tank, motor mounted on a beam with beam support, water, side barriers, light source such as white incandescent bulb, monochromatic filter, screen, single and double slit, micrometer

Introduction to this topic

In this topic, we discuss the behaviour of waves, specifically in terms of superposition, diffraction and interference. Use ropes and slinky springs to demonstrate the formation of a standing wave.

Several new terms are introduced in this topic and there is a new formula that learners will need to be able to use. Use the key words in the Learner's Book as a glossary and ask the learners to copy them down in the back of their books. Learners need to be confident with the theory and be able to apply it.

Starter activity

(LB pages 186)

This activity allows learners to familiarise themselves with new terms and remind themselves of familiar terms. Learners can do this activity as a class competition. The winning group is the one that finds all the words the fastest. It's a fun way to introduce a very theory-based topic.

Suggested answers

G	R	E	F	R	A	C	T	I	O	N	C
U	A	H	R	P	E	O	V	L	B	O	F
A	R	B	K	I	J	R	M	Q	M	R	V
M	E	R	U	C	R	E	N	P	E	I	E
P	F	B	J	O	D	O	R	Q	D	T	W
L	A	C	Z	I	B	E	U	R	I	T	A
I	C	I	U	I	S	E	A	G	U	A	V
T	T	M	B	S	N	T	F	V	M	W	E
U	I	Z	I	C	I	K	C	A	A	A	M
D	O	O	T	R	O	U	G	H	S	G	T
E	N	V	N	P	U	X	G	O	F	U	M
S	E	C	R	E	S	T	N	O	R	L	S

Sub-topic 2.6.1: Stationary waves

LB pages 187–191

Beginning these lessons

The best way to introduce this sub-topic is with a demonstration. You can produce a standing wave in class using a rope. One learner holds one end of the rope, while another learner holds the other end. Each learner moves their hand back and forth to produce a wave. They will only be able to produce a standing wave when the waves have the same frequency.

This will help learners relate to the theory. Start the lesson by asking the learners to predict what they will see. Ask the learners to identify the nodes and antinodes.

Superposition of waves, and comparing stationary and progressive waves (LB pages 187–191)

Teaching guidelines

This sub-topic is very content heavy. Ensure that the learners are familiar with the terminology used. Define any new words, like those in the key word boxes in the Learner's Book, in class.

Visual aids can be a big help in this sub-topic. Use diagrams like those on page 187 of the Learner's Book to help explain the difference between nodes and antinodes. Ensure that learners can determine the wavelength from the number of nodes.

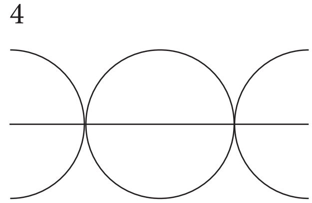
Homework

Learners can complete Activity 1 at home. It will allow you to gauge how much the learners actually understood. You can then mark the activity in class the next day.

Suggested answers

Activity 1: Describe stationary waves (LB page 189)

1. The principle of superposition of waves states that when waves meet at the same point in space, the resultant displacement will be the sum of the displacements of the individual waves.
2. **a)** **i)** DBC
   ii) AEF
   b) 4
3. **a)**



   b) 5 m

Experiment 1: Demonstrate stationary waves using microwaves (LB page 190)

1. The signal is zero when the incident and reflected waves form nodes.
2. The answer depends on the wave produced. A node occurs when the signal reading is 0.
3. Remember that the distance between two consecutive nodes is equal to half a wavelength. Use the distance between nodes to calculate the wavelength by multiplying that distance by 2.

Experiment 2: Demonstrate stationary waves using air columns (LB page 191)

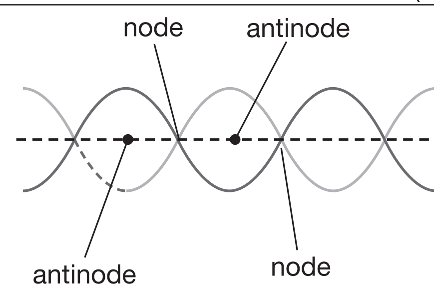
This experiment requires learners to determine the wavelength of a wave using resonance tubes. A resonance tube is any glass tube that is open at both ends. If the apparatus is available, allow each group to use a different tuning fork. This means that each group will produce a wave of a different frequency.

Use the learners' readings to discuss how the frequency of the tuning fork affects the wavelength of the wave produced.

Use the formula $\lambda = 2(L_2 - L_1)$ to determine the wavelength of the wave.

Activity 2: Understand standing waves in an air column (LB page 191)

1.



2. One
3. $\lambda = 2(L_2 - L_1)$
4. $v = 2f(L_2 - L_1)$

Informal assessment

You can use Experiment 2 on page 191 of the Learners' Book for informal assessment. Divide the class into groups of four. Each group must determine the wavelength of a wave produced by a tuning fork of specific frequency. The group must then tabulate their results. Assess their table according to the table rubric on page 94 of this

Teacher's Guide. Record this mark as part of their informal assessment mark.

Sub-topic 2.6.2: Diffraction

LB pages 192–193

Beginning these lessons

Introduce this lesson with a ripple tank. Make a ripple tank using a water trough and a ruler. Produce waves by moving the ruler up and down at constant intervals.

It is essential that learners can see diffraction happening because it is a hard concept to visualise. You can find simulations by typing "diffraction simulation" into your Internet browser if you have access to the Internet.

Diffraction (LB pages 192–193)

Teaching guidelines

Visual aids can be very beneficial when teaching this sub-topic. Demonstrating diffraction will help the learners understand how the motion of a wave changes.

You can shine a beam of light from a torch or a laser pointer through a very narrow slit cut in cardboard as an alternative to a ray box. It will help the learners visualise how the light spreads out after passing through the slit. You can use different slit widths, and you can ask the learners to formulate the relationship between the width of the slit and the amount of diffraction.

Homework

Do Experiment 3 as a demonstration in class, but the learners can write down their observations and answer the questions at home. This gives the learners the opportunity to draw their own conclusions based on what they experience. You can then go through and discuss the answers in class in the next lesson.

Suggested answers

Activity 3: Understand diffraction of waves (LB page 192)

1. The size of the gap through which the wave passes and the wavelength of the wave
2. **a)** The first wave will experience the most diffraction because the size of the gap is similar to the wavelength of the wave.
   b) The second wave will experience the least diffraction because the size of the gap is much larger than the wavelength of the wave.

Experiment 3: Demonstrate diffraction using a ripple tank (LB page 193)

1. As the waves pass through the gap, they spread out.
2. The smaller the gap, the greater the amount of diffraction experienced by the waves.

Sub-topic 2.6.3: Interference and two-source interference

LB pages 194–198

Beginning these lessons

Start these lessons by defining interference and coherence. Explain, using diagrams or simulations like those found at https://phet.colorado.edu/ (if you have access to the Internet), what is meant by these terms.

Interference and coherence

(LB pages 194–198)

Teaching guidelines

This sub-topic includes a new mathematical formula that you will need to explain in detail. Ensure that all learners know what each symbol in the equation means. Link this sub-topic to the previous sub-topics' terminology.

It is important that you use plenty of diagrams when teaching this sub-topic. You can demonstrate interference using a rope. A learner holds a rope at one end and another learner holds the rope at the other end, and they move their arms back and forth. Ask the learners to describe what happens to the amplitude of the wave produced.

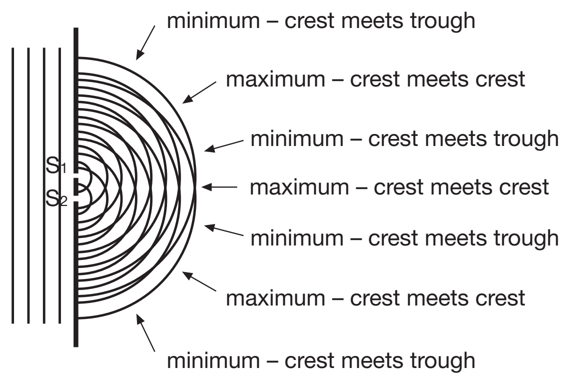
Homework

Do Experiment 4 as a demonstration in class, but the learners can write down their observations and answer the questions at home. This gives the learners the opportunity to draw their own conclusions based on what they see. You can then go through and discuss the answers in class in the next lesson.

Suggested answers

Activity 4: Describe interference (LB page 195)

1.



2. Maxima are formed when a crest overlaps with a crest or a trough overlaps with a trough. Minima are formed when a crest overlaps with a trough.

Experiment 4: Demonstrate two-source interference using water ripples (LB page 196)

1. Waves overlap forming minima (areas of zero displacement) and maxima (areas of maximum displacement).
2. Constructive interference occurs when crests overlap with crests or troughs overlap with troughs. The waves are in phase. Destructive interference occurs when crests overlap with troughs.

Experiment 5: Demonstrate two-source interference of light (LB page 197)

1. The learners will attain a variety of readings depending on the wavelength of the light waves used. Ensure the room is as dark as possible to allow for accurate readings to be taken.
2. Ensure that learners have used the formula correctly. All distances must be in metres.

Activity 5: Calculate wavelength from interference fringes (LB page 198)

$\lambda = \frac{ax}{D}$

$\lambda = \frac{5 \times 10^{-4} \times 2.25 \times 10^{-3}}{2.5}$

$\lambda = 4.5 \times 10^{-7}$ m

Sub-topic 2.6.4: Diffraction gratings

LB pages 199–200

Beginning these lessons

It is important that learners understand the previous sub-topics before moving onto this one. They need to understand the terminology used. In this sub-topic, we look at diffraction in more detail and learn how to determine the angle at which the interference fringes form.

If you have access to a ray box, use it to demonstrate the interference pattern to the class. The darker the classroom, the more effective the demonstration will be. You can use diagrams like those on page 199 of the Learner's Book as an alternative.

Diffraction (LB pages 199–200)

Teaching guidelines

This sub-topic includes a new mathematical formula that you will need to explain in detail. Ensure that all learners know what each symbol in the equation means.

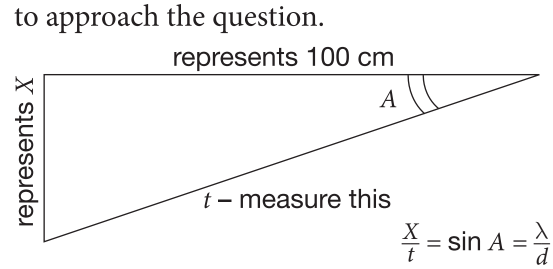
It is also important to emphasise that distance and wavelength must be measured in metres. Ensure that learners can convert from millimetres and centimetres to metres.

1 mm = 1×10^{-3} m, which means that to convert from millimetres to metres, the learners only need to multiple the value by 10^{-3}.

Suggested answers

Experiment 6: Use a diffraction grating to measure the wavelength of light (LB page 200)

Some learners may struggle with the trigonometry required for this experiment. Before starting the experiment, it may be useful to revise the principles required for the calculation. Use the drawing below to guide the learners as to how best to approach the question.



The learners' answers will vary depending on the frequency of light used.

Activity 6: Use $d\sin\theta = n\lambda$ (LB page 200)

$d\sin\theta = n\lambda$

$n = \frac{d\sin\theta}{\lambda}$

$d = \frac{1}{4.5 \times 10^5} = 2.22 \times 10^{-6}$ m

$n = \frac{2.22 \times 10^{-6} \times \sin 90°}{486 \times 10^{-9}}$

$n = 4.57 \approx 5$

Summary (LB page 201)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 202–203)

Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

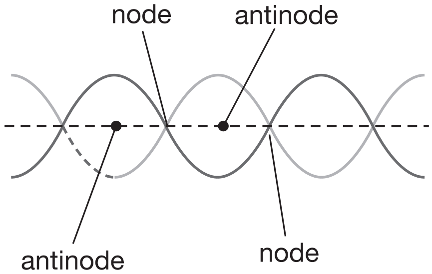
Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. D ✓ (1) [K]
2. A ✓ (1)[U]
3. D ✓ (1) [U]
4. C ✓ (1) [K]
5. A ✓ (1) [Ap]

[5]

6. a)



✓✓ (2) [U]

b) The distance between three nodes or antinodes ✓ (1) [U]

c) The nodes and antinodes will be closer together; ✓ the wavelength will be shorter. ✓ (2) [S]

[5]

7. $\lambda = 2(L_1 - L_2)$
$\lambda = 2(84 - 32)$ ✓ = 104 cm = 1.04 m ✓
$v = f \times \lambda$
$v = 300 \times 1.04 = 312$ m·s^{-1} ✓ (3) [Ap]

8. a) Coherence is defined as two waves that have the same frequency (and wavelength) ✓ and have a constant phase difference. ✓ (2) [K]

b) Light from independent sources would not have a constant phase difference. ✓ (1) [U]

[3]

9. a) 4 fringes = 8 mm
So, $x = 2$ mm = 0.002 m
$\lambda = \frac{ax}{D}$
$\lambda = \frac{0.4 \times 10^{-3} \times 0.002}{1.5}$ ✓
$\lambda = 5.33 \times 10^{-7}$ m ✓ (2) [Ap]

b) The distance between the fringes would be bigger. ✓ (1) [U]

[3]

10. $x = \lambda \times \frac{D}{a}$ ✓
$x = \frac{645 \times 10^{-9} \times 2}{0.3}$ ✓ $= 4.3 \times 10^{-6}$ m ✓ (3) [Ap]

11. a) The waves reflect off the wall, and the reflected wave undergoes constructive and destructive interference with the incident wave. ✓ (1) [U]

b) $\lambda = \frac{v}{f} = \frac{340}{1\,000} = 0.34$ m ✓
$\lambda = 2 \times$ the distance between minima
The distance between minima will equal $\frac{0.34}{2} = 0.17$ m. ✓ (2) [Ap]

[3]

Total: 25

Theme 3 Electricity

TOPIC 3.1 Electric fields

LB pages 206–214

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Understand the concept of an electric field • Know uniform electric fields
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with observations during demonstrations. Ensure all diagrams are enlarged to make it easier for them to see. All instructions should be given verbally.
Suggested teaching time	5 lessons
Additional resources needed	Tissue paper, plastic comb, nylon jersey, balloon

Introduction to this topic

This topic is not a new one for most learners. Try to keep this topic fun and practical. We will explore the concept of an electric field, and introduce the various formulae that can be used to determine electric field strength and the force experienced by a charge.

Relate electric field to situations that the learners are familiar with. Charge a balloon by rubbing it against a jersey, and then use it to make a learner's hair stand up.

Discuss the force produced by an electric field and link it to Sub-topic 1.5.1 (in Topic 1.5) in which the different types of contact and non-contact forces were discussed.

Starter activity (LB page 206)

This activity gives learners the opportunity to revise the work they did in Grades 10 and 11. It acts as a baseline for you to see how much the learners remember and which concepts you will need to revise.

Suggested answers

1. Lost electrons; electrons are negatively charged. For an object to become positively charged, it needs to have more protons than electrons. This only happens when an object loses electrons.
2. **a)** The comb picks up the tissue paper.
   b) The positive charge on the comb attracts the oppositely charged electrons on the tissue paper. This makes the side near the comb slightly negative and an attraction force towards the comb lifts the tissue paper. The opposite side of the paper becomes slightly positive.
   c) A non-contact force

Sub-topic 3.1.1: Concept of an electric field

LB pages 207–209

Beginning these lessons

You can introduce this sub-topic by making lightning in class. It is a fun activity that opens the class to discussion. You will need:

- rubber gloves
- plastic fork
- aluminium foil
- cutting board
- rubber balloon
- wool.

1. Turn off the lights and make the room as dark as possible. Try to do this experiment on a cool, dry day.

2. Wrap the foil around the fork. Make sure the edges are smooth; it should be as flat as possible.
3. Put on the rubber glove and use that hand to rub the wool against the balloon.
4. Place the balloon on the cutting board. Use the gloved hand to pick up the foil-covered fork.
5. Touch the balloon with the fork and describe what happens.

Electric field strength

(LB pages 207–208)

Teaching guidelines

Learners often get confused between the charge producing the field and the point charge placed in the field. Emphasise the difference by using a small "q" as the symbol for the point charge and a capital "Q" for the charge producing the field. Some learners may still struggle with changing the subject of the formula, so allow lots of practise time in class. Repetition is key.

Suggested answers

Activity 1: Calculate electric field strength

(LB page 208)

1. Repulsive force; like charges repel.
2. $E = \frac{F}{Q} = \frac{0.1}{2 \times 10^{-9}} = 5 \times 10^{7}$ N·C^{-1}
3. a) $F = Eq$

   $F = 3 \times 10^{4} \times 2 \times 10^{-9} = 6 \times 10^{-5}$ N

   b) $E = \frac{F}{q} = \frac{1.2 \times 10^{-3}}{2 \times 10^{-9}} = 6 \times 10^{5}$ N·C^{-1}

Electric field lines (LB pages 208–209)

Teaching guidelines

You will need to use visual aids for this section. Ensure that you include diagrams like those on pages 208 and 209 in the Learner's Book in your lessons. Ask the learners to copy the diagrams into their books. Emphasise that the electric field acts outwards from a positive charge and inwards towards a negative charge.

Homework

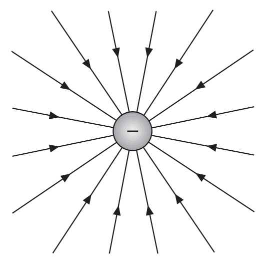
Learners can do Activity 2 for homework and you can mark it in the next lesson. It gives the learners the opportunity to practise what they were taught during the lesson.

Suggested answers

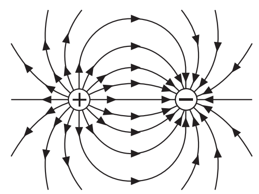
Activity 2: Draw electric field lines

(LB page 209)

1. a)



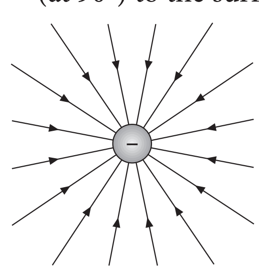
   b)



2. a) 3×10^{-9} C

   b) Example answers include the following:
   - Field lines never cross.
   - You draw field lines outwards from a positive charge and inwards towards a negative charge.
   - The greater the charge, the more field lines there are. The closer the lines are to one another, the stronger the field.
   - You draw the lines perpendicular (at 90°) to the surface.

   c)



Sub-topic 3.1.2: Uniform electric fields

LB pages 210–212

Beginning these lessons

The emphasis in this sub-topic is on calculations. Many learners struggle to identify what the question is actually asking for. Start the lesson by making the learners tabulate the symbols and their units used in calculations, for example, E, F and Q. The learners can then refer back to the table if they get stuck.

Electric field between parallel plates (LB pages 210–211)

Teaching guidelines

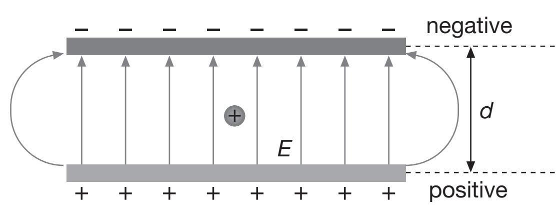
It is important to emphasise that the field is completely uniform between the two plates. Introduce this concept by drawing a diagram showing evenly spaced electric field lines between the two plates. Explain that the electric field runs from the positive plate to the negative plate.

Ensure all learners can convert nC and μC to C. For nC, you simply multiply by 10^{-9} and for μC, you multiple the value by 10^{-6}.

Suggested answers

Activity 3: Calculate electric field strength between parallel plates (LB page 211)

1.



2. $E = \frac{\Delta V}{\Delta d} = \frac{12}{0.075} = 160\ \text{V·m}^{-1}$
3. Units for $E = \frac{F}{Q} = \frac{N}{C} = \text{kg·m}^2\text{·s}^{-2}\text{·C}^{-1}$ (1)

   Units for $V = \frac{W}{Q} = \frac{\text{N·m}}{\text{C}} = \text{kg·m}^3\text{·s}^{-2}\text{·C}^{-1}$

   Units for $\frac{\Delta V}{\Delta d} = \frac{\text{kg·m}^3\text{·s}^{-2}\text{·C}^{-1}}{\text{m}} = \text{kg·m}^2\text{·s}^{-2}\text{·C}^{-1}$ (2)

   The units on the left and the right sides of the equation are the same. They are homogenous.

Calculating the force experienced by a point in a uniform field (LB pages 211–212)

Teaching guidelines

In this section, we link Newton's second law (Sub-topic 1.4) with electric fields. We use $F = ma$ to determine the force and acceleration of a point charge placed in an electric field.

Suggested answers

Activity 4: Calculate the force experienced by a point charge between two plates (LB page 212)

1. It moves towards the negatively charged plate. Opposite charges attract and like charges repel.
2. $F = \frac{QV}{d}$

   $F = \frac{3 \times 10^{-9} \times 1.5}{0.03} = 1.5 \times 10^{-7}\ \text{N}$

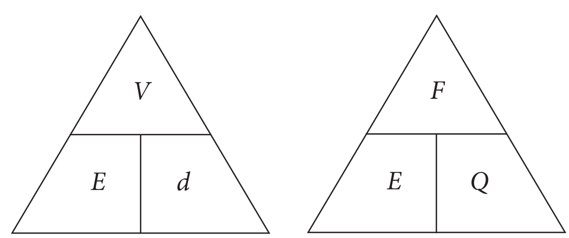
Homework

Ask the learners to work through the worked examples at home. Then at the start of the next lesson, check if they understood the concepts by writing only the question on the board, and letting them work out the answer in pairs (with their books closed). You could then ask for feedback on the steps they used from some of them.

Ensure that they understand how the answer is calculated before attempting the activities.

Remedial activity

Some learners struggle to change the subject of the formula. Ensure these learners copy the triangles below into their books and use them to complete the activities.



Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. You can give Activity 3 on page 211 of the Learners' Book to the learners to do as part of their informal assessment mark. Learners must complete this activity in their books during class time and then hand in their books for marking. Mark the activity according to the answers on this page.

Summary (LB page 213)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB page 214)

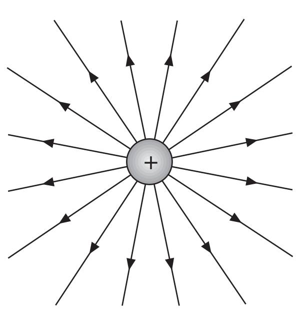
Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. C ✓ (1) [An]
3. A ✓ (1) [K]
[3]

4. a)



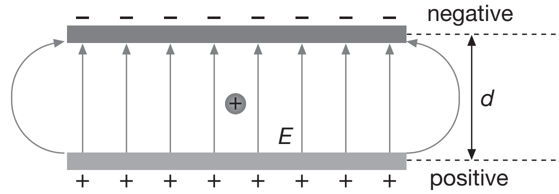
✓✓ (2) [S]

b) $F = E \times Q$
$F = 2.8 \times 2 \times 10^{-9}$ ✓
$F = 5.6 \times 10^{-9}$ N ✓✓ (3) [Ap]

c) Increase ✓ (1) [S]
[5]

5. a) A uniform electric field is one in which the field is constant. ✓ It occurs between parallel charged plates. ✓ (2) [K]

b)



✓ ✓ (2) [K]

c) $F = EQ$ but $E = \frac{V}{d}$ ✓
So, $F = \frac{VQ}{d}$ ✓ (2) [E]

d) $E = \frac{V}{d}$
$E = \frac{60 ✓}{0.02 ✓} = 3.00 \times 10^3$ V·m^{-1} ✓ (3) [Ap]

e) $F = EQ$
$F = 3.00 \times 10^3 \times 2 \times 10^{-9}$ ✓
$F = 6.0 \times 10^{-6}$ N ✓ (2) [Ap]
[11]
Total: 20

TOPIC 3.2 Current electricity

LB pages 215–229

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Understand electric current and its calculations • Show an understanding of potential difference and power including their calculations • Understand resistance and resistivity including their calculations
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning
Inclusive education	Visually impaired learners need assistance with observations during experiments. Ensure that all circuit diagrams are enlarged for ease of use.
Suggested teaching time	15 lessons
Additional resources needed	Resistor, light bulbs, power source, ammeter, voltmeter, conducting wires, crocodile clips

Introduction to this topic

Many of the concepts in this topic should be familiar to the learners. This topic covers all aspects of current electricity including charge, current, resistance and potential difference.

Try to use practical examples to introduce this topic. Identify electrical appliances in the classroom, such as a fan or lightbulb. Ask learners to explain their understanding of the flow of electricity. What do they think happens when the appliance is switched on and off?

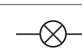
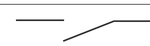
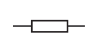
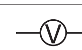
Starter activity

(LB page 215)

This activity revises some of the work covered in Grades 10 and 11. It is a good way to introduce the topic and ascertain how much the learners remember. Learners can do this activity as a competition. The pair that correctly matches each symbol to its description the fastest is the winner. Question 2 is more conceptual. Learners should use their previous knowledge from Grades 10 and 11 to answer the question.

Suggested answers

1.

Symbol	Component
1. 	Cell
2. 	Ammeter
3. 	Bulb
4. 	Open switch
5. 	Resistor
6. 	Voltmeter

2. a) Circuit X has a smaller total resistance than circuit Y. When resistors are in parallel, $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

b) The sum of the voltmeter readings in circuit Y will equal the voltmeter reading in circuit X. Because the resistors are of equal magnitude, the voltmeter reading over each resistor in circuit Y will equal half the reading of the voltmeter in circuit X.

Sub-topic 3.2.1: Electric current

LB pages 216–217

Beginning these lessons

You can introduce this sub-topic by allowing the learners to set up simple circuits. Ensure they understand the function of each component.

Use this an opportunity to revise the difference between components in series and in parallel. Revise the symbols and units for each of the quantities, and ensure the learners can convert units correctly. Learners can create a table of the symbols and units that are used in this sub-topic in their books, which they can then refer to.

Electric current and deriving *I* = *Anvq* (LB pages 216–217)

Teaching guidelines

It is essential that learners have a good foundation in electrical circuits before progressing further. If you have access to the Internet, you can use the blobz guide to electrical circuits to introduce the sub-topic. It allows the learners to create very simple circuits online and helps clarify misconceptions relating to how current flows.

Learners should be familiar with most of the formulae used. Learners who struggle mathematically will find it difficult to change the subject of the formula. Ensure that learners convert time into seconds. Allow plenty of time in class to practise examples that you can source from the Internet if you have access to it. Work through the answers step by step in class.

Homework

Learners can do Activity 1 for homework. It is revision of work they did in Grades 10 and 11. It also allows the learners to consolidate the work done in class. You can go over the questions in the next lesson.

Suggested answers

Activity 1: Calculate charge (LB page 217)

1. **a)** Current
   b) $I = \frac{Q}{\Delta t} = \frac{40}{2 \times 60} = 0.33$ A
2. $\Delta t = \frac{Q}{I}$
   $t = \frac{20}{3} = 6.67$ s

Activity 2: Use *I* = *Anvq* (LB page 217)

1. $A = \frac{I}{nvq}$
   $A = \frac{0.6}{2 \times 10^{28} \times 4 \times 10^{-4} \times 1.6 \times 10^{-19}}$
   $A = 4.69 \times 10^{-7}$ m^2
2. $Q = I\Delta t$
   $Q = 0.6 \times 120$
   $Q = 72$ C

Sub-topic 3.2.2: Potential difference and power LB pages 218–219

Beginning these lessons

In this sub-topic, we explore the concept of potential difference and power. Learners often have a number of misconceptions about this subject, so spend some time defining these concepts and explaining what they mean.

Compare a 3-V battery with a 1.5-V battery and explain what the difference between the two is. Bring electrical appliances into the classroom and ask learners to explain what is meant by the power ratings of the different appliances.

Potential difference and power (LB pages 218–219)

Teaching guidelines

This topic includes several calculations, which can be challenging for some learners. Always pair a learner who struggles with Mathematics with one who is more competent.

Explain the answers step by step and emphasise the units that the quantities must be measured in.

Homework

Learners can complete Activity 3 at home if they do not finish it in class. Work through the answers in the next lesson and ensure the learners understand where they went wrong.

Suggested answers

Activity 3: Calculate potential difference (LB page 219)

1. Electrical energy to light and heat energy
2. $W = VQ$
   $W = 15 \times 40$
   $W = 600$ J
3. $I = \frac{Q}{\Delta t}$
   $I = \frac{40}{5 \times 60} = 0.13$ A

Activity 4: Calculate power (LB page 219)

1. $P = \frac{W}{\Delta t}$
   $W = P \times \Delta t$
   $W = 15 \times 15 \times 60$
   $W = 13\ 500$ J
2. $P = \frac{V^2}{R}$
   $P = \frac{(240)^2}{6\ 000}$
   $P = 9.6$ W

Sub-topic 3.2.3: Resistance and resistivity LB pages 220–226

Beginning these lessons

In this sub-topic, we explore the concept of resistance and resistivity. Resistance is a measure of how much a substance restricts the flow of charge. In Grades 10 and 11, learners only learnt about ohmic resistors. This year, they will be introduced to non-ohmic resistors.

The best way to explain resistance is by using a practical approach. Build a simple circuit in which a piece of wire acts as a resistor. Use an ammeter connected in series to measure the amount of current that flows. Changing the length of the wire will alter its resistance. Ask the learners to draw a conclusion between the resistance of a resistor and the amount of current that flows.

Resistance (LB pages 220–223)

Teaching guidelines

This topic includes several calculations, which can be challenging for some learners. Always pair a learner who struggles with Mathematics with one who is more competent.

Explain the answers step by step and emphasise the units that the quantities must be measured in.

Homework

Learners can complete Activity 5 at home if they do not finish it in class. Work through the answers in the next lesson and ensure the learners understand where they went wrong.

Suggested answers

Activity 5: Calculate resistance (LB page 223)

1. a) $R_p = \frac{1}{R_1} + \frac{1}{R_2}$
   $R_p = \frac{1}{4} + \frac{1}{4} = \frac{2}{4}$
   $R_p = \frac{4}{2} = 2\ \Omega$
   b) $I = \frac{V}{R}$
   $I = \frac{12}{2} = 6$ A
   c) Each resistor is equal in magnitude, so:
   $I = \frac{6}{2} = 3$ A
2. a) $R = \frac{V}{I} = \frac{12}{0.004} = 3\ 000\ \Omega$
   b) $V = IR = 0.002 \times 3\ 000 = 6$ V

Ohm's law (LB pages 223–225)

Teaching guidelines

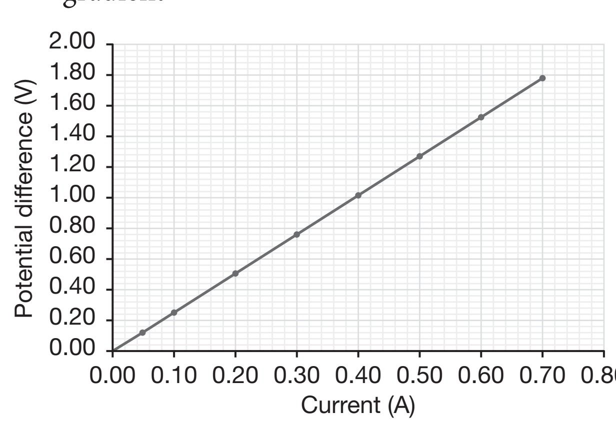
Ohm's law is revision of work learners did in Grades 10 and 11, but in this section, we build on the foundations taught in the lower grades. We introduce the concept of I–V characteristics and link it to diodes and thermistors.

Use a practical approach to teach this section. It is a good opportunity for learners to practise drawing graphs. Remember, that they must:
- always label the axes, including the units
- use a sharp pencil to draw crosses or encircled dots
- use an appropriate scale where the graph covers more than half the vertical and horizontal area of the grid.

Suggested answers

Experiment 1: Investigate Ohm's law (LB page 224)

1. A straight diagonal line with a positive gradient

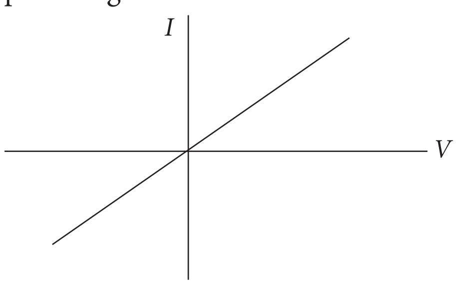


The current through the resistor is directly proportional to the potential difference across it.
The graph shows that current is proportional to potential difference.

2. resistance = gradient
   gradient = $\frac{\Delta y}{\Delta x}$

Activity 6: Investigate *I*–*V* characteristics of circuit components (LB page 226)

1. **a)** Ohmic; it obeys Ohm's law and forms a straight-line graph with a positive gradient.
   b) $R = \frac{V}{I}$ = inverse of gradient of graph
   $R = \frac{V}{I}$ = gradient
   $R = \frac{1.5 - 0}{0.15 - 0} = 10\ \Omega$
   c) The graph will form a curved line with a positive gradient.
2. **a)**



   b) The gradient of the graph would become steeper as the temperature increased.
   c) $I = \frac{V}{R} = \frac{3}{20\ 000} = 1.5 \times 10^{-4}\ A$

Resistivity (LB page 226)

Teaching guidelines

"Resistance" and "resistivity" sound very similar. Ask learners to copy the definitions given in the key word boxes on pages 220 and 226 of the Learner's Book, and ensure that they understand the difference between the two terms.

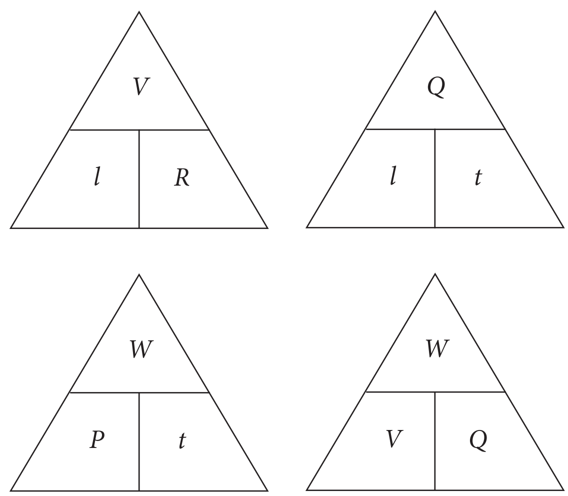
Suggested answers

Activity 7: Calculate resistivity (LB page 226)

1. The resistivity of a material is defined as the product of the resistance and cross-sectional area per length of the substance.
2. $A = \pi r^2$
   $A = 3.14 \times (0.5 \times 10^{-3})^2$
   $A = 7.85 \times 10^{-7}\ m^2$
   $\rho = \frac{RA}{L}$
   $\rho = \frac{0.75 \times 7.85 \times 10^{-7}}{0.55}$
   $\rho = 1.07 \times 10^{-8}\ \Omega{\cdot}m$
3. $A = \pi r^2 = 3.14 \times (0.22 \times 10^{-3})^2$
   $= 1.520 \times 10^{-7}\ m^2$
   $R = \frac{\rho \times L}{A}$
   $= \frac{1.07 \times 10^{-6} \times 0.9}{1.520 \times 10^{-7}}$
   $= 6.34\ \Omega$

Remedial activity

Some learners struggle to change the subject of the formula. Ensure these learners copy the triangles below into their books and use them to complete the activities.



Informal assessment

Note: We have used the term "informal assessment" throughout the topics, but it is also sometimes referred to as "diagnostic assessment" because the main purpose is to identify which learners struggle or do well, but need improvement in the mastery of certain aspects. You can use Experiment 1 as a diagnostic assessment to gauge the learners' understanding. Divide the class into groups of four. Each group works independently and records their findings in the form of an experimental report. Mark their report according to the rubric on page 95 of this Teacher's Guide. These marks form part of their informal assessment.

Summary (LB page 227)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but it also helps them consolidate what they have learnt.

Self-assessment (LB pages 228–229)

Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. A ✓ (1) [K]
2. B ✓ (1) [U]
3. B ✓ (1) [U]
4. B ✓ (1) [U]
[4]

5. a) The product of the resistance ✓ and cross-sectional area per length ✓ of the substance (2) [K]

b) $\rho = \frac{RA}{L}$

$\rho = \frac{2 \times 3 \times 10^{-7}\ ✓}{2.4\ ✓}$

$\rho = 2.5 \times 10^{-7}\ \Omega \cdot m$ ✓ (3) [Ap]

c) Make R the subject of the equation for ρ and see that R is directly proportional to L and inversely proportional to A.

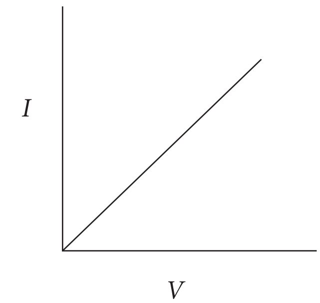
Therefore $R = \frac{2}{\frac{1}{2}} \times 2 = 8\ \Omega$ ✓ (3) [E]

[8]

6. a) The resistance of resistor R ✓ (1) [E]

b) Independent variable: potential difference; ✓ dependent variable: current ✓ (2) [An]

c)



Labelled axes ✓
Positive gradient ✓
Shape of graph ✓ (3) [S]

d) Ohm's law ✓ (1) [K]
[7]

7. a) $A = \frac{\pi d^2}{4} = \frac{3.14(1.5 \times 10^{-3})^2}{4} = 1.77 \times 10^{-6}\ m^2$ ✓

$R = \frac{\rho L}{A}$

$R = \frac{1.7 \times 10^{-8} \times 15\ ✓}{1.77 \times 10^{-6}\ ✓}$

$R = 0.14\ \Omega$ ✓ (4) [Ap]

b) Greater than. ✓ The Constantan wire has a higher resistivity ✓ than copper, so its resistance is higher. ✓ (3) [E]
[7]

8. a) It would decrease. ✓ The resistance of thermistors decreases with an increase in temperature. ✓ (2) [K]

b) $V = IR$

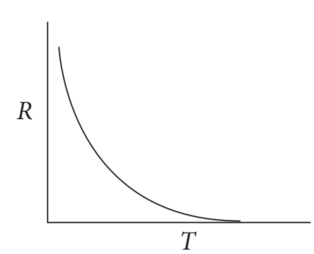
$V = 5 \times 10^{-3} \times 200$ ✓ $= 1.5$ V ✓ (2) [Ap]

c) $VT = V + V_{thermistor}$

$3 = V + 1.5$ ✓

$V = 2$ V ✓ (2) [Ap]

d)



Axes labelled correctly ✓
Correct shape ✓✓ (3)[S]
[9]

Total: 35

TOPIC 3.3 DC circuits

LB pages 230–245

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	• Understand practical circuits including calculations • Apply Kirchhoff's laws in calculations • Understand potential dividers and calculations
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Learners with dyscalculia will really struggle with this section. Teach the calculations using a step by step method and focus on the simpler examples.
Suggested teaching time	9 lessons
Additional resources needed	Calculator

Introduction to this topic

We start this topic by revising the symbols used in circuit diagrams. We also introduce internal resistance. Ensure the learners understand what is meant by the term "direct current".

We explore Kirchhoff's laws, and how they relate to the total current and potential difference in a circuit.

Kirchhoff's law can be very confusing. A video can help learners visualise the concept. If you have access to the Internet, there is an excellent video on YouTube. Type "simplest explanation of Kirchhoff's laws" into YouTube, and use the video to introduce the topic.

Starter activity

(LB page 230)

This activity gives learners the opportunity to revise the work they did in the previous topic. It acts as a baseline for you to see how much the learners understand and which concepts you will need to revise before moving on. It is essential that learners have a good grasp of the previous topic before moving on to the new one.

Suggested answers

1. a) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$

$\frac{1}{R_p} = \frac{6}{6}$

$R_p = 1\ \Omega$

b) $I = \frac{V}{R}$

$I = \frac{6}{1} = 6\text{ A}$

c) $I = \frac{V}{R} = \frac{6}{3} = 2\text{ A}$

2. a) The ratio of the potential difference across a resistor (or conductor) to the current through it

b) $R = \frac{V}{I}$

$R = \frac{12}{5} = 2.4\ \Omega$

c) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{2.4} = \frac{1}{3} + \frac{1}{R}$

$\frac{1}{R} = 0.0833$

$R = 12\ \Omega$

d) $I = \frac{V}{R} = \frac{12}{3} = 4\text{ A}$

Sub-topic 3.3.1: Practical circuits

LB pages 231–233

Beginning these lessons

Introduce this sub-topic by revising the symbols used in circuit diagrams. You could do this as a class competition. You can draw the symbols on the board and the learner that can identify the most symbols correctly in the shortest amount of time is the winner.

Circuit symbols, electromotive force and potential difference

(LB pages 231–233)

Teaching guidelines

This sub-topic can be a challenging one for learners. Many learners are confused by the difference between emf and potential difference. It is essential that you explain the definitions in a way that learners can understand.

Practise examples in class and emphasise the fact that emf is always bigger than potential difference. If you have access to the Internet, you can use it to find practice questions for the learners.

You can demonstrate this practically by building a simple circuit including a voltmeter, cell, resistor and switch. Attach the voltmeter parallel to the cell. Measure the reading on the voltmeter when the circuit is flowing and then measure it when the switch is open. Ask the learners to explain the difference in readings.

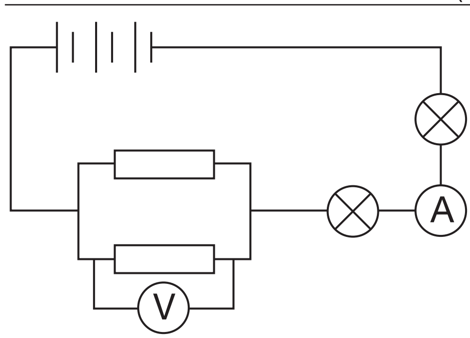
Homework

Learners can do Activity 1 for homework and you can mark it in the next lesson. It is revision of the work done in Grades 10 and 11, so the learners should be able to complete the activity independently.

Suggested answers

Activity 1: Draw circuit diagrams

(LB page 232)



Activity 2: Calculate internal resistance

(LB page 233)

1. We define the electromotive force of a source as the energy transferred per unit charge in driving charge round a complete circuit.
2. emf = $V + Ir$
   $10 = 8 + 2r$
   $r = 1\ \Omega$
3. **a)** If a current of 1 A flows through the 6-Ω resistor, a current equivalent to double that will flow through the 3-Ω resistor, i.e. 2 A.
   $I_T = 1 + 2 = 3$ A
   b) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$
   $\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3}$
   $\frac{1}{R_p} = \frac{3}{6}$
   $R_T = \frac{1}{R_p} = \frac{6}{3} = 2\ \Omega$
   $R_T = 2 + 2 = 4\ \Omega$
   $V = IR$
   $V = 3 \times 4 = 12$ V
   c) emf = $V + Ir$
   $14 = 12 + 3r$
   $r = 0.67\ \Omega$

Sub-topic 3.3.2: Kirchhoff's laws

LB pages 234–237

Beginning these lessons

Start this sub-topic by revising the way in which we calculate the total current through resistors in parallel. This sub-topic lends itself to class discussion. Ask learners to predict the total current travelling through a circuit when given the individual currents flowing through each resistor. Ask the learners to link this with the law of conservation of energy.

Kirchhoff's first and second laws, and using them to determine total resistance

(LB pages 234–237)

Teaching guidelines

Learners often struggle to see the direction of the loop and forget to take direction into account at all. Give the learners plenty of examples to work through (which you can source from the Internet if you have access to it). Give the learners the opportunity to work independently.

Use diagrams like those in the worked example on page 235 of the Learner's Book to help explain how to approach the problem.

Homework

Learners can complete Activity 3 at home. It gives the learners the opportunity to put into practise what they were taught during the lesson. You can then discuss the answers in the next lesson.

Suggested answers

Activity 3: Use Kirchhoff's laws (LB page 236)

1. Loop ACDB: $6 = 20I_1 + 10I_3$
   Loop CDFE: $5 = 10I_3 + 30I_2$
   Loop ACEFDB: $6 - 5 = 1 = 20I_1 - 30I_2$
   At junction C: $I_1 + I_2 = I_3$
   $6 = 20I_1 + 10(I_1 + I_2)$
   $6 = 20I_1 + 10I_1 + 10I_2$
   $6 = 30I_1 + 10I_2$
   $(1 = 20I_1 - 30I_2) \times 1.5$
   $1.5 = 30I_1 - 45I_2$
   $1.5 + 45I_2 = 30I_1$
   $6 = (1.5 + 45I_2) + 10I_2$
   $4.5 = 55I_2$
   $I_2 = \frac{4.5}{55} = 0.082$ A
   $I_1 = 0.62$ A and $I_3 = 0.70$ A
2. Let I_1 = total current, I_2 = current through R_1 and R_2, I_3 = current through R_3: $I_1 = I_2 + I_3$ (1)
   Loop 1: emf = $I_2R_1 + I_2R_2 + I_1R_4$
   $12 = 30I_2 + 10I_2 + 20I_1$
   $12 = 40I_2 + 20I_1$ (2)
   Loop 2: emf = $I_3R_3 + I_1R_4$
   $12 = 40I_3 + 20I_1$ (3)
   Subtract equation (3) from (2) to show $I_2 = I_3$
   Therefore $I_1 = 2I_2$ (equation 1)
   Substitute $I_1 = 2I_2$ into equation (2):
   $12 = 40I_2 + 20(2I_2)$
   Therefore: $I_2 = 0.15$ A $= I_3$, $I_1 = I_2 + I_3 = 0.3$ A
3. Let I_1 = total current, I_2 = current through R_2, I_3 = current through R_3: $I_1 = I_2 + I_3$ (1)
   Loop 1: emf = $I_1R_1 + I_2R_2 + I_1R_4$
   $10 = 20I_1 + 30I_2 + 20I_1$
   $10 = 40I_1 + 30I_2$ (2)
   Loop 2: emf = $I_1R_1 + I_3R_3 + I_1R_4$
   $10 = 20I_1 + 50I_3 + 20I_1$
   $10 = 40I_1 + 50I_3$ (3)
   Subtract equation (3) from (2) to show
   $I_3 = 0.6 \times I_2$
   Substitute $I_3 = 0.6I_2$ into eqn.(1) then solve eqn.(2) for I_2:
   $I_2 = 0.106$ A. Solving further: $I_1 = 0.170$ A, $I_3 = 0.064$ A

Activity 4: Calculate current using Kirchhoff's laws (LB page 237)

1. The current flowing through resistors in series is constant. Resistors in parallel are current dividers because the current is split between them.
2. a) $I_1 = \frac{18}{3} = 6$ A
   $I_2 = \frac{18}{6} = 3$ A
   $I = 6 + 3 = 9$ A
   b) $I = \frac{18}{(6 + 3)} = 2$ A

Sub-topic 3.3.3: Potential dividers

LB pages 238–241

Beginning these lessons

This sub-topic is far more relatable to learners because it introduces the more practical components of a DC circuit. Introduce this topic by working though practical applications of potentiometers and how they are used in our everyday lives. Revise the symbol for a potentiometer and explain its functioning in a circuit.

Potential dividers and potentiometers (LB pages 238–241)

Teaching guidelines

Diagrams are a useful way to explain what is happening in a circuit. Approach the problems in a step by step methodical manner and ensure that the learners understand the theory behind the calculations. Practise examples in class, but also allow learners the opportunity to work through the examples on their own.

Homework

Learners can complete Activity 5 at home if they do not finish it in class. It gives the learners the opportunity to put into practice what they were taught during the lesson. You can discuss the answers in the next lesson.

Suggested answers

Activity 5: Solve potentiometer problems (LB page 241)

1. a) $R_s = R_1 + R_2$
   $R_s = 15 + 5 = 20\ \Omega$
   b) $I = \frac{V}{R}$
   $I = \frac{10}{20} = 0.5$ A

c) $V_{out} = \frac{V_{in}R_2}{(R_1 + R_2)}$

$= \frac{10 \times 5}{15 + 5}$

$= 2.5$ V

2. Light-dependent resistors are used so that the lights only turn on when it gets dark. This saves electricity, which reduces costs.
3. The heat from the fire causes the temperature to increase. The resistance of the resistor decreases, allowing current to flow to the siren so that it can make a noise.

Informal assessment

Ask the learners to work through the worked examples at home. Then at the start of the next lesson, check if they understood the concepts by writing only the question on the board and letting them work out the answer in pairs (with their books closed). You could then ask for feedback on the steps they used from some of the pairs. Ensure that they understand how the answer is calculated before attempting the activities.

Summary (LB page 242)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but also helps them consolidate what they have learnt.

Self-assessment (LB pages 243–245)

Note: You could let learners do this section as a self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. C ✓ (1) [K]
2. A ✓ (1) [U]
3. A ✓ (1) [K]
4. B ✓ (1) [An]
5. A ✓ (1) [U]

[5]

6. a) Potentiometers are variable resistors with three terminals that act as adjustable potential dividers. ✓ By controlling the resistance, we can control the amount of current flowing through the conductor. ✓ (2) [K]

b) $V_{out} = \frac{V_{in}R_2}{(R_1 + R_2)}$

$V_{out} = \frac{9 \times 2\,000 ✓}{(3\,000 + 2\,000) ✓}$

$V_{out} = 3.6$ V ✓ (3) [Ap]

c) Decrease; ✓ Potential difference V_{out} is proportional to R_2. ✓ (2) [An]

[7]

7. a) Kirchhoff's first law states that the total current entering a junction is equal ✓ to the total current leaving the junction. ✓ (2) [K]

b) $I = I_1 + I_2 + I_3 + \ldots$ (according to Kirchhoff's first law) ✓

Since $I = \frac{V}{R}$. ✓

$I_1 = \frac{V}{R_1}$ and $I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$. ✓ If we substitute these values into the first equation, we see that :

$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

Since V is constant for resistors in parallel, we can take it out the equation:

$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$ ✓

$R_T = \frac{V}{I}$ which means that:

$\frac{1}{R_T} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$ ✓ (5) [E]

c) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_p} = \frac{1}{1} + \frac{1}{2} + \frac{1}{6}$ ✓

$\frac{1}{R_p} = \frac{10}{6}$

$R_p = \frac{6}{10} = 0.6\ \Omega$ ✓ (2) [Ap]

d) $R = \frac{V}{I}$, so $I = \frac{V}{R}$

$I = \frac{6}{2}$ ✓ $= 3$ A ✓ (2) [Ap]

[11]

8. a) Kirchhoff's second law states that the net electromotive force around a closed-circuit loop is equal ✓ to the sum of potential drops around the loop. ✓ (2) [K]

b) $I_2 = 0.015 - 0.0015$ ✓ $= 0.0135$ A ✓

200×0.0135 ✓ $= 2.7$ V

According to loop 1: $E = 2.7 - 1.5$ ✓

$= 1.2$ V ✓ (5)

[7]

Total: 30

Theme 4 Modern physics

TOPIC 4.1 Atoms, nuclei and radiation

LB pages 248–260

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Show an understanding of the concepts of atoms and nuclei in relationship to radiation
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Environmental learning
Inclusive education	Visually impaired learners need assistance with the nuclide notation of an atom. Ensure they are given an enlarged copy of the Periodic Table so that they can identify the atomic and mass numbers easily.
Suggested teaching time	5 lessons
Additional resources needed	Periodic Table

Introduction to this topic

This topic introduces nuclear radiation for the first time. Most learners will have heard of nuclear physics, but very few will know the details regarding the reactions that occur. In this topic, we will explore the particles that make up an atom and the changes they undergo when a nuclear reaction takes place.

Introduce this topic by revising the structure of the atom. A three-dimensional model is ideal, but you could use the diagram on page 249 of the Learner's Book as an alternative. You could even construct your own model of the atom using wire and balls like ping pong balls. Emphasise the idea that the nucleus of an atom consists of protons and neutrons, and that the majority of an atom is actually made up of empty space.

Starter activity (LB page 248)

This activity allows the learners to revise atomic structure. It is important that the learners understand the basics before moving on to nuclear decay. This activity acts as a baseline for you to see how much they remember from Grades 10 and 11, and how much needs to be revised.

Suggested answers

a) Positive
b) 1
c) Electron
d) $\frac{1}{1\ 840}$
e) Neutral

Sub-topic 4.1.1: Atoms, nuclei and radiation

LB pages 249–260

Beginning these lessons

This sub-topic lends itself to class discussion. Ask the learners what they understand by the term "nuclear radiation". As a class, discuss the advantages of nuclear power as an energy source. If you have access to the Internet, allow the learners to research the advantages and disadvantages of nuclear power.

The structure of the atom and nuclide notation (LB pages 249–251)

Teaching guidelines

It is important that learners have a good foundation in atomic structure before moving on. Take time in class to revise the sub-atomic particles and ensure that all learners can identify the number of each in an atom of an element.

It is difficult for learners to visualise how small an atom is, so try to relate the size of an atom to an everyday object. For example, a grain of sand contains 1×10^{22} atoms!

Remind the learners that every element in the Periodic Table has two numbers. The bigger value is the number of protons and neutrons (nucleon number) and the smaller value is the number of protons.

Homework

Ask learners to research the history of the atom. If they have access to the Internet, the history of the atom is described in a song by science teacher Mr Parr. Type "Mr Parr, the atom song" into YouTube to watch the video.

Suggested answers

Activity 1: Understand nuclide notation (LB page 251)

1. Electrons are found in energy shells, but because electrons are too small to contribute to the mass of an atom, the number of energy shells does not really affect its mass.
2. **a)** Protons: 3; electrons: 3; neutrons: 4
   b) Protons: 11; electrons: 11; neutrons: 12

Isotopes (LB pages 251–252)

Teaching guidelines

Although isotopes should be a familiar concept for most learners, it can prove challenging to some. Use diagrams like Figure 4.1.3 on page 251 of the Learner's Book to explain how the electron configuration and proton number of an atom stays constant. It is just the number of neutrons that changes.

Suggested answers

Activity 2: Understand isotopes (LB page 252)

1. Isotopes are atoms of an element that have the same proton number, but a different number of neutrons.
2. They differ in the number of neutrons, which results in a difference in mass.
3. They have the same number of protons and electrons. Protium has no neutrons.

Radioactivity (LB pages 252–256)

Teaching guidelines

Radioactivity was introduced in Grades 10 and 11, but at a very superficial level. In Grade 12, it becomes more complicated and will require a more methodical approach.

Give learners plenty of opportunity to practise what is taught. You can use the Internet, if you have access to it, to source practice questions for the learners. Work through the worked example on page 255 as a class, before asking the learners to complete Activity 3 independently.

Link the nuclide equations with the structure of the atom. Make sure that learners understand what alpha- and beta-particles consist of before starting the lesson on nuclide equations.

Suggested answers

Activity 3: Write nuclide equations (LB page 256)

1. **a)** ${}^{231}_{91}\text{Pa} \rightarrow {}^{227}_{89}\text{Ac} + {}^{4}_{2}\text{He}$
   b) ${}^{211}_{87}\text{Fr} \rightarrow {}^{207}_{85}\text{At} + {}^{4}_{2}\text{He}$
2. **a)** ${}^{24}_{11}\text{Na} \rightarrow {}^{24}_{12}\text{Mg} + {}^{0}_{-1}\text{e}$
   b) ${}^{42}_{19}\text{K} \rightarrow {}^{42}_{20}\text{Ca} + {}^{0}_{-1}\text{e}$

Behaviour of radioactive particles and rays in an electric field (LB pages 256–257)

Teaching guidelines

Once learners understand the charge on the particles, they will have a better understanding of how they behave. In this section, we relate the properties of those particles to the way they behave in a uniform electric field. Link this topic to Sub-topic 3.1. Opposite charges attract, so a negatively charged particle will move towards the positively charged plate.

You can also link this section to Newton's laws. We can use $F = ma$ to determine the acceleration experienced by a particle. Revise the electrostatic formula with the learners before working through the worked example on page 257 of the Learner's Book.

Informal assessment

Learners can complete the research project at home. You can then mark this project according to the rubric provided. You can use these marks for informal assessment.

Research activity

This activity acts as an extension activity for learners. It is important for learners to go beyond the scope of the syllabus and relate what they have learnt to the world around them. If learners have access to the Internet, they can use it to research the advantages and disadvantages of nuclear power. The learners are required to make a poster stating the advantages and disadvantages of nuclear power.

Assess the activity according to the project rubric on page 95 of this Teacher's Guide.

Summary (LB page 258)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, it also but helps them consolidate what they have learnt.

Self-assessment (LB pages 259–260)

Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

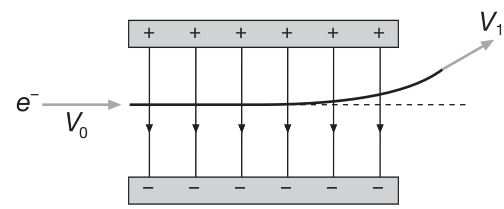
1. C ✓ (1) [U]
2. B ✓ (1) [K]
3. B ✓ (1) [Ap]
4. C ✓ (1) [K]
5. C ✓ (1) [K]

[5]

6. a) Protons = 92; electrons = 92; neutrons = 143 ✓ (1) [U]
   b) i) Atoms that have the same number of protons, but different numbers of neutrons (1) [K]
      ii) They react in the same way. ✓ They have the same number of valence electrons, ✓ which controls reactivity. (2) [U]
   c) i) During alpha-decay, an alpha-particle is emitted, which means the daughter nucleus has two protons and two neutrons fewer than the parent nucleus. ✓ (1) [K]
      ii) Protactinium ✓ (1) [K]
      iii) $^{235}_{92}\text{U} \rightarrow {}^{231}_{90}\text{Pa} + {}^{4}_{2}\text{He}$ ✓✓ (2) [Ap]

[8]

7. a)



✓✓ (2) [S]

   b) $F = EQ$ and $F = ma$, so $a = \frac{EQ}{m}$ ✓

   $a = \frac{500 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}$ ✓

   $a = 8.78 \times 10^{13}\ \text{m·s}^{-2}$ in the direction of the positive plate ✓ (3) [Ap]

   c) $v_f^2 = v_i^2 + 2ax$

   $v_f^2 = 0 + 2(8.78 \times 10^{13}) \times 0.05$ ✓

   $v_f^2 = 8.78 \times 10^{12}$

   $v_f = 2.96 \times 10^{6}\ \text{m·s}^{-1}$ ✓ (2) [Ap]

[7]

Total: 20

TOPIC 4.2 Fundamental particles

LB pages 261–266

Syllabus coverage	See the syllabus grid (year plan) in Section B.
General objectives	Show an understanding of the fundamental particles
Specific objectives	The specific objectives are listed in the syllabus grid (year plan) in Section B in this Teacher's Guide and also at the start of each sub-topic in the Learner's Book.
Cross-cutting issues	Information and communication technology
Inclusive education	Visually impaired learners need assistance with the nuclide notation of an atom. Ensure they are given an enlarged copy of the Periodic Table so they can identify the atomic and mass numbers easily.
Suggested teaching time	4 lessons
Additional resources needed	Periodic Table

Introduction to this topic

This topic introduces the concept of fundamental particles. It discusses quarks and how they determine the type of sub-atomic particle present. It also goes into more detail regarding beta-decay and the changes that take place during this reaction.

The best way to introduce this topic is by using diagrams. It is a very abstract concept that learners often find difficult to visualise. Start the lesson by drawing a mind-map of how matter is broken down into quarks. Use the diagram on page 262 of the Learner's Book as a reference.

Starter activity (LB page 261)

This activity revises the content covered in the previous topic. It gives the learners the opportunity to put the theory into practise. It acts as a baseline for you to assess how much was understood and whether any misconceptions still exist before moving on to the next topic.

Suggested answers

1. An electron and an antineutrino
2. A neutron changes into a proton.
3. A positron and a neutrino would be released.

Sub-topic 4.2.1: Fundamental particles

LB pages 262–266

Beginning these lessons

This sub-topic introduces quarks for the very first time. For years, learners have been taught that atoms are the smallest unit of matter, so it is hard for them to visualise something even smaller than an atom.

A video is a fantastic way to introduce the concept of a quark. If you have access to the Internet, type "fuseschool what is a quark" into YouTube. An excellent video will help introduce the topic, which can help start the class discussion.

Fundamental particles, and protons and neutrons (LB pages 262–264)

Teaching guidelines

This sub-topic can be challenging because there is a lot of new terminology and the similarity between the quarks makes it harder to distinguish between them.

Give learners time to consolidate the theory. Help them summarise the content and ensure that any work done in their books is taken down correctly. Diagrams can be a useful tool in explaining the concepts.

Homework

Ask the learners to copy down all new terminology with explanations in their book. Use the key word boxes as a guide for which words might be unfamiliar to the learners.

Suggested answers

Activity 1: Understand protons and neutrons (LB page 263)

1. No; fundamental particles are particles that cannot be broken down into smaller particles. Atoms can be broken down into protons, neutrons and electrons, so they cannot be fundamental particles.
2. Protons: 2 up quarks and 1 down quark with an overall charge of +1; neutrons: 2 down and 1 up quark with an overall charge of 0.

The quark model and beta-decay

(LB page 264)

Teaching guidelines

This sub-topic links what the learners now know about quarks to what they learnt in Sub-topic 4.1. It is important that they memorise the quarks that make up protons and neutrons.

Use this as opportunity for learners to practise their tabulation skills. Ask learners to draw a table that summarises the quarks that make up protons and neutrons, and link the table to beta-decay.

Suggested answers

Activity 2: Understand beta-decay and the quark model (LB page 264)

	β+ decay	β– decay
Quarks in nucleon that decays	d u u	d d u
Quarks in nucleon after decay	u d d	d u u
Leptons emitted	Positron and neutrino	Electron and antineutrino

Informal assessment

Learners can complete Activity 2 at home. You can mark it in the next lesson and use these marks for informal assessment. Each completed cell in the table is allocated one mark to give a total of 6 marks.

Summary (LB page 265)

Learners can use the summary for revision and self-study before they do the assessment exercises that follow. This not only supports their study skills, but it also helps them consolidate what they have learnt.

Self-assessment (LB page 266)

Note: You could let learners do this section as self-assessment, and then either give them the memorandum to mark their own work, or you could mark their work and give feedback. In either case, it acts as a diagnostic assessment tool.

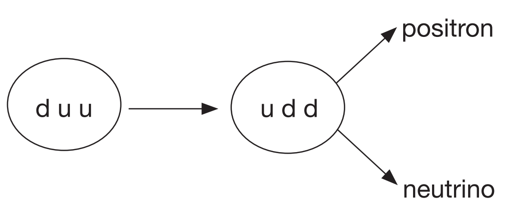
Suggested answers

Note: See page iv of this Teacher's Guide for an explanation of the abbreviations of the Bloom's levels (in square brackets) for the questions below.

1. B ✓ (1) [K]
2. B ✓ (1) [U]
3. B ✓ (1) [U]
[3]

4. a) Strange **b)** $-\frac{1}{3}$
c) Down **d)** d
e) u **f)** $+\frac{2}{3}$
(Subtract 1 mark for every incorrect answer.) ✓✓✓ (3) [K]

5. a) i) Two up quarks and one down quark ✓
ii) Two down quarks and one up quark ✓ (2) [K]
b)



✓✓ (2) [S]
[4]

6. Leptons can be charged as in the case of electrons or neutral as in the case of neutrinos. ✓ Particles include electrons, neutrinos and antineutrinos. ✓ Hadrons consist of baryons, such as neutrons and protons, ✓ and mesons. ✓ They are always charged. (max 3) [E]

7. No; ✓ fundamental particles cannot be broken down or simplified, ✓ but protons and neutrons consist of smaller particles called quarks. ✓ (3) [S]

8. a) Positron ✓ (1) [U]
b) A proton ✓ changes into a neutron. ✓ (2) [U]
c) β+ decay ✓ (1) [U]
[4]

Total: 20

Section D Resources for teachers

Generic assessment tools

In this section, you will find generic rubrics that you can use to mark practical work and research activities. The table, graph and experiment rubrics can be used as diagnostic assessment in preparation for Paper 3. A two-hour practical examination is challenging for many learners and the more time learners have to practise their skills in class, the better.

Graph rubric

Graphs form the basis for many questions in Paper 3. It is essential that learners understand the formatting required when plotting a graph.

Criteria	0–1 mark	2–3 marks	4–5 marks
Labels and units	Learner did not label the axes and no units were included.	Axes were labelled, but units were not included.	Axes were labelled, including units.
Scale	An appropriate scale was not used.	Points covers only one half of the horizontal or vertical area.	An appropriate scale was chosen. Points cover more than half the vertical and horizontal area.
Line of best fit	No line of best fit was drawn.	Line of best fit was attempted, but was incorrectly drawn.	Correct line of best fit was drawn. The same number of points are on either side of the line.
Plotting of points	Points were incorrectly plotted.	Most points were correctly plotted.	All points were correctly plotted.
Anomalous points	Anomalous points were included in the line of best fit.	Anomalous points were not included in the line of best fit, but they were not labelled as anomalous points.	Anomalous points were correctly labelled and were not included in line of best fit.
Neatness	Graph was untidy.	Attempts were made to work neatly, but the line drawn was not smooth.	A smooth pencil line was drawn.

Total: 30

Experiment rubric

This rubric can be used to assess any of the practical activities in the Learner's Book. It can be adapted to suit a specific experiment.

Criteria	1–2 marks	3-4 marks	5 marks
Followed instructions	Required assistance for all parts of the activity.	Required assistance for some sections of the activity.	Required no assistance.
Apparatus set-up	Required help to set up apparatus.	Required some help when setting up apparatus.	Required no help.
Variables	Correctly identified one variable.	Correctly identified two variables.	Correctly identified all three variables.
Table	Table was illogical.	Table has logical headings, but units not included.	Table is logical with both headings and units included.
Graph	All points correctly plotted, but axes are not to scale and line of best fit is incorrect. Axes labelled and units not included.	All points plotted correctly. Scale is correct, but line of best fit is incorrect. Axes labelled and units included.	All points plotted correctly. Scale is correct, as is line of best fit. Axes labelled and units included.
Conclusion	Conclusion incorrect.	Conclusion correct, but incorrectly stated.	Conclusion correct and correctly stated.

Total: 30

Table rubric

This rubric can be used whenever data has to be tabulated, for example, in Experiment 1 of Sub-topic 1.4 where learners determine the relationship between mass and acceleration. This rubric can be applied to any activity requiring tabulation.

Criteria	0–1 mark	2–3 marks	4–5 marks
Headings	Poorly thought out headings, description is not clear.	Headings are not descriptive enough.	Heading are clear and unambiguous.
Units	No units included.	Units are included, but incorrect.	Units are included and correct.
Significant figures	Significant figures are inconsistent throughout the table.	Readings are given to a consistent number of significant figures, but the number of significant figures is inappropriate.	Significant figures are used correctly and consistently throughout the table.
Layout	Illogical layout. Table is poorly designed. Not all the information required is provided.	All information required is tabulated, but the table's layout is illogical.	Table is well-laid out and all information is tabulated.

Total: 20

Project rubric

This rubric can be adapted for PowerPoint or oral presentations.

Criteria	1 mark	2 marks	3–4 marks	5 marks
Organisation	Clutter, no definitive sections and impossible to follow. Not all sections present.	No heading, but sectioned. Hard to follow, requires assistance. Missing parts. Obvious refinement required.	All sections present, but unclear. Must reread for clarity. Some evidence of refinement.	Defined sections. Clear headings. Flows nicely to assist the reader without help. Finished product.
Creativity	Bland, no variability. No use of colour or diagrams. Does not catch your attention. Interest, motivation, effort and time obviously absent.	Very little use of colour or pictures, but enough to engage and hold attention.	Some use of colour, diagrams, etc. Will engage but will not stimulate.	Interesting, engaging and visually stimulating. Aesthetically appealing use of colour, diagrams and text. Interest, motivation, effort and time obviously present.
Science content and literacy	No analysis of science topic. No explanation. No science-specific connection. No use of resources.	Poor explanation. Inaccurate science connection. Misinterprets the science. Only one resource used.	Adequate explanation. Science connection present but could be developed further. More than one resource present.	Concept fully and properly explained. Insight present. Science-specific connection made. Content is accurate, comprehensive and well supported. Excellent use of resources.
Level and difficulty of understanding	Task difficulty not suitable for grade level/not related to science (too easy). Superficial/irrelevant task.	Explanation describes minimal level of validity. Needs serious refinement.	Task difficulty could be increased or developed. Some level of understanding shown.	Difficulty appropriate for grade level. Understanding present and apparent.

Generic record sheets

This section contains generic record sheets that you can adapt for use wherever you need them.

Class record sheet

Use this sheet for recording marks. You can write down the actual marks, for example, 5/10, or use these symbols:

- A = Achieved objectives exceptionally well
- B = Achieved objectives very well
- C = Achieved objectives well
- D = Achieved objectives satisfactorily
- E = Achieved the minimum number of objectives to be considered competent
- U = Ungraded

Name	Date	Specific objective tested	Marks

Individual learner record sheet

Compile a sheet like this for each learner. Make notes about the type of task and insert a tick if the learner has achieved the knowledge, skills and values associated with each task.

Date: ______________________________

Subject/activity: ______________________________

Learner's name: ______________________________

Date	Task	Comment	Suggestions/notes

Answers to practice examination (LB pages 275–289)

Paper 1 memo (LB pages 275–282)

1. C
2. C
3. B
4. D
5. C
6. A
7. B
8. A
9. D
10. C
11. B
12. A
13. A
14. A
15. A
16. A
17. B
18. C
19. C
20. A
21. B
22. B
23. A
24. B
25. B
26. C
27. B
28. A
29. A
30. C
31. C
32. A
33. B
34. C
35. B
36. A
37. B
38. C
39. C
40. B

40 × 1 = [40]
Total: 40

Paper 2 memo

(LB pages 283–285)

Question 1

a) i) m^3 ✓ (1)

ii) density = $\frac{\text{mass}}{\text{volume}} = \frac{\text{kg}}{\text{m}^3}$ = kg.m^{-3} ✓ (1)

b) i) Uncertainty means the range of possible values within which the true value of the measurement lies. ✓ (1)

ii) % uncertainty = $\frac{\text{uncertainty}}{\text{measurement}} \times 100$

$1.6 = \frac{\text{uncertainty}}{0.022} \times 100$ ✓ (1)

uncertainty = 3.52×10^{-4} ✓ (1)

[5]

Question 2

a) i) A progressive wave is an oscillation that transfers energy from one place to another without any net movement of the medium. ✓ (1)

ii) The amplitude of a wave is the maximum displacement of the particles from the equilibrium position. ✓ (1)

b) i) Light spreads out, ✓ forming alternating bands of light and dark ✓ on either side of a central bright band. ✓ (3)

ii) $d = \frac{1}{2\,000}$ ✓ $= 5 \times 10^{-4}$ cm $= 5 \times 10^{-6}$ m ✓

$\sin\theta = \frac{\lambda}{d} = \frac{6.8 \times 10^{-7}}{5 \times 10^{-6}}$ ✓ $= 0.136$ ✓

$\theta = \sin^{-1} 0.136 = 7.82°$ ✓ (5)

iii) The wavelength of blue light is shorter, ✓ so the angle will be smaller. ✓ (2)

[12]

Question 3

a) $W = mg$

$W = 1.25 \times 9.8$ ✓ $= 12.25$ N ✓ (2)

b) i) k = gradient

$k = \frac{9 - 0}{1 - 0}$ ✓ $= 9$ ✓ (3)

ii) 300 mm + 1.4 mm ✓ = 301.4 mm ✓ (2)

c) i) The ratio between the change in the length of the material and its original length ✓ (1)

ii) $\varepsilon = \frac{e}{L} = \frac{1.4}{300}$ ✓ $= 0.00467$ ✓ (no units ✓) (3)

[11]

Question 4

a) $v = f \times \lambda$ but $v = \frac{d}{\Delta t}$ ✓

Therefore $d = (f \times \lambda)\Delta t$ ✓ (2)

b) i) The number of complete waves that pass a point every second ✓ (Also accept the number of oscillations per second.) (1)

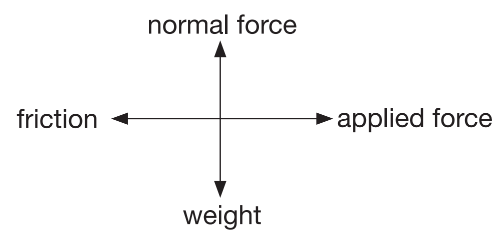
ii) $t = 3 \times 0.2 \times 10^{-3}$ ✓ $= 6 \times 10^{-4}$ s ✓

$f = \frac{1}{6} \times 10^{-4} = 1.67 \times 103$ Hz ✓ (3)

[5]

Question 5

a) i)



✓✓ (2)

ii) 2.4 N ✓ (1)

iii) Newton's first law ✓ (1)

b) i) $m_1u_1 + m_2u_2 = (m_1 + m_2)v$ ✓

$4 \times 0.2 + x(0) = (4 + x)0.1$ ✓

$x = 4$ kg ✓ (3)

ii) Initial $E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2}(4)\,(0.2)^2$ ✓ $= 0.08$ J ✓

Final $E_k = \frac{1}{2}(7)(0.1)^2$ ✓

$= 0.035$ J✓

This is an inelastic collision as the kinetic energy of the system changes. ✓ (5)

[12]

Question 6

a) $V = IR = 0.4 \times 15$ ✓ $= 6$ V ✓ (2)

b) emf $= V + Ir$

$12 = 11.4$ ✓ $+ 0.4r$ ✓

$r = 1.5\ \Omega$ ✓ (2)

c) I through $R_1 = 0.2$ A ✓

$R_1 = \frac{V}{I} = \frac{5.4 ✓}{0.2 ✓} = 27\ \Omega$ ✓ (4)

[8]

Question 7

a) A neutron is converted into a proton ✓ and an electron is released. ✓ (2)

b) ${}^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e}$ ✓✓ (2)

(${}^{0}_{-1}\text{e}$: β particle)

c) A proton consists of two up quarks ✓ and one down quark, ✓
therefore $+\frac{2}{3} + \frac{2}{3} - \frac{1}{3} = +1$. ✓ (3)

[7]

Total: 60

Paper 3 memo

(LB pages 288–289)

Question 1

a) Follows instructions and includes units ✓ (2)

b) Measures the distance between the metre rule and the table at both ends. ✓ Readings must be equal. ✓ (2)

c) **i)** Correct reading and unit ✓✓ (2)

ii) Correct reading and unit ✓✓ (2)

d)
- Correct headings ✓
- Units included ✓
- Repeats an appropriate number of times ✓ (3)

e)
- Axes labelled ✓
- Appropriate scales (plots occupying at least half grid) ✓
- Plots correct (to $\frac{1}{2}$ square) ✓
- Well-judged line, fine plots, thin and neat line ✓ (4)

f) Gradient = $\frac{\Delta y}{\Delta x}$, ✓ correct substitution, ✓ correct number of significant figures ✓ (3)

g) Correctly uses the formula, ✓ units included ✓ (2)

[20]

Question 2

a) **i)** Approximately 1.3 cm ✓
Recorded to the nearest mm ✓ (2)

ii) 2.3 N or 2.26 N ✓ (1)

iii) Least number of significant figures in the calculation is the mass with two significant figures, so the answer may be given to two or three significant figures.
Mass identified as the least number of significant figures. ✓
Mass has two significant figures, so answer can be 2 or 3. ✓ (2)

iv) Correct formula $\frac{\Delta t}{t} \times 100$ = % uncertainty ✓
Reaction time of a human is approximately 0.1 s.
$\frac{0.1}{3.24} \times 100 = 3\%$ ✓ (2)

b) Less than funnel 1 ✓ (1)

c) **i)** Correct value of first k found. ✓
Second value of k smaller than first value of k. ✓ (2)

ii) Calculation of % difference in k.
$\frac{\Delta k}{k_{smallest}} \times 100$ ✓
Justification based on criteria set by learner; % difference between k values should be no more than 10% for there to be a relationship. ✓ (2)

d) **i)** Two results are not enough to justify a relationship. ✓
Difficult to judge when all the sand has passed through the funnel. ✓
Some sand may stick to the funnel. ✓
Difficult to release the sand and simultaneously start the stopwatch. ✓ (4)

ii)
- Take more readings (six) and plot a graph. ✓
- Use a video recorder with a stopwatch in the shot to time the flow of sand more accurately. ✓
- Measure the mass of the sand and use it in the calculation. ✓
- Use a mechanical hand to release the sand and start the stopwatch at the same time. ✓ (4)

[20]

Total: 40