Excellence in

Physics

SENIOR SECONDARY

1

TEACHER'S GUIDE

Published by Cambridge University Press
Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

Distributed in Nigeria by Cambridge University Press Nigeria Ltd
252E Muri Okunola Street, Victoria Island, Lagos State, Nigeria

Cambridge University Press & Assessment is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

First published 2016

Printed in India by Multivista Global Pvt Ltd.

ISBN 978-1-316-50491-8 Paperback

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Cover image by: ShutterStock © Anteromite/ShutterStock

Acknowledgements
The publishers and authors would like to thank the following individuals and organisations for permission to use their material in either the original or adapted form:

Photographs
FotosStock S.A: p. 28

Contents

Theme 3 is not included as per the Nigerian Educational Research and Development Council (NERDC) curriculum.

Introduction

The purpose of the curriculum

The general objectives of the curriculum are to:

- provide basic literacy in Physics for functional living in society
- ensure that students acquire basic concepts and principles of Physics as a preparation for further studies
- ensure that students acquire essential scientific skills and attitudes as a preparation for the technological application of Physics
- stimulate and enhance creativity.

The goals of the curriculum

The goals of the curriculum place emphasis on:

- student-activity
- experimentation
- questioning
- discussion
- problem solving.

Time allocation

To cover this curriculum, the recommended weekly time allocation is two periods of 40 minutes each. Students need to do regular revision at home in order to cope with the content and new terminology.

The role of the teacher

One of the principle duties of a Physics teacher is to prepare and present good lessons to his or her students. The teacher has to:

- be as well informed as possible on the scheme of work of the subject
- know the aims and objectives of each topic
- select appropriate content materials
- decide on the best methods of presentation, such as PowerPoint, workstations, videos, discussion groups, worksheets, question–answer sessions, debate or experiments
- gather equipment and other resources required for the activities
- keep informed about new developments and news in Physics in Nigeria and the rest of the world
- arrange outings and guest speakers from time to time.

To be effective in presentation, the teacher must make a written or typed plan for each lesson. This plan must include aims, objectives, resources, time frames, content for the lesson, activities, homework, assessment and ideas or additional worksheets to cater for students requiring extension or learning support (remedial).

Prepare each topic in advance. Many teachers go into the classroom inadequately prepared. It is your responsibility as a Physics teacher to involve your students actively in the learning process. It is a proven fact that students learn far more by *doing* than by *listening*.

You should endeavour to apply the scientific method throughout. Science involves being curious and asking questions. Wherever possible, ask questions to engage the students and to encourage independent thought processes. Start your lessons by asking the students to write down answers to (approximately five) questions related to your lesson. This will settle them into the lesson.

You can ask different types of questions in your lessons:

- **diagnostic** questions to determine prior knowledge on the topic
- questions for **consolidation** of challenging concepts during the lesson
- questions for **stimulation** of interest in the subject
- questions for **concluding** the lesson. These will assist you to find out whether students have understood the concepts or terminology in the lesson. It will also highlight any areas that they need to revise at home or for you to revisit in the next lesson.

Teachers must ensure that they do not appear to have favourites in the class, so devise a system to ensure that you ask questions fairly, but be careful not to embarrass weak students if they cannot answer questions.

How to use the book

The purposes of this Teacher's Guide are to assist you to use the Student's Book and to assist you to be more thoroughly prepared so that your teaching will be more meaningful to your students. This book supports a hands-on approach and lays a solid foundation for SS2 and SS3.

You need to be familiar with the key features of the Student's Book.

The Student's Book is divided into 18 topics. Each topic is structured in the following way:

- performance objectives required by the curriculum:
- content required by the curriculum
- activities to be completed individually, with a partner, in groups or as a class
- summary of the topic
- key words – this is essential vocabulary for the topic
- practice tests for revision of the topic.

Please note that Theme 3: Waves: Motion without material transfer is not covered in the SS1 curriculum and is only introduced in SS2.

How to use the scheme of work

A scheme of work is defined as the part of the curriculum that a teacher will be required to teach in any particular subject. Its primary function is to provide an outline of the subject matter and its content, and to indicate how much work a student should cover in any particular class. A scheme of work allows teachers to clarify their thinking about a subject, and to plan and develop particular curriculum experiences that they believe may require more time and attention when preparing lessons. The criteria all teachers should bear in mind when planning a scheme of work are continuity in learning and progression of experience. You can add your own notes to the scheme of work provided on pages vi to x.

The scheme of work is sequential. The sequence of the scheme of work is aligned with the textbook. Do not be tempted to jump around. Rather spend time carefully planning the term to ensure that you adhere to the scheme of work.

The year is divided into three terms.

Each term is divided into 13 weeks. There are seven topics in Term 1, six topics in Term 2 and five topics in Term 3. The end of term allows time for revision and an examination. This time frame may vary depending on the planning of your particular school.

The right hand column gives the suggested lessons for each topic. This has been divided according to the content of the topic. These vary from three to seven lessons per topic.

The first lesson is usually an introduction to the topic. Make an effort to make this lesson exciting and informative. You should always explain the meaning of the topic in this lesson, for example: What is Physics? What is Matter? What is Space? What is Time? What is measurement?

The last lesson is allocated to revision. In this lesson, you can give the class a revision worksheet, a test or design a fun activity such as a game or a quiz to consolidate the topic. Students can also do their own revision by making mind maps, concept maps or other types of summaries. They can also set tests for each other.

It is important to note that these are a *suggested* number of lessons for the topic. The amount will vary according to the ability of the students in your class and their prior knowledge. Your management of the class will have an enormous influence on your ability to adhere to the time frames. Focus on effective discipline strategies. You will have fewer discipline issues if you are punctual and well prepared, follow a plan (write this on the board at the start of the lesson), keep your word (don't make empty threats), consistently adhere to rules (especially rules related to laboratory safety) and strive to make Physics an exciting subject.

A teacher of Physics is a professional instructor who facilitates, promotes and influences students to achieve the outcomes of the scheme of work. It is the wish of the authors that the students will, at the end of each course in the series (SS1, SS2 and SS3) attain a level of proficiency in Physics that will equip them for future studies in this field.

Table 1 Physics Teaching Scheme of Work for Senior Secondary 1

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
Term 1				
1/2	1: Interaction of matter, space and time	1.1 Fundamental and derived quantities and units (SB p. 1)	• Distinguish between fundamental and derived quantities. • Distinguish between fundamental and derived units.	1. Fundamental quantities: mass, length, time and electric charge 2. Fundamental units: kg, m, s, etc. 3. Derived quantities: force, speed, etc. 4. Derived units: m/s, m^3, m^2, etc. 5. Revision
3		1.2 Position, distance and displacement (SB p. 9)	• Distinguish between distance and displacement in a translational motion.	1. Measurement of distance 2. Distinction between distance and displacement 3. Revision
4		1.3 Time (SB p. 14)	• Construct a simple clock for measuring time intervals, by using a system that shows repetitive motion.	1. Concept of time 2. Ways of measuring time 3. Revision

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
5/6		1.4 Motion (SB p. 19)	• List various types of motion in a given environment. • Classify different types of motion (random, relational, oscillatory and translational). • Identify the forces that cause a body to move or change its movement. • Identify the forces that slow down and stop a moving body. • Identify friction as a force resisting the motion between bodies in contact and moving relative to each other. • Reduce friction in given situations. • Identify circular motion.	1. Types of motion: • Random motion • Translational motion • Rotational motion • Oscillatory motion • Relative motion 2. Cause and effects of motion 3. Types of force: • Contact force • Force field 4. Reducing friction 5. Simple idea of circular motion 6. Revision
7/8		1.5 Speed and velocity (SB p. 29)	• Distinguish between speed and velocity. • Plot a distance–time graph and deduce the speed of motion from the gradient or slope of the graph.	1. Concept of speed 2. Concept of velocity 3. Distance–time graph or displacement graph 4. Revision
8/9		1.6 Rectilinear acceleration (SB p. 35)	• Explain the concept of uniform motion. • Determine acceleration from a velocity–time graph.	1. Concept of acceleration 2. Uniform/non-uniform acceleration 3. Velocity–time graph 4. Analysis of rectilinear motion 5. Revision
10		1.7 Scalars and vectors (SB p. 40)	• Distinguish between scalar and vector quantities.	1. Concept of scalars 2. Concept of vectors 3. Distinction between scalars and vectors 4. Revision
11	Revision			
12/13	Examination			

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
Term 2				
1/2	2: Conservation principles	2.1 Work, energy and power (SB p. 45)	• Explain work, energy and power, and give at least one example of each. • Calculate: – the amount of work done, given a force and the amount of displacement it produces in the direction in which the force is acting. – the gravitational potential energy at a height *h* above a given reference plane. • Calculate the power, in watts, given an applied force and the time it takes to produce a given displacement. • Identify the type of energy possessed by a body under given conditions. • Distinguish between kinetic and potential energy. • Identify energy transformation from one form into another. • State the law of conservation of energy.	1. Concept of work, energy and power 2. Interchangeability of work and energy 3. Determination of work, energy and power 4. Work done in a force field 5. Types of energy (mechanical): • Potential energy • Kinetic energy 6. Conservation of mechanical energy 7. Revision
3/4		2.2 Heat energy (SB p. 57)	• Explain temperature, expansion, change of state and vaporization using the kinetic molecular theory. • Explain conduction, convection and radiation in terms of the kinetic molecular theory.	1. Concept of temperature 2. Effects of heat on change of state, expansion, vaporization 3. Expansivity 4. Transferred heat by conduction, convection, radiation 5. Revision
5/6		2.3 Electric charges (SB p. 74)	• Charge a body by friction, induction and contact. • Identify bodies of similar and opposite charge.	1. Production of charges 2. Types of charges 3. Distribution of charges 4. Storage of charges 5. Revision

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
7	4: Fields at rest and in motion	4.1 Description and properties of fields (SB p. 85)	• Identify force fields. • Identify the properties of force fields.	1. Concept of fields 2. Types of field: • Gravitational field • Magnetic field • Electric field 3. Properties of a force field 4. Revision
7/8		4.2 The gravitational field (SB p. 92)	• Identify force fields form a set of forces. • Explain why two solid bodies of different masses released simultaneously from rest at the same height accelerate towards the ground at the same rate and reach the ground at the same time. • Describe the shape of the Earth.	1. Acceleration due to gravity 2. Shape and dimension of the Earth 3. Revision
8/9/10		4.3 Electric fields (SB p. 102)	• Be able to draw electric lines of force around: – an isolated positive charge – an isolated negative charge – two like charges placed near each other – two unlike charges placed near each other. • Generate a continuous flow of charges. • Explain electric current. • Set up a simple electric circuit. • Distinguish between conductors and insulators. • Define resistance as opposition to flow of electrons. • Calculate the electrical work done in a given circuit.	1. Electric lines of force 2. Potential difference and electric current 3. Production of electric current 4. Electric circuit 5. Electric conduction through materials 6. Ohm's Law 7. Revision
11	Revision			
12/13	Examination			

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
Term 3				
1/2/3	5: Energy quantization and duality of matter	5.1 Particulate nature of matter (SB p. 125)	• Formulate simple hypotheses and test them before drawing conclusions based on specific information. • Explain how the molecules of a substance move relative to other molecules of the same substance. • Describe the atomic structure of matter. • State the constituents of the atom. • Use molecular theory to explain the three states of matter. • Describe the structure of simple crystals. • Distinguish between crystalline and amorphous substances. • Use the concept of the photon to explain that light behaves like particles.	1. Structure of matter: • Evidence of particle nature of matter • Simple atomic structure 2. Molecules: • Their nature • Size 3. Crystal structure of matter 4. States of matter: • Solid • Liquid • Gas 5. Photons: Particle nature of photons 6. Revision
4/5		5.2 Fluids at rest and in motion (SB p. 140)	• Define surface tension in liquids. • Classify fluids according to their viscous properties. • Give at least two examples of the application of surface tension and viscosity.	1. Surface tension: Definition and effects 2. Viscosity 3. Applications 4. Revision
6	6: Physics in technology	6.1 Units of measurement (SB p. 151)	• Identify units used in industry.	1. Units used in industry 2. Revision
7		6.2 Electrical continuity testing (SB p. 156)	• Construct a simple electrical continuity tester.	1. Continuity faults in electric circuits 2. Revision
8		6.3 Solar collectors (SB p. 158)	• Construct a solar collector. • Explain the use of solar energy panels for energy supply.	1. Solar energy 2. Solar panel for energy supply 3. Revision
9/10		All practicals		
11		Revision		
12/13		Examination		

THEME 1 Interaction of matter, space and time

TOPIC 1: Fundamentals and derived quantities and units
Performance objectives
1.1 Distinguish between fundamental and derived quantities. **1.2** Distinguish between fundamental and derived units.

Introduction

It is worth spending a little time on this topic in class discussions. As always, students should be given an opportunity to contribute to the discussion and to show what they know. This helps to build their confidence. Another practice we have found useful in confidence building is to get individual students to read parts of the text aloud to the class and to invite questions on the material.

Activity 1.1: Measuring mass

GROUPS (SB p. 3)

Resources

notebooks, pens, bathroom scale, kitchen scale, jug (with volume markings up to at least 1 litre), various pieces of fruit or vegetables (such as apples, pawpaws, cabbages or cauliflowers), cupful of dry beans

Guidelines

The school laboratory probably has a bathroom scale. If not, perhaps one could be bought using school funds. As the activity suggests, two such scales will allow students to compare masses recorded on the two instruments.

1. Facilitate: Be sure to show students how to adjust the scale to a zero reading when nothing is on the weighing platform.
2. Facilitate: One of the relationships that students should be encouraged to remember is that one litre of water has a mass of one kilogram. Ask the class whether it is necessary, in expressing the mass of a litre of water, to specify the temperature at which the measurements are made.

3. and 4. Facilitate: In recording the masses of items of fruit, raise the matter of water content with the class. How would they estimate the water content of an apple, for example? It may also be a good idea to hydrate the beans, after weighing them, and to record a wet mass.

Activity 1.2: Measuring length

PAIRS (SB p. 4)

Resources

notebooks, pens, rulers

Guidelines

Facilitate: Remind students about the error of parallax and the proper placement of their rulers to measure from zero.

Activity 1.3: Writing down derived quantities and units

INDIVIDUAL (SB p. 6)

Resources

notebooks, pens

Guidelines

Facilitate: Encourage the students to work from memory. It may be helpful to follow this activity with a class discussion so that any common misunderstandings can be addressed.

How are you doing?

(SB p. 8)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

acceleration – a change of velocity (which is speed in a direction)
derived quantities – those quantities we make, or 'create', by combining two or more fundamental quantities
derived units – units made out of combinations of fundamental (basic) units
dimension – one of the basic quantities; length (*L*), mass (*M*), time (*T*)
electric charge – a property of the smallest particles of matter that influences how these particles interact with each other
force – something that causes a body to change from a state of rest (that is, not moving) to a state of motion, or to change its state of motion
formalism – an agreed way of doing something
fundamental quantities – the basic quantities – mass, length, time and electric charge
fundamental units – basic units used to measure the fundamental quantities
interval (duration) – the amount of time that separates two events in time
length – the distance between two points or two bodies
mass – the amount of matter in an object
operational definition – a way of defining something by giving instructions about how to measure it
speed – a distance (length) moved in one unit of time

Practice test: Answers

1. a) The students should define 'fundamental quantity' as given in the text (the very basic, simple things we use to build our knowledge of the physical world and to give us a foundation). Check that students use their own words.✓ (1)
   b) mass,✓ length,✓ time✓ and electric charge✓ (4)
2. Derived quantities are those quantities we make, or 'create',✓ by combining two or more✓ fundamental quantities.✓ Examples: speed, acceleration, force, work, power (any two✓✓) (5)
3. Fundamental units: kilogram, metre, second, coulomb (any two✓✓). Derived units: metres per second, metres per second per second (metres per second squared), kilogram metres per second squared (newtons), newton-metre (joule), joule per second (any two✓✓). Clear labels.✓ (5)
4. The name is that of a scientist who contributed theoretical work in the area.✓✓ (Also ask for other examples – N for Isaac Newton, J for James Joule etc.) (2)
5. An operational definition is one that carries instructions for measuring✓ the thing that is defined.✓ (2)
6. Electrostatics is a branch of physics✓ concerned with charges✓ at rest.✓ (3)
7. a) The newton is named after Isaac Newton.✓ (1)
   b) The abbreviation of the newton is an upper-case N.✓ (1)
8. Force = mass✓ × acceleration✓ (2)
9. Acceleration is measured in metres per second squared.✓✓ (2)
10. Rectilinear acceleration is acceleration✓ in a straight line.✓ (2)

Total marks: 30

TOPIC 2: Position, distance and displacement
Performance objective
2.1 Distinguish between distance and displacement in a translational motion.

Introduction

The ideas covered in this topic are simple ideas to get across and it is an opportunity to have some fun with the students. Let them take turns to contribute examples of distances and displacements between various objects.

Activity 1.4: Defining reference points

INDIVIDUAL (SB p. 9)

Resources

notebooks, pens

Guidelines

Facilitate: It may be helpful to have a class discussion once students have defined reference points and thought of their own examples. Help learners to think about appropriate reference points in different contexts.

Activity 1.5: Measuring length and calculating area and volume

GROUPS (SB p. 10)

Resources

notebooks, pens, rulers, steel tape measures (at least 3 m long)

Guidelines

1. Facilitate: Point out to students that measuring distances with inappropriate measuring apparatus is laborious and conducive to inaccuracy. Make this point by having some students measure the size of the classroom with an ordinary ruler, and comparing the results with values obtained with a three-metre steel tape measure. Also, encourage students to estimate values before they actually measure them. This will improve their 'feel' for quantities.

2. to 5. Facilitate: Guide students in their calculations of the area and volume of the classroom. Discuss the area per person and convey some idea of an 'optimum' quantity of space per person.

Activity 1.6: Measuring distance and displacement

PAIRS (SB p. 11)

Resources

steel tape measures (at least 3 m long)

Guidelines

Facilitate: Follow up this pair work activity with a class discussion. Call for a volunteer from the class to explain, aloud to the class, his or her procedures. Make sure the student understands the importance of a reference point. Call for alternative reference points, and ask how any specified reference point might be characterized.

Activity 1.7: Teaching and learning

PAIRS (SB p. 11)

Resources

various household or classroom objects, such as cups, pens or books

Guidelines

This activity might be set as a homework task. Ask a few of the students to report back, during the next lesson, on how they managed in their role of 'teacher' and what questions their efforts solicited.

How are you doing? (SB p. 12)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

displacement – a measurement that contains information about the distance and the direction from one point, or body, to another

distance (length) – a measurement of how far one reference point is from another

scalar quantity – a quantity which is completely specified by a magnitude (an amount) and does not involve a direction, e.g. distance

translational motion – movement which involves a change in position (location)

vector quantity – a quantity which is specified by a magnitude (an amount) and a direction, e.g. displacement

Practice test: Answers

1. Distance is a length between two reference points.✓ Distance is a scalar quantity – it has magnitude ('size'), but no direction.✓ Displacement is a distance in a specified direction.✓ Displacement is a vector quantity – it has magnitude and direction.✓ The statement should be checked for language and accuracy. (4)
2. Displacement describes a distance in a direction, so it tells us not only how far something is from a reference point, but also where it is in relation to that reference point.✓✓ For example, A and B might be two metres apart, but the displacement from A to B is two metres in a northerly direction✓ and the displacement from B to A is two metres in a southerly direction.✓ (4)
3. Make sure that graph paper is available for all members of the class. (8)

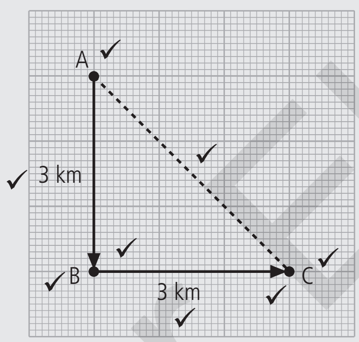

Figure 1.1 Vector diagram for Question 3

4. Reference points are points from which measurements are made to identify the position or movement of a point or body.✓ Reference points must be chosen so that other people are able to recognize and use these points.✓ (2)
5. A 'scalar' is a quantity which has magnitude ('size') but no direction.✓ Distance is an example of a scalar quantity.✓ (2)
6. The distance between two points depends on the 'path' (route) travelled to get from one to the other.✓✓ (2)
7. The displacement of Lagos from Abuja is about 540 km in a south-westerly direction.✓✓ (2)
8. The standard unit in which displacement is measured is metres (m).✓ (1)

Total marks: 25

TOPIC 3: Time	
Performance objective	
3.1	Construct a simple clock for measuring time intervals, by using a system that shows repetitive motion.

Introduction

Time is a sufficiently fascinating subject that you should encourage students to share their views on what time 'really is'. (There are no 'correct' answers!) Draw their attention to Woody Allen's definition.

Activity 1.8: Measuring rates and intervals PAIRS (SB p. 15)

Resources

notebooks, pens, wristwatches with second hands or stopwatches, egg timers

Guidelines

Facilitate: You may need to help students locate the pulse in their wrists. They should use the index and middle fingers to feel the pulse. Tell them not to press too hard – if they do they will close the vessel and obliterate the pulse! If you want to generate some discussion, invite them to take another pulse reading after performing five to ten rapid deep knee bends. They may enjoy discussing the pulse rate changes.

Activity 1.9: Measuring time with repetitive events CLASS (SB p. 16)

Resources

dictionary, calendar

Guidelines

Facilitate: Encourage students to provide examples from their own experience. The important thing in this activity is for the students to realise that short-period events are chosen for events that occur frequently, and events of longer periodicity are used for events more widely spaced in time. They should realise that day and night, seasons, etc. are themselves 'cyclic' and therefore repetitive. Guide the students, as necessary, in the use and usefulness of the dictionary. It may be useful to find out whether all the students know the English alphabet to use the dictionary effectively – a surprising number of students don't.

Activity 1.10: Making and using pendula GROUPS (SB p. 17)

Resources

notebooks, pens, dictionary, for each group: two sets of pendulum equipment (see details below), wristwatch with a second hand or stopwatch

Pendulum equipment: It will be much more effective if you provide the students with their materials in a half-prepared state.

For the *bobs*, use aluminium discs (which won't rust and will last indefinitely). The discs should be at least 4 mm thick and have different masses: have some of 6–8 cm in diameter and others of perhaps 10–12 cm. Drill a hole of about 4–5 mm in diameter in each disc. Weigh the discs before the activity and mark each disc with its mass, so that the students can compare the periods of pendula with different masses.

For the *suspending cord*, use thin string of different lengths (e.g. 50 cm and 100 cm) and make a small loop at each end. One loop can be used as a 'lassoo' to fix the cord to the bob and the other to hang the pendulum. Prepare hooks or nails on a convenient wall, with sufficient room for the pendula to swing freely.

Guidelines

Facilitate: It is important when doing these activities that the students discover the difference in period between short and long pendula. Give each group two discs (of different, marked masses) and two cords (of different lengths) and show them how to attach the bob to the string and the string to the pre-prepared hooks or nails.

How are you doing? (SB p. 17)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

antemeridian (am) – before noon (*ante-* means 'before')

chronometer – a 'chronometer' is an instrument that measures time – it is a clock; the word is usually applied to a very accurate type of clock

duration – the length of time that something endures (how long it lasts)

elapsed time – the amount of time that has passed since some reference time

interval – (duration) the amount of time that separates two events in time

period – the amount of time required for a repetitive process to be completed once; for example, a planet's period is the amount of time it takes to complete one orbit (revolution around its circular path), the period of a pendulum is the time it takes for one complete swing both ways; (note that the word 'period' has several other meanings in language; it may simply refer to a segment of time during which something happens)

postmeridian (pm) – after noon (*post-* means 'after')

Practice test: Answers

1. An interval is the length of time between two events.✓ Again, students should use their own words for the description. (1)
2. Repetitive events are those which happen regularly✓ with the same interval between them✓ which can be used to measure the passing of time.✓ Examples include annual national holidays or religious celebrations, birthdays and anniversaries. (3)
3. a) A pendulum is a weight on a length of string or chain with one fixed end.✓ A pendulum swings backwards and forwards with a specific period.✓ (2)
   b) No.✓ In deep space a pendulum will not swing,✓ because there will not be a sufficient 'pull' of gravity✓ to accelerate the bob.✓ (4)
4. No.✓ Changing the weight does not change the period of the pendulum.✓ (2)
5. Lengthening the 'arm' or 'string' of the pendulum increases its period.✓ It swings more slowly.✓ (2)
6. Postmeridian: 'after midday'.✓✓ (2)
7. Etymology is the study of the origins and original meanings of words.✓✓ (2)
8. '*Chronos*': 'time' (from Greek)✓✓ (2)

Total marks: 20

TOPIC 4: Motion
Performance objectives
4.1 List various types of motion in a given environment. **4.2** Classify different types of motion (random, relational, oscillatory and translational). **4.3** Identify the forces that cause a body to move or change its movement. **4.4** Identify the forces that slow down and stop a moving body. **4.5** Identify friction as a force resisting the motion between bodies in contact and moving relative to each other. **4.6** Reduce friction in given situations. **4.7** Identify circular motion.

Introduction

We have always found this subject an especially rewarding one to teach, because motion is familiar to all of us, yet physics requires us to see aspects of it in a new way. Give the students the opportunity to grasp the ideas of relative motion, a frame of reference, uniform motion in a straight line and accelerated motion. They may need time and some help to understand that uniform motion in a straight line is unaccelerated motion. Try to get these ideas across to them before introducing the other types of motion – oscillation, rotatory motion, etc.

Activity 1.11: Describing motion

PAIRS (SB p. 22)

Resources

notebooks, pens, optional: tennis ball, stringed instrument or elastic band

Guidelines

1. Facilitate: This is simply an exercise in writing down, from the textbook, the types of 'pure motion'. Encourage students to use their own words and good English.
2. Facilitate: If possible, use a tennis ball to demonstrate different types of movement. The students should recognize that a number of different types of motion may be occurring at the same time and that the answer depends on the precise movement of the ball.
3. Facilitate: The main type of movement will be oscillatory. If possible, a stringed instrument or elastic band could be used to demonstrate the motion.

Activity 1.12: Experiencing forces

GROUPS (SB p. 23)

Resources

pre-prepared variety of everyday objects of different masses (weighed in advance and each marked with its mass), optional: a coil spring

Guidelines

This is an 'experiential' activity, in which students are asked to lift various bodies of known mass. Remind them that one litre of water has a mass of one kilogram (not counting the container!). If you have any sportsmen or sportswomen in the class, raise the matter of the greatest masses that can be lifted by humans. Keep them aware of the difference between mass and weight. Weight is a force. Mass is not. Weight is the force caused by gravity acting on mass. If time constraints allow it, introduce to them the idea of lifting masses on the moon. The gravitational 'pull' on the moon's surface is one sixth of what it is on the surface of the Earth. Hence a man who can lift 50 kg on Earth can lift 300 kg on the moon. Again, emphasise to them that the kilogram is a unit of mass, not of force. Ask them to name the unit of force.

Activity 1.13: Experiencing the force of friction

GROUPS (SB p. 24)

Resources

notebook, pen, various books (or similar pieces to use as masses), small blocks of wood, wooden planes (such as a bread board or short plank), protractor or similar device to measure angles

Guidelines

1. Facilitate: Make sure the students understand that the area of the surfaces in contact (book and desk) are the same, regardless of whether one, two or more books are stacked on top of each other. The greater force required to push the heavier pile is due to the greater force (pressure) between the moving surfaces.
2. Facilitate: Students will enjoy 'playing' with inclined boards and blocks of wood (or other convenient materials).

How are you doing?

(SB p. 27)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

Brownian motion – the random, jerky motion of particles

centrifugal – this literally means 'flying away from the centre' (sometimes called 'centrifugal force'); an effect caused by a body being rotated fast

centripetal – the opposite of 'centrifugal', which means 'pulling or moving towards the centre'; the centripetal force in a length of string is what causes a weight to move in a curved path when it is whirled around some point

circular motion (curvilinear motion) – movement along a curved path

force fields – have magnitude (also called strength) and direction; different points in a force field correspond to different strengths and directions

friction – a force that opposes (acts against) movement between two surfaces in contact

lubricant – something that is used to reduce friction between bodies in contact with each other (e.g. engine oil); the lubricant takes up the very small space between the bodies and allows them to move more easily than they would be able to move without the layer of lubricant between them

motion – movement

mixed motion – movement of more than one type at the same time

oscillatory motion – a repeated back-and-forth movement; a type of movement that involves going in opposite directions repetitively; an oscillator moves in a way that is called simple harmonic motion (SHM)

perfect translational motion – movement in a straight line at a constant speed

random motion – disordered and chaotic movement that does not have any 'plan' controlling it and is therefore impossible to predict accurately

relative translational motion – movement of a body relative to a reference point or system

translational motion – movement which involves a change in position (location)

Practice test: Answers

1. Types of motion: random motion,✓ perfect translational motion (uniform motion in a straight line),✓ relative motion,✓ oscillatory (vibratory) motion,✓ rotational motion,✓ circular motion✓ (6)
2. In this very simple type of motion, the body is not rotating or rocking or moving along a curved path or moving back and forth. It is not changing the speed or the direction of its movement. Each part of the body is moving in a straight line. So, uniform motion in a straight line (perfect translational motion✓) is movement✓ in a straight line✓ at a constant speed.✓ (4)
3. The important point is that no external or net forces✓✓ are acting on a body moving with uniform motion in a straight line.✓✓ (4)
4. A body moving in a curved path is doing so because some net force is acting on it.✓✓ A moving body with no forces acting on it will not change direction to move in a curved path.✓✓ (4)
5. Friction is a force that opposes (acts against) movement between two surfaces in contact with each other.✓✓ Friction is called a 'contact force', because it exists between bodies that are in contact with each other.✓✓ For example, the force that causes a ball to slow down and stop is called friction. (4)
6. A lubricant is used to reduce friction.✓✓ (2)
7. Centripetal: 'towards the centre'.✓✓ (2)
8. Examples: a pendulum bob, a plucked guitar string, a plucked elastic band, a swing in motion (any one✓✓) (2)
9. Brownian motion is the random, 'jiggling', jerky, disordered motion of fine particles, such as powder.✓✓ (Brownian motion is named after its discoverer, botanist Robert Brown.) (2)

Total marks: 30

TOPIC 5: Speed and velocity

Performance objectives

5.1 Distinguish between speed and velocity.
5.2 Plot a distance–time graph and deduce the speed of motion from the gradient or slope of the graph.

Introduction

The ideas here are straightforward and should present no difficulty to the students. They must, of course, be familiar with the concept of scalars and vectors, which they encountered in Topic 2. They must understand that speed (a scalar) has magnitude only, but velocity (a vector) has a magnitude and a direction. It is quite acceptable to speak of the magnitude of a velocity, even though velocity is a vector. If we talk of the magnitude we are talking only of that part of velocity which is the speed. Take time to ensure that all students are comfortable with the graphic representation of information.

Activity 1.14: Working with speed and velocity

PAIRS (SB p. 31)

Resources

notebooks, pens, calculators, dictionary

Guidelines and answers

1. a) Students must understand that the problem simply involves calculating the amount of time for the journey and dividing this into the distance. It is easiest to convert the time into minutes, and to re-convert to hours after the division has been done.

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{43\text{ km}}{87\text{ min}} = 0.49\text{ km/min} = 29.7\text{ km/h.}$$

As a further exercise, ask the class what they need to assume in calculating the average speed from the information given. They need to assume that the car spent all of this time moving. If it spent some time motionless, its average speed would need to be much greater!

b) The 'trick' question, about calculating the velocity, is that the displacement is zero. The car ends its journey at the place from which it started. Thus its displacement is zero, and its average velocity is therefore zero.

2. Ensure that all students are able to do the necessary calculations and work neatly. (Note that the unit for Question 2a) should be km not km/h and Question 2b) should ask for 12 km/h to be given in m/s.) For b), remind them that they need to convert to metres per second because these are SI units, which should be used in all scientific measurements and calculations.

a) $$\text{distance} = \text{speed} \times \text{time} = 12\text{ km/h} \times 46\text{ min} = 12\text{ km/h} \times 0.77\text{ h} = 9.24\text{ km}$$

b) $$12\text{ km/h} = 12\text{ km} \times \frac{1\,000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 3.33\text{ m/s}$$

3. An 'odometer' is an instrument for measuring the distance travelled by a wheeled vehicle.

Activity 1.15: Converting units of speed and calculating velocity

PAIRS (SB p. 33)

Resources

notebooks, pens, calculators

Answers

1. $650 \text{ km/h} = 650 \text{ km} \times \frac{1\,000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}}$

   $= 180.6 \text{ m/s}$

2. $\text{velocity} = \frac{\text{distance north}}{\text{time}}$

   $= \frac{650 \text{ km}}{70 \text{ min}}$

   $= 9.29 \text{ km/min}$

   $= 557.4 \text{ km/h}$

How are you doing?

(SB p. 33)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

average speed – distance moved in a specific unit of time

average velocity – distance moved in a direction in a specific unit of time

uniform (constant) speed – movement at the same speed in each unit of time

uniform (constant) velocity – movement at an unchanging speed and in an unchanging direction

velocity – the rate of change of displacement; a vector quantity which is specified completely by a speed and the direction in which the movement is happening, so a change in the speed or the direction of the movement involves a change in the velocity

Practice test: Answers

1. The value given is only the magnitude of the velocity.✓ The direction is not given;✓ therefore, the statement is not wrong, but incomplete.✓ (3)
2. average speed $= \frac{\text{distance}}{\text{time}}$✓
   $= \frac{30 \text{ km}}{35 \text{ min}}$✓
   $= 0.86$ km/min✓
   $= 51.4$ km/h✓ (4)
3. a) i) B✓
   ii) A✓
   iii) C✓ (3)
   b) i) C✓
   ii) A✓
   iii) B✓ (3)
4. The x-axis is also called the abscissa.✓✓ (2)
5. By convention,✓ you would put time on the x-axis✓ because time is the independent variable.✓ (3)
6. The x-axis and the y-axis meet at the origin.✓ (1)
7. Average velocity is defined as displacement divided by time.✓ If the pendulum swings once every second, after exactly four hours, the bob will be in exactly the same place that it was four hours before.✓ Thus, the displacement is zero,✓ and the average velocity is therefore zero.✓ (4)
8. The symbol for displacement is s.✓✓ (2)

Total marks: 25

TOPIC 6: Rectilinear acceleration

Performance objectives

6.1 Explain the concept of uniform motion.
6.2 Determine acceleration from a velocity–time graph.

Introduction

A large part of mastering elementary science is the challenge of familiarising oneself with the relevant vocabulary. It is vitally important that students become comfortable with the technical words that are new to them, but central to an understanding of the subject. 'Rectilinear' is an example of such a word.

Activity 1.16: Exploring acceleration

GROUPS (SB p. 37)

Resources

notebooks, pens, calculators, graph paper

Guidelines and answers

This activity requires, and tests, familiarity with graphs and interpretation of graphs.

1. AB: constant acceleration; BC: constant velocity; CD: constant deceleration.
2. Students should be encouraged to study the information in the tables *before* plotting the graphs (for Question 3), because much can be learned simply by studying the figures. Thus, it should be obvious to them that, in Table A, the speed added in each five-second interval is 0.3 s, thus the acceleration is uniform (= constant). It is very easy to see this because the time intervals are equal (all five seconds). Table B must therefore be the one in which the acceleration is not uniform. This is not immediately obvious on inspection of the data in Table B, because the time intervals given are not constant, but some mental arithmetic should come to the aid of the students, if they know what to look for. Nothing can be concluded about the overall acceleration from the speed increase during the first interval (4 to 8 seconds = 4 seconds). In this four-second interval, the increase in speed is 32 km/h (74 – 42 = 32 km/h). We are not told the speed at time zero. The second interval (8 to 22 seconds = 14 seconds) shows, in that segment of time, a speed increase of 46 km/h (120 – 74 = 46 km/h). By mental calculation, we recognise that a speed increase of 32 km/h in four seconds is not proportional to a speed increase of 46 km/h in a time interval of 14 seconds. The second time interval is more than three times as long. The increase in speed, during that time, is less than twice what it is in the previous interval. The rate of acceleration is slowing down. Try to ensure that the students follow this argument (and calculation) before they start plotting the data on graphs.
3. Make sure the students understand how to use the graphs to arrive at speeds during times not specifically given in the Table(s), but easily accessible from the graphs of the data.

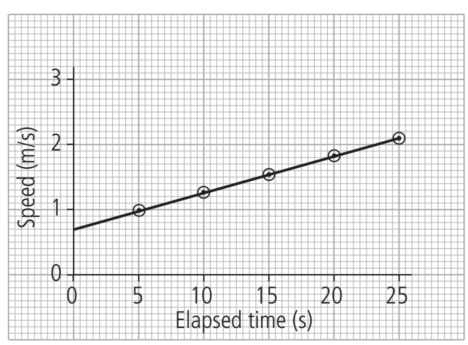

Figure 1.2 Graph A

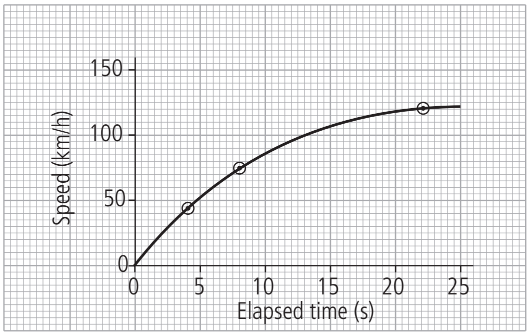

Figure 1.3 Graph B

4. As discussed in 2, in B the body is not moving with uniform acceleration. As we saw, the increase in speed, during the second interval is less than twice what it is in the first. The rate of acceleration is slowing down. Students should be able to interpret this from the graph as well as from the table.
5. a) Table A does not allow us to calculate the speed after three seconds exactly, because this elapsed time occurs before the first interval. However, we can use Graph A to determine the speed at three seconds by reading off the speed at time 3 s.
   b) Facilitate: Guide students in following the formula and description on page 35 of the SB to calculate the acceleration from the slopes of their graphs. Remind them that they should get the same results from either the table or the graph since both give the same information.
6. a) Again, students should be guided in using Table B and Graph B to determine the speed of the body at 15 seconds.
7. $120 \text{ km/h} = 120 \text{ km} \times \frac{1\,000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}}$
   $= 33.33 \text{ m/s}$

How are you doing? (SB p. 38)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

acceleration – a rate of change of velocity (speed in a direction), when a body is travelling in a straight line
deceleration – negative acceleration
negative acceleration – decreasing velocity
positive acceleration – increasing velocity
rectilinear acceleration – movement of a body in a straight line with a change in speed
uniform motion – movement in which nothing about the motion is changing; movement with no change in speed or direction

Practice test: Answers

1. 'Rectilinear': 'a straight line'✓
   'uniform': 'unchanging'✓ (2)
2. a) Without going into more advanced vector analysis, negative acceleration can be described as that in which a body is slowing down.✓ It is 'decelerating'.✓ (2)
   b) Any body which is slowing down✓ will have negative acceleration.✓ For example, a motor car applying its brakes can be said to have negative acceleration.✓ (3)
   c) 'Deceleration' is another word for negative acceleration.✓ (1)
3. a)

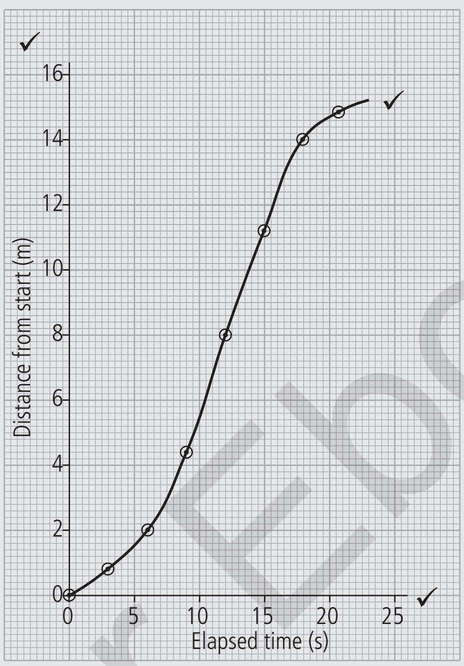

Figure 1.4 Graph for Question 3

(3)

   b) The changing slope of the graph shows the changing acceleration of the car. A slope with a constant gradient shows that the car is moving at a constant speed. A changing slope shows acceleration or deceleration.✓✓✓ (3)
4. A total of 9.8 metres per second is added in each second.✓✓ (You may agree to 10 metres per second as an approximation, but make sure the students realise that it is an approximation. They will later be expected to know the value of 9.8 metres per second.) (2)
5. Sir Isaac Newton developed the equations we use for calculating velocity, displacement and acceleration.✓✓ (2)
6. A body will fall 4.9 metres in the first second of free fall. (This is because it starts from zero velocity. In each subsequent second it adds 9.8 metres to the distance covered in the previous second.)✓✓ (2)
7. An unaccelerated body moves with uniform motion in a straight line.✓ In other words, its speed and the direction of its movement remain constant.✓ If a body changes its speed and/or the direction of its movement, this is, by definition, an acceleration.✓ It tells us that the body is being acted on by a force, or forces.✓ In the case of a planet, its movement is along a curved path, thus it is accelerating, and we know that a force must therefore be acting on it.✓ This force is, of course, the sun's gravitational 'pull'. (5)
8. The ball is being pulled towards the centre of the Earth,✓ but it gains so much speed on the way down that it will carry on past the centre and will travel very nearly to the other side of the Earth.✓ It will then fall back.✓ Eventually, after a lot of backwards and forwards movement,✓ it will stop at the centre of the Earth.✓ What will make it stop? The friction of the

Earth's atmosphere will 'erode' its speed slowly.✓ (If you did this experiment on the moon, which does not have an atmosphere, the ball would fall backwards and forward through the hole, to each side of the moon, forever.) (6)

9. What makes the acceleration constant (or uniform) is the fact that, in each second of time,✓ the same amount of speed is added to the speed the body had in the previous second.✓ The amount of speed added in each second is 9.8 m/s.✓ This is what is constant, and this is why the acceleration is described as constant.✓ (4)

Total marks: 35

TOPIC 7: Scalars and vectors

Performance objective

7.1 Distinguish between scalar and vector quantities.

Introduction

Students have already been introduced to scalars and vectors and a brief revision of the main ideas should be carried out with the class before starting on this topic.

Activity 1.17: Exploring scalar and vector quantities INDIVIDUAL (SB p. 40)

Resources

notebooks, pens

Guidelines

This is simply a recording by the students of quantities that fall into the categories 'vector' and 'scalar'. You may decide to make it into a test, by not allowing the students to look up the identities of the various quantities listed, or they may simply refer to the relevant parts of the textbook.

Answers

temperature (S), mass (S), force (V), speed (S), velocity (V), displacement (V), time (S), electric charge (S)

Activity 1.18: Completing a vector analysis PAIRS (SB p. 42)

Resources

notebooks, pens, calculators, rulers, graph paper

Guidelines and answers

1. a) Remind the students that the distances between the points should be drawn with arrows. The arrows should be drawn to scale and show the direction of movement.

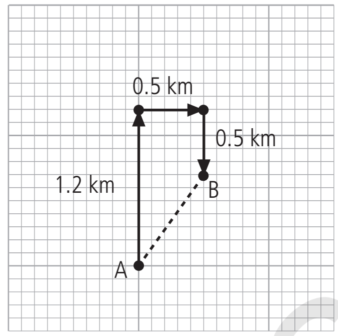

Figure 1.5 Vector diagram for Activity 1.18

   b) The distance covered is simply the sum of each part of the route: 1.2 km + 0.5 km + 0.5 km = 2.2 km
   c) The displacement can be calculated (using the correct ratio) by measuring the length between Point A and Point B on the graph.
2. a) The friends walk along the same route back to their starting point, so the distance walked, will be double that calculated in (1a), i.e. 4.4 km.
   b) This question has the same 'catch' as we put into an earlier question about average velocity, but we have not mentioned that there is a catch this time! Velocity is a *displacement* per unit of time. When the friends arrive back at Point A, they will be back at their starting point. Thus their displacement is zero. Before explaining this to the class, give them an opportunity to see the 'catch' without warning them about it.

How are you doing? (SB p. 43)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

analysis – literally means to 'break something up' or to take it apart to learn something about it; you can analyze a sentence, a substance or a movement; analysis involves reducing something to its simpler components (the opposite of analysis is 'synthesis'; to synthesize something is to put it together)

scalar quantities – a quantity which is completely specified by a magnitude (an amount) and does not involve a direction, e.g. distance

vector quantities – a quantity which is specified by a magnitude (an amount) and a direction, e.g. displacement

Practice test: Answers

1. a) distance travelled in 1 minute
   = 50 cm × 60 second
   = 3 000 cm/minute✓
   distance travelled in 1 hour
   = 3 000 cm/minute × 60 minutes
   = 180 000 cm/hour✓
   ∴ distance travelled in 3 hours
   = 180 000 cm/hour × 3 hours
   = 540 000 cm✓
   Because this is a large number, the value would be better expressed as metres (540 000 cm = 5 400 m) or kilometres (540 000 cm = 5.4 km).✓ (4)

   b) speed = $\frac{\text{distance}}{\text{time}}$✓
   = $\frac{50 \text{ cm}}{\text{s}}$✓
   = 0.5 m/s✓✓ (4)

   c) At the end of the three hours (or any other whole number of hours)✓ the bob ends up exactly where it was at the start of the measured time interval✓ Thus the displacement is zero,✓ and the average velocity is therefore zero.✓ (4)
2. Magnitude means size.✓ (1)
3. Scalars are quantities that possess only magnitude (size). We can therefore add them using simple arithmetic.✓ Vectors have both magnitude and direction.✓ Clearly we cannot add vectors using simple arithmetic. We need a way of adding vectors which takes into account their direction(s).✓ (3)
4. Her displacement is four kilometres east.✓ Because east and west are in 'opposite' directions, we could call east positive and west negative and get: 2 km – 3 km + 5 km = 4 km.✓ Since the result is positive, we know that the direction is east.✓ (3)
5. Time is regarded as a fourth dimension.✓ We use three dimensions to 'locate' a point in space, but we need to 'locate' bodies in time as well as space. Thus, 'spacetime' (or space-time) is four dimensional.✓ (2)
6. Mass and weight are related, but they are not the same, and there is therefore no reason why they should both be scalars.✓ Specifically, weight is a force.✓ A force has direction as well as magnitude, and is therefore a vector.✓ (3)
7. Torque should be pronounced 'tork'.✓✓ (2)
8. Speed is a scalar.✓ Thus, a change in direction does not mean that the speed has changed.✓ Speed may remain constant while direction changes. But a velocity, as a vector, is defined in terms of speed (the magnitude of the velocity) and a direction. By definition, a change in speed or direction involves a change in velocity.✓ No, if the speed of a body changes its velocity must necessarily change.✓ (4)

Total marks: 30

THEME 2 Conservation principles

TOPIC 1: Work, energy and power
Performance objectives
1.1 Explain work, energy and power, and give at least one example of each. **1.2** Calculate: **1.2.1** the amount of work done, given a force and the amount of displacement it produces in the direction in which the force is acting. **1.2.2** the gravitational potential energy at a height h above a given reference plane. **1.3** Calculate the power, in watts, given an applied force and the time it takes to produce a given displacement. **1.4** Identify the type of energy possessed by a body under given conditions. **1.5** Distinguish between kinetic and potential energy. **1.6** Identify energy transformation from one form into another. **1.7** State the law of conservation of energy.

Introduction

Conservation is an extremely important concept in physics and you are advised to spend a little class time allowing students to familiarize themselves with the idea of a 'conserved quantity'. Use the opportunity to revise with the students some of the main forms of energy – heat, light, movement, sound, etc.

Activity 2.1: Calculating work

PAIRS (SB p. 46)

Resources

notebooks, pens, calculators, rulers, graph paper

Answers

1. work = force × distance
   = 300 N × 5 m
   = 1 500 J
2. He must overcome the force of friction, which resists his efforts to move the box.

Activity 2.2: Calculating work

PAIRS (SB p. 47)

Answers

The force of gravity is pulling the bag vertically downwards. The man exerts a force vertically upwards to balance the force of gravity. As the man carries the bag along the horizontal road, the force he is applying is not in the direction of his movement. The force is at right angles to the direction of movement. The force does not move upward: it remains at the height of his shoulders. (This is the same sort of problem as the one about the man pushing against a wall. There is no movement.)

Because there is no movement in the direction of the force, the man has done no work.

Activity 2.3: Calculating work

GROUPS (SB p. 48)

Resources

notebooks, pens, calculators

Guidelines and answers

Facilitate: The students are told to use the mass-weight relationship 1 kg = 10 newtons. Remind them this is an approximation of 1 kg = 9.8 N. Taking the kilogram to be equivalent to 10 newtons makes this an exercise in mental arithmetic.

Work done = force × displacement (in the direction of the force)
= (35 kg × 10 N/kg) × 5 m
= 350 N × 5 m
= 1 750 J

Activity 2.4: Experimenting with potential energy

GROUPS (SB p. 49)

Resources

a variety of small bodies (such as blocks of wood or small stones) of different masses

Guidelines

Fascilitate: This is a very small and simple exercise for the students to do. Make sure there are plenty of small bodies available for them to drop onto their hands. The bodies should be of different masses so that students can feel that a heavier body hits with more force than a lighter body dropped from the same height.

Activity 2.5: Calculations using kinetic energy

PAIRS (SB p. 52)

Resources

notebooks, pens, calculators

Guidelines and answers

The rifle bullet travels upward for four seconds before running out of kinetic energy. At this height, where it has zero kinetic energy, it has maximum gravitational potential energy. In falling back to Earth, all this potential energy is reconverted to kinetic energy.

When the bullet reaches the ground, it has zero potential energy, but the same kinetic energy with which it started its upward flight. (This is because of the conservation of mechanical energy and the inter-convertibility of potential and kinetic energy.) Thus, the kinetic energy lost by the bullet on the way up (converted into potential energy) is equal to the kinetic energy gained on the way down. The mass of the bullet is constant.

Kinetic energy is $\frac{1}{2}mv^2$. The magnitude of the acceleration due to gravity is the same upwards as downwards. Thus, because the velocity with which it leaves the ground is the same as the velocity with which it arrives back on the ground, the time taken to complete the upward journey must equal the time taken to complete the return (downward) journey. We are told that the bullet travelled upwards for four seconds. Therefore, it travels downwards for the same time: four seconds.

Activity 2.6: Calculating power

PAIRS (SB p. 54)

Resources

notebooks, pens, calculators

Guidelines

These questions involve exercises in calculation. Students may use either the full names or the abbreviated forms of the relevant units: joules (J), watts (W), newtons (N). Use this as an opportunity to remind students that the abbreviation is upper case, but lower case is used when the name of the unit is written in full.

Answers

1. He must overcome the force of friction, which resists his effort to move the box.

$$\text{work} = \text{force} \times \text{displacement}$$
$$= 300\ \text{N} \times 5\ \text{m}$$
$$= 1\ 500\ \text{J}$$
$$\text{power} = \frac{\text{work}}{\text{time}}$$
$$= \frac{1\ 500\ \text{J}}{6\ \text{s}}$$
$$= 250\ \text{J/s}$$
$$= 250\ \text{W}$$
$$= 0.25\ \text{kW}$$
$$1\ \text{hp} = 746\ \text{W}$$
$$\therefore 1\ \text{W} = 1.3 \times 10^{-3}\ \text{hp}$$
$$250\ \text{W} = 0.325\ \text{hp}$$

2. Use the approximation 1 kg = 10 N

$$\text{work} = \text{force} \times \text{displacement}$$
$$= (150\ \text{kg} \times 10\ \text{N/kg}) \times 5\ \text{m}$$
$$= 7\ 500\ \text{J}$$
$$\text{power} = \frac{\text{work}}{\text{time}}$$
$$= \frac{7\ 500\ \text{J}}{3\ \text{s}}$$
$$= 2\ 500\ \text{J/s}$$
$$= 2\ 500\ \text{W}$$
$$= 2.5\ \text{kW}$$

3.

$$\text{work} = \text{force} \times \text{displacement}$$
$$= 8\ \text{N} \times 50\ \text{m}$$
$$= 400\ \text{J}$$
$$\text{power} = \frac{\text{work}}{\text{time}}$$
$$= \frac{400\ \text{J}}{25\ \text{s}}$$
$$= 16\ \text{J/s}$$
$$= 16\ \text{W}$$

How are you doing? (SB p. 55)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

energy – something which allows work to be done; energy is such a 'basic' part of our world that we have difficulty in defining it, but we have many different ways of measuring energy

generator – device that converts mechanical energy into electrical energy by rotating a coil in a magnetic field

kinetic energy – the mechanical energy that a body has because of its movement; if its movement changes, we can make it do some work and therefore get energy out of it

potential energy – the mechanical energy that a body has because of its position in a gravitational field; strictly called 'gravitational potential energy'

power – the rate at which work is done; the faster a piece of work is accomplished, the more power is involved

transducer – a machine that converts one form of energy into another form of energy; examples of transducers are generators (mechanical energy to electrical energy), electrical motors (electrical energy into mechanical energy) and the motors of petrol-burning cars (chemical energy into mechanical energy)

work – an amount of force moving a body through a certain distance in the direction of the force; if the movement is at right angles to the direction of the force, no work is done

Practice test: Answers

1. Work is the product of the force and the distance through which the force acts, in the same direction as the movement.✓✓ (2)
2. work = force × displacement
   = 300 N × 0 m
   = 0 J✓
   He has done no work,✓ because the force acting on him has not moved.✓ (3)
3. work = force × displacement✓
   = 60 N × 5 m✓
   = 300 J✓
   = 0.3 kJ✓ (4)
4. work = force × displacement✓
   = (100 kg × 10 N/kg) × 500 m✓
   = 5×10^5 N·m
   = 500 kJ✓ (4)
5. Mechanical energy can be divided into kinetic energy✓ and gravitational potential energy.✓ (2)
6. No.✓ In deep space a pendulum will not swing,✓ because there will not be a sufficient 'pull' of gravity.✓ to accelerate the bob.✓ (4)
7. The water in a dam has a tendency to move downwards,✓ in response to the pull of gravity.✓ The further the water is able to move downwards,✓ the greater is its potential energy:✓ exactly as with a weight which is some distance above ground ('reference') level.✓ (5)
8. She needs to overcome the force of friction,✓ which acts in such a direction as to oppose the movement.✓ (2)
9. The man moves a weight (force) of 900 N directly against gravity, through a (vertical) distance of three metres.
   work = force × displacement✓
   = 900 N × 3 m
   = 2 700 J✓
   power = $\frac{\text{work}}{\text{time}}$
   = $\frac{2\ 700\ \text{J}}{10\ \text{s}}$
   = 270 J/s
   = 270 W✓
   = 0.27 kW✓ (4)

Total marks: 30

TOPIC 2: Heat energy
Performance objectives
2.1 Explain temperature, expansion, change of state and vaporization using the kinetic molecular theory.
2.2 Explain conduction, convection and radiation in terms of the kinetic molecular theory.

Introduction

This topic is about the effect of heat on matter. Start off by defining temperature and explaining why referring to temperature as 'the degree of hotness or coldness of an object' is not sufficient. Explain the subjectivity of such a definition by using examples, such as placing a finger in hot water and then immediately in ice water. The ice water will feel warm initially. Although we will only confirm this in Senior Secondary 2, it is advisable to introduce temperature as a measure of the average kinetic energy of the molecules. Emphasize that heat and temperature are not the same. Also explain the idea of thermal equilibrium.

Discuss the three effects of heat on matter. A more detailed discussion of the changes in state will occur in Senior Secondary 2. The emphasis in this topic is on the expansion and contraction of matter and the different methods of heat transfer.

Activity 2.7: Exploring the expansion and contraction of air

GROUPS or CLASS (SB p. 59)

Resources

balloon, conical flask (preferably Pyrex), a source of heat (such as a hot plate or a Bunsen burner), wire gauze (if using the Bunsen burner), optional: ball-and-ring apparatus

Guidelines

This activity is to show that gases expand on being heated and contract when they are cooled. An alternative method is to use a large gas syringe with its nozzle closed.

In this activity, using the flask and balloon, it is important to emphasize that the flask and balloon are not empty but contain air. One can perform this activity using a coloured gas, such as bromine, in the flask, but bromine is a poisonous gas and is not easily available.

When heating the flask, which should be of Pyrex glass, move the burner around the bottom of the flask to distribute the heat evenly, and do not heat for too long so that the flask does not crack.

As the flask is heated, the air in the flask expands and fills the balloon. Although the balloon itself expands, the rate of expansion of the air inside the balloon is greater than the rate of the expansion of the balloon. When the flask is cooled, the air inside it contracts, and hence the balloon becomes deflated.

If your school has a ball-and-ring apparatus, the demonstration to show the expansion and contraction of solids will be very useful. Remember to heat only the ball and not the ring. A follow-up to the demonstration could be to cool the ring first and see if the ball passes through it.

Emphasize that the particles in matter do not expand when heated, but that the spaces between them become larger.

We can expand the equation $\Delta L = \alpha L_0 \Delta T$ as follows:

$$\Delta L = L - L_0 = \alpha L_0 \Delta T$$

$$L = L_0 + \alpha L_0 \Delta T = L_0(1 + \alpha \Delta T)$$

Activity 2.8: Determining linear expansivity of a metal

GROUPS or CLASS (SB p. 62)

Resources

linear expansion apparatus, steam generator, thermometer

Guidelines

This activity leads naturally to a discussion of cubic expansivity and the derivation of $\gamma = 3\alpha$ for solids, which follow here along with an example exercise.

Figure 2.1 shows a steam generator. If you do not have this apparatus in your school, you can make a steam generator using a glass filter flask (see Figure 2.2).

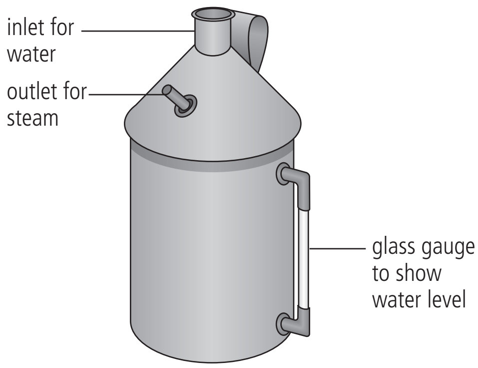

Figure 2.1 A steam generator

Figure 2.2 A glass filter flask

The lever must be set to 0 at room temperature, and any subsequent reading on the scale must be recorded as ΔL. The corresponding ΔT will be the recorded thermometer reading minus the room temperature reading.

From the equation: $\Delta L = \alpha L_0 \Delta T$
we have: $\alpha L_0 = \frac{\Delta L}{\Delta T}$

Thus, the gradient of the ΔL (y-axis) versus ΔT (x-axis) will give αL_0, from which we can find α. (If ΔT is plotted on the y-axis, then the gradient will be equal to $\frac{1}{\alpha L_0}$.)

Cubic expansivity

The derivation below is to show that $\gamma = 3\alpha$ for solids.

Consider a solid box of dimensions l, w and h. Its volume at some temperature T_0 is $V_0 = lwh$. If the temperature changes to $T_0 + \Delta T$, its volume changes to $V_0 + \Delta V$.

Now, each of the dimensions will change according to our linear expansion formula. Therefore:

$$\begin{aligned} V_0 + \Delta V &= (l + \Delta l)(w + \Delta w)(h + \Delta h) \\ &= (l + \alpha l\Delta T)(w + \alpha w\Delta T)(h + \alpha h\Delta T) \\ &= lwh(1 + \alpha\Delta T)^3 \\ &= V_0 (1 + 3\alpha\Delta T + 3(\alpha\Delta T)^2 + (\alpha\Delta T)^3) \end{aligned}$$

The fractional change in volume is then given by:

$$\frac{\Delta V}{V_0} = 3\alpha\Delta T + 3(\alpha\Delta T)^2 + (\alpha\Delta T)^3$$

Because $\Delta T << 1$, we can neglect the terms $3(\alpha\Delta T)^2$ and $(\alpha\Delta T)^3$. With this approximation, we have:

$$\Delta V = 3\alpha V_0 \Delta T$$

Comparing this equation to $\Delta V = \gamma V_0 \Delta T$, we can conclude that $\gamma = 3\alpha$.

Note that this relationship is only true for solids, which are isotropic in expansion. These solids expand by the same amount in all their dimensions.

A similar proof can be used to show that $\beta = 2\alpha$ for area expansion of isotropic solids.

The apparent cubic expansivity (γ) of a liquid is defined as the increase in volume per unit volume per unit temperature rise relative to that of the material of the containing vessel.

Example

A 60 l steel petrol tank in a car is completely filled with petrol at a temperature of 20 °C. The expansivity of petrol is 950×10^{-6} (°C)$^{-1}$ and that of steel is 36×10^{-6} (°C)$^{-1}$.

Determine:

1. how much petrol will overflow from the tank when the temperature of the tank reaches 40 °C.
2. the apparent cubic expansivity of petrol.

Solution

1. The volumes of both the petrol and the steel tank will increase when the temperature increases and the difference between these two increased volumes will be the volume of the petrol that overflows.

$$\begin{aligned}\Delta V_{overflow} &= \Delta V_{petrol} - \Delta V_{tank} \\ &= (\gamma_{petrol} - \gamma_{tank})V_0\Delta T \\ &= (950 \times 10^{-6}(°C)^{-1} - 36 \times 10^{-6}(°C)^{-1}) \times 60\ l \times (40\ °C - 20\ °C) \\ &= 1.097\ l\end{aligned}$$

2. The apparent expansivity is given by:

$$\begin{aligned}\alpha_{app} &= \frac{\Delta V_{overflow}}{V_0\Delta T} \\ &= \frac{1.097\ l}{60\ l \times 20\ °C} \\ &= 9.14 \times 10^{-4}(°C)^{-1}\end{aligned}$$

Note that this result can also be obtained using: $\alpha_{app} = \alpha_{petrol} - \alpha_{tank}$

Activity 2.9: Investigating conduction

GROUPS or CLASS (SB p. 65)

Resources

small birthday candles, rods of different materials (copper, iron, aluminium, lead) of equal length and thickness, retort stand, source of heat (such as a Bunsen burner), stopwatch

Guidelines and answers

This activity can also be done with an Ingenhousz apparatus (see Figure 2.3).

Notice that the rods are different metals, but have the same length and diameter.

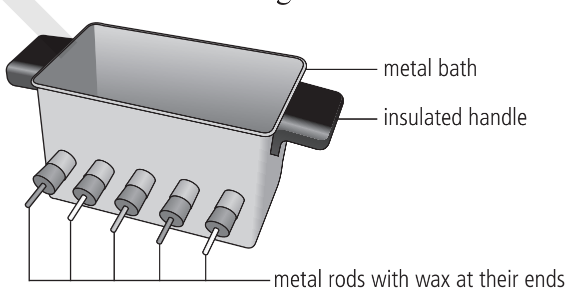

Figure 2.3 Ingenhousz apparatus

Answers to Step 5

Candle D falls off first and Candle A falls off last.

Rods listed in order of thermal conductivity with best conductor first: copper, aluminium, iron, lead.

Activity 2.10: Investigating conductivity

GROUPS or CLASS (SB p. 65)

Resources

glass test tube, ice cubes, small metal weight, retort stand or test tube holder, Bunsen burner

Guidelines

Remind students that, when heating glassware, the Bunsen burner should be kept moving slowly around the bottom of the test tube to avoid cracking the glass.

Activity 2.11: Investigating convection

GROUPS or CLASS (SB p. 66)

Resources

glass beaker, potassium permanganate crystals, a glass tube or drinking straw, wire gauze, tripod stand, Bunsen burner

Guidelines and answers

Some other substances which can be used in this activity are copper sulphate, ink or food colouring.

Answers to Step 4

a) The colour change occurs first at the point of heating.
b) The coloured water moves upwards and then down.
c) The coloured water follows a cyclical path as shown in Figure 2.31 of the SB.

Activity 2.12: Testing the effect of colour on thermal radiation

GROUPS or CLASS (SB p. 69)

Resources

for each group: two similar cans with lids, two thermometers, a stopwatch, cans of black and white paint and some very hot water

Guidelines and answers

This activity can also be done with a Leslie cube (see Figure 2.4).

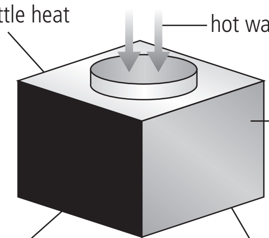

Figure 2.4 A Leslie cube

Answers to Step 6

a) The black can will cool down more quickly.
b) The black can is the better radiator of thermal energy.

Activity 2.13: Testing thermal radiation and absorption

GROUPS or CLASS (SB p. 70)

Resources

for each group: two thermometers and two equal-sized rectangular sheets of paper (one black piece and one white piece)

Guidelines and answers

Encourage students to predict their findings before recording the readings on the thermometers.

Answers to Step 4

a) The thermometer under the black paper will have the higher reading.
b) The black paper is a better absorber of radiant energy.
c) The white paper is a better reflector of radiant energy.

How are you doing? (SB p. 71)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

area expansion – the fractional change in the area of a solid per degree Celsius change in temperature

bimetal strip – two metals with different expansion coefficients bound together to form a strip which bends in two different directions in response to temperature changes

boiling point – the temperature at which a substance changes from the liquid state to the gas state

conduction – a process in which thermal energy is transferred from hotter regions to colder regions without any movement of the molecules themselves

convection – a process in which thermal energy is transferred from hotter regions to colder regions by the movement of the molecules themselves

convection current – in a vessel that is being heated, the cycle of heated liquid moving to the top and cool liquid moving to the bottom of the vessel

evaporation – vaporization at below the boiling point of a substance, which is accompanied by a decrease in the volume and temperature of the vaporizing liquid

heat – a form of energy which always transfers from a hotter region to a cooler region

insulator – a substance which does not conduct (heat or electricity) well

kinetic molecular theory – describes the relationship between temperature and the arrangement and movement of particles of matter

land breeze – convection current in the atmosphere formed during the night in which warm air above the sea rises and the cold air above the land sinks to take its place

linear expansion – the fractional change in the length of a solid per degree Celsius change in temperature

melting point – the temperature at which a substance changes from the solid state to the liquid state

radiation – a process in which thermal energy is transferred from hotter regions to colder regions by means of electromagnetic waves

reversible – a process that is able to run both forwards and backwards

sea breeze – convection current in the atmosphere formed during the day in which warm air above the heated land rises and the cold air above the sea sinks to take its place

states of matter – the temperature-dependent molecular arrangement of particles in a substance to form a solid, liquid or gas

temperature – the property of an object which determines the direction in which heat will flow; a measure of the average kinetic energy of the molecules in a body

thermal conductor – a substance which conducts heat well

thermometer – instrument used to measure temperature

vaporization – when a substance changes from the liquid state to the gas state at temperatures equal to the boiling point

volume expansion – the fractional change in the volume of a solid per degree Celsius change in temperature

Practice test: Answers

1. A✓✓ (2)
2. B✓✓ (2)
3. A✓✓ (2)
4. C✓✓ (2)
5. D✓✓ (2)
6. B✓✓ (2)
7. C✓✓ (2)
8. D✓✓ (2)
9. C✓✓ (2)
10. C✓✓ (2)
11. The linear expansion of one rail is:

    $\Delta L = \alpha L_0 \Delta T$✓

    $= 9 \times 10^{-7}(°C)^{-1} \times 12\ m \times (40\ °C - 20\ °C)$✓

    $= 2.16 \times 10^{-4}\ m$✓

    $= 0.22\ mm$✓

    Therefore, the spacing between adjacent rails must be a minimum of 0.22 mm. (Each rail will expand 0.11 mm at each end).✓ (5)
12. From the linear expansion formula, we have:

    $\Delta T = \frac{\Delta L}{\alpha L_0}$✓

    $= \frac{10 \times 10^{-3}\ m}{9.8 \times 10^{-6}(°C)^{-1} \times 25\ m}$✓

    $= 40.82\ °C$✓ (3)
13. The linear expansion of the steel tower is:

    $\Delta L = \alpha L_0 \Delta T$✓

    $= 9 \times 10^{-7}(°C)^{-1} \times 301\ m \times (-2\ °C - 22\ °C)$✓

    $= -6.5 \times 10^{-3}\ m$

    $= -6.5\ mm$

    So, the height will decrease by 6.5 mm.✓ (3)
14. Let the initial area of the rivet be A_0.

    The final area of the rivet will be:

    $A = \pi r^2 = \pi(\frac{d}{2})^2 = \pi(\frac{4.50\ mm}{2})^2$

    $= 15.9\ mm^2$✓

    (Note: We are using the diameter instead of the radius in the area formula.)

    From the area expansion formula, we have:

    $A_0 = \frac{A}{(1 + \beta \Delta T)}$✓

    $= \frac{15.9\ mm^2}{(1 + 4.8 \times 10^{-5}(°C)^{-1} \times (-78\ °C - 22\ °C))}$

    $= 15.977\ mm^2$✓

    From $A_0 = \pi(\frac{d_0}{2})^2$, the initial diameter is given by:

    $d_0 = 2(\sqrt{\frac{A_0}{\pi}})$

    $= 2(\sqrt{\frac{15.977\ mm^2}{\pi}})$

    $= 4.51\ mm$✓ (4)
15. First, we have to find the area expansion of the lid and of the glass opening.

    $\Delta A_{lid} = \gamma_{lid} A_0 \Delta T$✓

    $= 3.6 \times 10^{-5}(°C)^{-1} \times \pi(\frac{500\ mm}{2})^2 \times (50\ °C - 25\ °C)$

    $= 176.71\ mm^2$✓

    $\Delta A_{glass} = \gamma_{glass} A_0 \Delta T$✓

    $= 1.4 \times 10^{-5}(°C)^{-1} \times \pi(\frac{500\ mm}{2})^2 \times (50\ °C - 25\ °C)$

    $= 68.72\ mm^2$✓

    Since $\Delta A_{lid} > \Delta A_{glass}$, the lid will come off the jar.✓ (5)
16. $\Delta V_{spill} = \Delta V_{oil} - \Delta V_{flask}$✓

    $= (\gamma_{oil} - \gamma_{flask}) V_0 \Delta T$✓

    $= (6.8 \times 10^{-4}(°C)^{-1} - 5.1 \times 10^{-5}(°C)^{-1}) \times 200\ cm^3 \times (40\ °C - 25\ °C)$✓✓

    $= 1.89\ cm^3$

    So, 1.89 cm^3 (1.89 ml) oil will spill from the jar.✓ (5)

Total marks: 45

TOPIC 3: Electric charges

Performance objectives

3.1 Charge a body by friction, induction and contact.
3.2 Identify bodies of similar and opposite charge.

Introduction

This topic focuses on charges: how to produce, detect and store charges; the effect of charges on each other and finally the effect of charges on us.

The text gives two methods to show that there are two charge types which repel (two like charges) and attract (two opposite charges) each other. A third method is to use cellophane (scotch) tape. Stick two pieces of the tape to a table top (see Figure 2.5). Then pull them off the table top and bring them close to each other. They should repel each other. Now stick another piece on the table top, and a second piece on top of the first. If you pull them off each other and bring them close, they will attract each other.

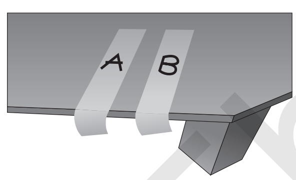

Figure 2.5 Tape attached to a table top

Activity 2.14: Making an electroscope

GROUPS or CLASS (SB p. 76)

Resources

for each group: a glass or plastic jam bottle, aluminium foil, a paper clip or a similar piece of wire, some cardboard, scissors, insulation tape

Guidelines

You may wish to share or direct your students to a few sites on YouTube showing how to make an electroscope. For example:

1. <https://www.youtube.com/watch?v=2PmWlPjV6n0>. This RimstarOrg video series also shows the triboelectric series and charging by induction.
2. <https://www.youtube.com/watch?v=SzQ2EZ0HPuY>.
3. <https://www.youtube.com/watch?v=3qyeQO1guKk>.
4. <https://www.youtube.com/watch?v=Z3PSkpd0K4w>.

How are you doing? (SB p. 82)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

attract – to move towards each other (unlike charges attract)
attractive forces – forces that pull unlike charged objects together
capacitor – a device used to store charge
charged – having an excess of positive or negative charge
earthing – when excess charges travel to or from the ground via contact to neutralize a charge
electroscope – an instrument used to detect charges
induction – a transfer of charge without contact
lightning – a very large spark, which occurs during an electrical discharge between the clouds and the ground
negative charge – an excess of electrons
positive charge – a deficiency of electrons
repel – to move away from each other (like charges repel)
repulsive forces – forces that push like charged objects apart
spark – a sudden movement of electric charge across an air gap which causes the air to be heated to very high temperatures resulting in a glow

Practice test: Answers

1. A✓✓ (2)
2. D✓✓ (2)
3. B✓✓ (2)
4. B✓✓ (2)
5. C✓✓ (2)
6. B✓✓ (2)
7. a) The woollen cloth will become positively charged.✓ (1)
   b) The rubber rod will gain electrons (and become negatively charged).✓ (1)
8. a) Electrons were added to the electroscope.✓ (1)
   b) The rod would have been negatively charged.✓ (1)
   c) The rod would have been positively charged.✓ (1)
   d) The leaves of the electroscope will diverge (move apart) when a negatively charged rod is brought near to the dome.✓✓✓ (3)
   e) The leaves of the electroscope will collapse (move together) when a negatively charged rod is brought near to the dome.✓✓✓ (3)
9. a) negative, b) positive, c) negative, d) negative, e) negative, f) negative (0.5 marks for each correct answer✓✓✓) (3)
10. a) In Diagram A, charges will be induced on the ball✓ and it will become attracted to the rod.✓ In Diagram B, electrons will move from the rod to the ball, making it negatively charged.✓ In Diagram C, the negatively charged ball will be repelled by the negatively charged rod.✓ (4)
    b) To use the negatively charged rod to give the ball a positive charge, bring the rod close to the ball✓ without touching it.✓ Then momentarily touch the ball with a finger,✓ and thereafter remove the rod. The ball will be positively charged.✓ (4)

Total marks: 34

THEME 4

Fields at rest and in motion

TOPIC 1: Description and properties of fields
Performance objectives
1.1 Identify force fields. **1.2** Identify the properties of force fields.

Introduction

This short chapter is an introduction to the different types of force fields that the students will encounter in their studies of physics. Force fields are regions where objects, charges and magnetic materials experience forces. The forces at each point in a force field are different in magnitude and/or in direction. We can thus regard a force field as a group of force vectors. Emphasize that these are forces which act at a distance. All force fields can be visualized by field lines, which are imaginary lines. The properties of the field lines for the three different force fields are similar.

Activity 4.1: Investigating magnetic fields

GROUPS (SB p. 87)

Resources

for each group: a bar magnet, a horseshoe magnet, iron filings, plotting compasses, a piece of white A4 paper or A4 acetate sheet

Guidelines

Facilitate: This activity is a useful way of helping students to visualize force fields by showing the magnetic force field lines around a magnet. Help students to identify the different poles of the plotting compasses. Then guide them, as necessary, to work out the poles of the bar and horseshoe magnets from the orientations of the plotting compasses. They should also notice the varying strength (intensity) of the magnetic force and the corresponding density of the iron filings.

How are you doing?

(SB p. 89)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

electric field – a region in space in which a charge will experience an electrostatic force

electric field lines – lines of force that radiate outwards from a positive charge and inwards towards a negative charge

force fields – have magnitude (also called strength) and direction; different points in a force field correspond to different strengths and directions

gravitational field – a region in space in which a mass will experience a gravitational force

magnetic field – a region in space in which a magnet (or magnetic material) will experience a magnetic force

non-contact forces – forces that act at a distance (without contact)

Practice test: Answers

1. a) A gravitational field is a region in space in which a mass will experience a gravitational force.✓ (1)
   b) An electric field is a region in space in which a charge will experience an electrostatic force.✓ (1)
   c) A magnetic field is a region in space in which a magnet or magnetic material will experience a magnetic force.✓ (1)
   d) A line of force is an imaginary line drawn to show the direction and density of a force field.✓ (1)
2. a) The strength of a gravitational field at any point is dependent on both the size of the mass and the distance of that point from the mass.✓ Since the distance is the same from both the Earth and the sun, the strength of the gravitational field will depend only on the mass.✓ The sun has the larger mass,✓ so it will have the larger gravitational field at the point midway between the Earth and the sun.✓ (4)
   b) The gravitational field of the sun is inversely proportional to the square of the distance from the centre of the sun.✓ Because the Earth is closer to the sun,✓ the gravitational field of the sun will be stronger on Earth than on Mars.✓ (3)
   c) The gravitational field of any mass is inversely proportional to the square of the distance from the centre of the mass.✓ Because the moon is closer to the Earth,✓ the gravitational field of the Earth is stronger on the moon than that of the sun.✓ This makes the moon orbit the Earth instead of the sun.✓ (4)
3. B✓✓ (2)
4. D✓✓ (2)
5. a) 1: b; 2: a; 3: a; 4: c; 5: c; 6: a; 7: none; 8: c (8×0.5 marks✓✓✓✓) (4)
   b) The magnetic field is strongest at points 5 and 6.✓ (1)
6. a) ✓✓✓ (3)

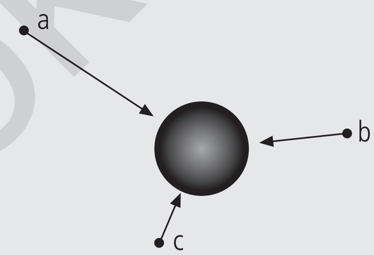

Figure 4.1 Answer to Question 6a)

   b) The electric field is weakest at a.✓ (1)
7. a) A: north pole; B: south pole.✓
   b) A and B are both north poles.✓ (Note: They cannot both be south poles because the magnetic field is radiating *away* from the poles.) (2)

Total marks: 30

TOPIC 2: The gravitational field

Performance objectives

2.1 Identify force fields from a set of forces.
2.2 Explain why two solid bodies of different masses released simultaneously from rest at the same height accelerate towards the ground at the same rate and reach the ground at the same time.
2.3 Describe the shape of the Earth.

Introduction

Students should be given generous amounts of time to grasp the notions of acceleration due to gravity. It is particularly important that they achieve some understanding of the fact that all masses accelerate at the same rate in a given gravitational field, provided friction can be ignored. This is 'counterintuitive' and not easily assimilated by all students.

Activity 4.2: Calculating gravitational potential energy

PAIRS (SB p. 95)

Resources

notebooks, pens, calculators

Guidelines

Facilitate: Once students have had the opportunity to solve the questions in pairs, it may be useful to have a class discussion to ensure that the students are comfortable with the material.

Answers

1. PE = mgh
   $= 0.5 \text{ kg} \times 9.8 \text{ m/s}^2 \times 3 \text{ m}$
   $= 14.7 \text{ kg·m}^2/\text{s}^2$
   $=14.7 \text{ J}$
2. PE = mgh
   $= 1 \text{ kg} \times 9.8 \text{ m/s}^2 \times 3 \text{ m}$
   $= 29.4 \text{ kg·m}^2/\text{s}^2$
   $=29.4 \text{ J}$
3. PE = mgh
   $= 0.5 \text{ kg} \times 9.8 \text{ m/s}^2 \times 9 \text{ m}$
   $= 44.1 \text{ kg·m}^2/\text{s}^2$
   $=44.1 \text{ J}$

Activity 4.3: Explaining gravity and acceleration

PAIRS (SB p. 98)

Guidelines

Facilitate: Encourage the pair groups to ask each other questions to check their understanding. Once students have completed their discussion in pairs, it may be beneficial to have a student or two explain these concepts to the class.

How are you doing?

(SB p. 100)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

counterintuitive – something that seems to go against common sense; for example, it is counterintuitive that all bodies fall towards Earth at the same rate, regardless of their weights

field – a part of space in which an effect can be felt and measured; in physics, the 'effect' is a force (e.g. gravitational fields and magnetic fields); various types of instrument are used to detect and measure these fields (e.g. a magnetic compass detects a magnetic field; a pendulum can be used to detect and measure the strength of a magnetic field)

free fall – when a body falls in a gravitational field with no other forces acting on it; bodies usually fall through the atmosphere, so the force of friction acts on them so they are strictly not in free fall; in many cases we can ignore the effect of air friction

geoid – the term used to describe the shape of the Earth (roughly a sphere with a bulge at the equator and some flattening at the poles); '*geo-*' means 'Earth'

projectile – a body that is thrown or fired and moves in a path determined by the gravitational force acting on it; a projectile has no means of propelling or steering itself

Practice test: Answers

1. Perhaps the simplest answer is that gravity 'pulls' masses✓ with forces in proportion to the masses of the bodies.✓ (The forces are the weights of the bodies, and students should understand this.) A body with twice the mass of another body✓ is pulled with twice the force✓ – therefore it accelerates at the same rate as the less massive body.✓ (5)
2. The value of g is close to 9.8 m/s^2.✓ It varies somewhat at different parts of the Earth's surface. Students should note and use the formalism (convention) whereby g is italicised.✓ (2)
3. The SI unit of force is the newton (N).✓ One newton is a force which accelerates a body✓ with a mass of 1 kg✓ at an acceleration of 1 m/s^2.✓ (4)
4. Mass, force and acceleration are related by the equation conventionally written as: $f = ma$✓✓✓✓ (4)
5. The shape of the Earth is described by the word 'geoid'.✓✓ (2)
6. The bulge at the equator✓ is due to Earth's rotation,✓ which causes a 'centrifugal force'.✓✓ (4)
7. A pendulum can be used to measure small differences in the strength of a gravitational field.✓✓ (2)
8. The gravitational field is strongest at sea level.✓ (It is in fact slightly stronger down a mine shaft, but it could be argued that this is not the surface of the Earth.) The reason is that the pull of gravity (the force field) is stronger at sea level✓ because the further we are from the centre of our planet, the weaker the gravitational field.✓ (3)
9. The equatorial circumference is 40 075 km.✓✓ (2)
10. Astronaut David Scott performed the feather-and-hammer-drop demonstration in 1971.✓✓ (2)

Total marks: 30

TOPIC 3: Electric fields
Performance objectives
3.1 Be able to draw electric lines of force around: • an isolated positive charge • an isolated negative charge • two like charges placed near each other • two unlike charges placed near each other. **3.2** Generate a continuous flow of charges. **3.3** Explain electric current. **3.4** Set up a simple electric circuit. **3.5** Distinguish between conductors and insulators. **3.6** Define resistance as opposition to flow of electrons. **3.7** Calculate the electrical work done in a given circuit.

Introduction

This topic continues the discussion of electric fields which was started earlier. The idea of electric field lines is consolidated. We then move on to discuss the important concepts of potential difference, current, and resistance which are the key elements of current electricity. The different methods of generating current electricity are introduced to the students. The students investigate the factors which determine the resistance of an electrical conductor. The students are then shown the two different methods of connecting resistors in a circuit. The topic concludes with how to determine electrical energy and power in an electric circuit.

The following website is a good teaching source for this section <http://supportingphysicsteaching.net/El01PN.html>.

Activity 4.4: Observing electric field patterns for a single isolated charge

DEMONSTRATION (SB p. 102)

Resources

a high-voltage generator (about 5 kV), electric field apparatus, connecting leads, sunflower oil, grass or semolina seeds

Guidelines

Facilitate: If your school does not have an electric field apparatus, you can see how to make one here: <https://www.youtube.com/watch?v=Y6YdC2UoDYY>. (This is an excellent video which shows you the different ways to visualize an electric field.)

There are also some excellent visuals on electric fields here: <https://www.youtube.com/watch?v=7vnmL853784> and here: <https://www.youtube.com/watch?v=63FnT0W-Hxc>.

Compare a charge moving in an electric field to a mass moving in the Earth's gravitational field. Differences in gravitational potential energy can be compared to differences in electrical potential energy and potential differences.

Activity 4.5: Completing a table

PAIRS (SB p. 104)

Resources

notebooks, pens

Answers

Quantity	Quantity symbol	Unit	Unit symbol
Charge	Q	coulomb	C
Potential difference	V	volt	V
Current	I	ampere	A

Activity 4.6: Making an electric cell: Producing current from chemical energy
GROUPS or CLASS (SB p. 105)

Resources

for each group: a beaker, water, table salt, connecting leads with crocodile clips on both ends, a magnesium strip, steel wool, a low-voltage light bulb or diode (LED)

Guidelines

Facilitate: Other materials that could be used, include:
1. a lemon with copper wire and iron nail as electrodes with an LED (see <https://www.youtube.com/watch?v=AY9qcDCFeVI>)
2. copper and zinc rods in dilute sulphuric acid
3. any two dissimilar metals and an electrolyte.

Activity 4.7: The Seebeck effect: Current from thermal energy
DEMONSTRATION (SB p. 106)

Resources

a steel rod, a thick insulated copper wire, a Bunsen burner, connecting leads, a digital multimeter

Guidelines

Facilitate: Constantan and copper wire can also be used for this activity.

For a demonstration on the Seebeck effect, watch: <https://www.youtube.com/watch?v=eG_PLY6C2bU>.

Activity 4.8: Producing current from mechanical energy
DEMONSTRATION (SB p. 107)

Resources

a current generator apparatus

Guidelines

Facilitate: This activity should be a useful visual aid for learners to see the effect of increasing energy (by increasing the spinning speed) on the light bulb in the circuit.

Activity 4.9: Producing current from solar energy
DEMONSTRATION (SB p. 108)

Resources

connecting leads, a low-wattage light bulb, a light source, a solar cell

Guidelines

Solar cells are available in shops that sell electronic equipment, such as diodes, transistors, IECs, etc.

Activity 4.10: Classifying electrical conductors and insulators
GROUPS (SB p. 110)

Resources

for each group: a cell, a light bulb holder with a light bulb, an ammeter, connecting wires, four wires of equal length and thickness (made of copper, iron, aluminium and nichrome), pieces of rubber, plastic, wood, ceramic, glass and paper

Guidelines

Facilitate: Students may need some guidance in setting up the electrical circuits and changing the materials. It may be helpful to begin with a class discussion on the expected findings based on the list of materials. Students should be encouraged to get into the habit of predicting likely outcomes (and potential problems) before beginning any experimental procedure.

Activity 4.11: Investigating the effect of length and cross-sectional area of a conductor on its resistance

GROUPS (SB p. 111)

Resources

for each group: one metre each of 10-gauge, 12-gauge, 15-gauge and 20-gauge nichrome wires; an ammeter; a voltmeter; a cell or battery; a metre stick; connecting leads; prestik (reusable adhesive) or insulation tape; graph paper

Note

In Table 4.5 of the Student's Book (SB p. 112), the diameter of the 12-gauge wire should be 2.05 mm, not 1.21 mm as provided.

Guidelines and answers

The resistance of 10 cm of 20-gauge wire is 0.194 Ω and the resistance of 100 cm of this wire will be 1.94 Ω. If you use a 1.5 V cell, your range of current will be 7.7 A to 0.7 A. Do not keep the switch on for too long, because the wire will get hot and the cell will run down.

Here are some typical results for the first part of the activity using 20-gauge nichrome wire.

Length of wire (cm)	Voltmeter reading (V)	Ammeter reading (A)	Resistance, $\frac{V}{I}$ (Ω)
10	1.4	7.5	0.19
20	1.4	3.7	0.38
40	1.4	1.8	0.78
80	1.4	0.9	1.56
100	1.4	0.7	2.00

The graph for Step 7:

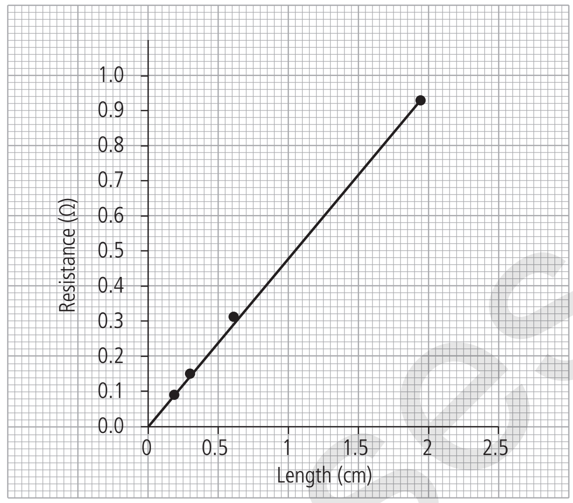

Figure 4.2 Resistance vs wire length

Step 8: The resistance is directly proportional to the length of the wire.

Some typical results for the second part are shown below.

Gauge of wire	#10	#12	#15	#20
Diameter of wire (mm)	2.59	2.05*	1.45	0.81
Cross-sectional area of wire, A (mm^2)	5.27	3.3	1.65	0.52
Inverse of cross-sectional area, $\frac{1}{A}$ (mm^{-2})	0.19	0.30	0.61	1.94
Voltmeter reading (V)	1.4	1.4	1.4	1.4
Ammeter reading (A)	15.5	9.2	4.5	1.5
Resistance, $\frac{V}{I}$ (Ω)	0.09	0.15	0.31	0.93

*This reading erroneously appears as 1.21 in the Student's Book.

The graph for Step 14:

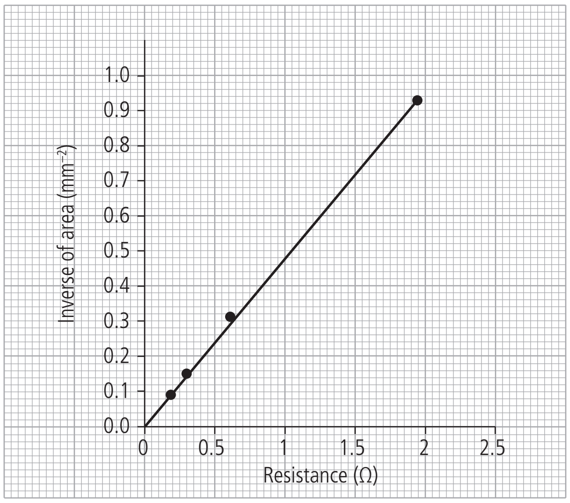

Figure 4.3 Inverse of area vs resistance

Step 15: The resistance of the conductor is inversely proportional to the cross-sectional area of the conductor.

Activity 4.12: Verifying Ohm's law and determining resistance of a resistor

GROUPS (SB p. 114)

Resources

for each group: a 6 V battery, a resistor of unknown resistance, a rheostat, an ammeter, a voltmeter, a switch, connecting leads, graph paper

Guidelines and answers

You can use any fixed resistor, such as a wire-wound resistor, metal-oxide or carbon-film resistors (see Figure 4.4).

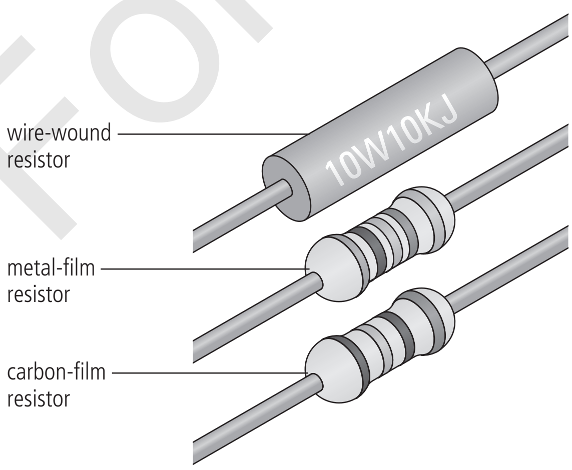

Figure 4.4 Types of fixed resistor

A typical graph for Step 5:

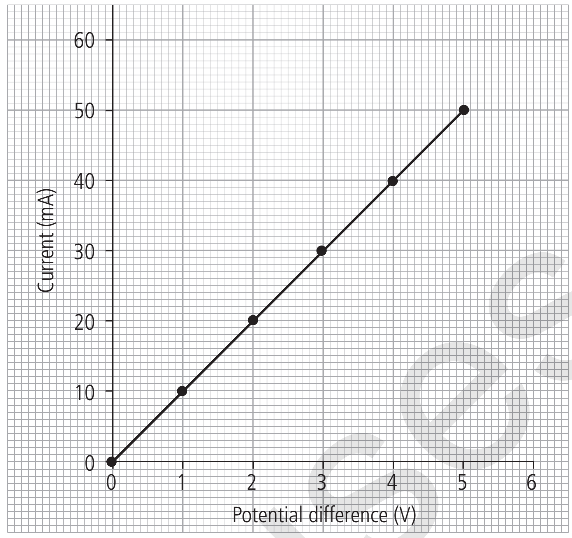

Figure 4.5 Current vs potential difference

Step 7: Gradient = $\frac{\Delta I}{\Delta V} = \frac{1}{R}$

Activity 4.13: Examining resistors in series

GROUPS (SB p. 115)

Resources

for each group: two different resistors, a cell or battery, an ammeter, a voltmeter, connecting leads, a switch

Guidelines and answers

Step 10: The reading I_1 is equal to reading I_2.

Step 11: The reading V_1 is smaller/larger than the reading V_2. The sum of V_1 and V_2 is equal to V_3.

Activity 4.14: Examining resistors in parallel

GROUPS (SB p. 116)

Resources

for each group: two different resistors, a cell or battery, an ammeter, a voltmeter, connecting leads, a switch

Guidelines and answers

Step 12: The reading V_1 is equal to reading V_2.

Step 13: The reading I_1 is smaller/larger than the reading I_2. The sum of I_1 and I_2 is equal to I_3.

Activity 4.15: Solving circuit problems

INDIVIDUAL (SB p. 118)

Resources

notebooks, pens, calculators

Note

The battery reading in the circuit for this activity should be 12 V, not 6 V as shown in Figure 4.42 in the Student's Book.

Answers

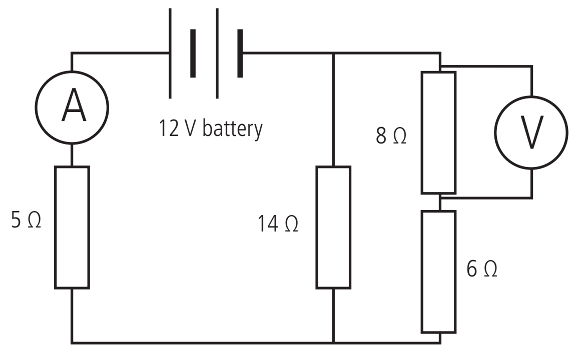

Figure 4.6 Circuit diagram for Activity 4.15

1. The current in the 8 Ω resistor is:
   $I_{8\Omega} = \frac{V_{8\Omega}}{R_{8\Omega}} = \frac{4\ \text{V}}{8\ \Omega} = 0.5\ \text{A}$
2. The potential difference across the 6 Ω resistor is:
   $V_{6\Omega} = IR_{6\Omega} = 0.5\ \text{A} \times 6\ \Omega = 3\ \text{V}$
3. The p.d. across the 14 Ω resistor is:
   $V_{14\Omega} = 4\ \text{V} + 3\ \text{V} = 7\ \text{V}$
   So, the current through this resistor is:
   $I_{14\Omega} = \frac{V_{14\Omega}}{R_{14\Omega}} = \frac{7\ \text{V}}{14\ \Omega} = 0.5\ \text{A}$
4. The reading on the ammeter is:
   $I = 0.5\ \text{A} + 0.5\ \text{A} = 1\ \text{A}$
5. The potential difference across the 5 Ω resistor is:
   $V_{5\Omega} = IR_{5\Omega} = 1\ \text{A} \times 5\ \Omega = 5\ \text{V}$

Activity 4.16: Converting electrical energy into mechanical energy

DEMONSTRATION (SB p. 119)

Resources

an electric motor from a toy, a small pulley, mass pieces, cotton thread, connecting leads, a rheostat, an ammeter, a voltmeter, adhesive tape, a stopwatch

Guidelines

You can adjust the speed of the motor by adjusting the rheostat. If the current to the motor is small, the motor will take a longer time to pull up the mass from above the floor to the table top. By adjusting the current and the size of the mass piece, you can choose the time taken. Very small values of time will be difficult to measure on a stopwatch (or mobile phones with stopwatches) and will lead to greater inaccuracies in the measurement of the time.

The electrical power (*VI*) will be approximately equal to the mechanical power (*mgh*).

Some of the reasons for the inaccuracies are:

- Not all of the electrical energy is converted into mechanical energy, because of the heat generated in the motor's moving parts and also because of some air friction.
- Other inaccuracies include: the reaction times in starting and stopping the stopwatch and inaccuracies in reading the mass meter, ammeter, voltmeter, stopwatch and the lifting height (*h*) of the mass piece.

Activity 4.17: Creating a short circuit

GROUPS or CLASS (SB p. 120)

Resources

for each group: a battery, an ammeter, a voltmeter, a piece of nichrome wire, a pencil, conducting leads, a small piece of uninsulated copper wire, a fuse wire, a light bulb with holder, a switch

Guidelines and answers

A strand from a coil of steel wool used in kitchens for cleaning dishes serves as a good fuse wire. Test its current-bearing capacity before using it in the circuit. You can use two or three strands twisted together to allow a greater current through the fuse wire. Do not maintain the short circuit for too long, because it will run down the battery and may blow the light bulb.

How are you doing? (SB p. 122)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

ammeter – a device to measure current in a circuit

battery – (also called a cell) a store of chemical energy with two terminals (one positive and the other negative)

chemical energy – a chemical store of energy (e.g. a battery)

electric current – the amount of charge moving past a point per unit time; measured in amperes (A)

electric field lines – lines of force that radiate outwards from a positive charge and inwards towards a negative charge

electrical conductor – material that conducts electric current well

electrical energy – energy of current flowing in a circuit

electrical insulator – material that resists the flow of electric current

fuse – safety devices made of wires with low resistance and low melting points; they blow (get hot and melt) if the current in the circuit goes above their maximum rating

generator – device that converts mechanical energy into electrical energy by rotating a coil in a magnetic field

mechanical energy – energy from movement

non-ohmic conductor – conductor which does not obey Ohm's law; it does not offer a constant resistance

ohmic conductor – conductor which has a constant resistance when the potential difference across it is varied at constant temperature

parallel (connection) – connections between electrical components such that the potential difference across the resistors is the same and the total current through the resistors is the sum of the current through each resistor

potential difference (p.d.) – the work done between two points per unit charge; measured in volts (V)

resistance – the degree to which a material does not allow electric current to flow through it; measured in ohms (Ω)

resistivity – a constant (ρ) which indicates the degree of resistance offered by a conductor

resistor – any electrical component that has resistance

rheostat– a variable resistor

Seebeck effect – the conversion of thermal energy into electrical energy by heating two different metals, which are attached to each other, at different temperatures

series (connection) – connections between electrical components such that the current through each resistor is the same and the potential difference across all the resistors is the sum of the potential difference of each resistor

short circuit – an unintended path of least resistance in a circuit

solar cell – devices made of silicone materials which can easily release electrons under sunlight

solar energy – energy from the sun

thermal energy – energy of heat

turbine – huge coils of wire turned mechanically between very large magnets to generate electricity

voltmeter – a device to measure potential difference across two points in a circuit

Practice test: Answers

1. B✓✓ (2)
2. C✓✓ (2)
3. D✓✓ (2)
4. D✓✓ (2)
5. D✓✓ (2)
6. C✓✓ (2)
7. D✓✓ (2)
8. a) $V = \frac{W}{Q}$

   $= \frac{4.5 \times 10^{-4}\ \text{J}}{50 \times 10^{-6}\ \text{C}}$

   $= 9\ \text{V}$✓✓✓ (3)

   b) $I = \frac{Q}{t}$

   $= \frac{50 \times 10^{-6}\ \text{C}}{20\ \text{s}}$

   $= 2.5 \times 10^{-6}\ \text{A}$

   $R = \frac{V}{I}$

   $= \frac{9\ \text{V}}{2.5 \times 10^{-6}\ \text{A}}$

   $= 3.6 \times 10^{6}\ \Omega$✓✓✓ (3)
9. a) $A = \pi r^2$

   $= \pi \frac{d^2}{4}$

   $= \pi \frac{(1.45 \times 10^{-3}\ \text{m})^2}{4}$

   $= 1.65 \times 10^{-6}\ \text{m}^2$

   $R = \rho \frac{L}{A}$

   $= 1 \times 10^{-6}\ \Omega\cdot\text{m} \times \frac{0.7\ \text{m}}{1.65 \times 10^{-6}\ \text{m}^2}$

   $= 0.42\ \Omega$✓✓✓ (3)

   b) $I = \frac{V}{R}$

   $= \frac{3\ \text{V}}{0.42\ \Omega}$

   $= 7.1\ \text{A}$✓✓✓ (3)

   c) No. The current will be twice the previous value since the resistance will now be half of the previous value.✓✓ (2)
10. Since the potential difference across each of the wires is the same, the current will be inversely proportional to the resistance of the wires. This implies that the wire with the larger current will be the one with the smaller resistance. Since resistance is directly proportional to resistivity, this implies that the larger current will flow through the wire with the smaller resistivity, which is aluminium.✓✓✓ (3)
11.

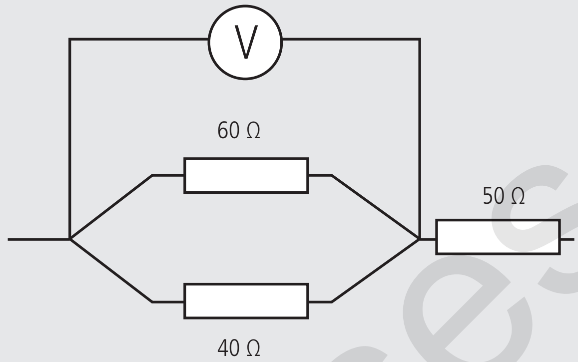

Figure 4.7 Circuit diagram for Question 11

   a) $I_{60\Omega} = \frac{V_{60\Omega}}{R_{60\Omega}}$

   $= \frac{12\ \text{V}}{60\ \Omega}$

   $= 0.2\ \text{A}$✓✓✓ (3)

   b) $I_{40\Omega} = \frac{V_{40\Omega}}{R_{40\Omega}}$

   $= \frac{12\ \text{V}}{40\ \Omega}$

   $= 0.3\ \text{A}$

   $I_{50\Omega} = I_{60\Omega} + I_{40\Omega}$

   $= 0.2\ \text{A} + 0.3\ \text{A}$

   $= 0.5\ \text{A}$✓✓✓ (3)

   c) $W = I^2Rt$

   $= (0.6\ \text{A})^2 \times 50\ \Omega \times 2 \times 60\ \text{s}$

   $= 2\ 160\ \text{J}$✓✓✓ (3)
12.

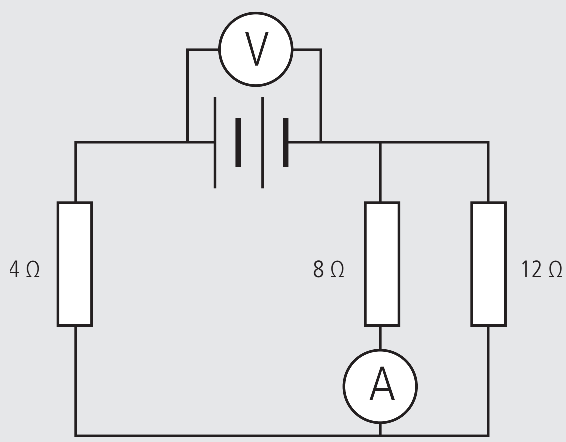

Figure 4.8 Circuit diagram for Question 12

   a) $V_{8\Omega} = IR_{8\Omega}$

   $= 1.5\ \text{A} \times 8\ \Omega$

   $= 12\ \text{V}$✓✓ (2)

b) The p.d. across the 12 Ω resistor is the same as that across the 8 Ω resistor, because the two resistors are in parallel.

$I_{12\Omega} = \frac{V_{12\Omega}}{R_{12\Omega}}$

$= \frac{12\text{ V}}{12\ \Omega}$

$= 1.0$ A✓✓ (2)

c) The current in the 4 Ω resistor is:

$I_{4\Omega} = I_{8\Omega} + I_{12\Omega} = 1.5\text{ A} + 1.0\text{ A}$

$= 2.5$ A

$P = \frac{I^2}{R}$

$= (2.5\text{ A})^2 \times 4\ \Omega$

$= 25$ W✓✓✓ (3)

d) The reading on the voltmeter is the sum of all the potential differences in the circuit.

$V = I_{4\Omega}R_{4\Omega} + 12\text{ V}$

$= (2.5\text{ A} \times 4\ \Omega) + 12\text{ V}$

$= 22$ V✓✓ (2)

13.

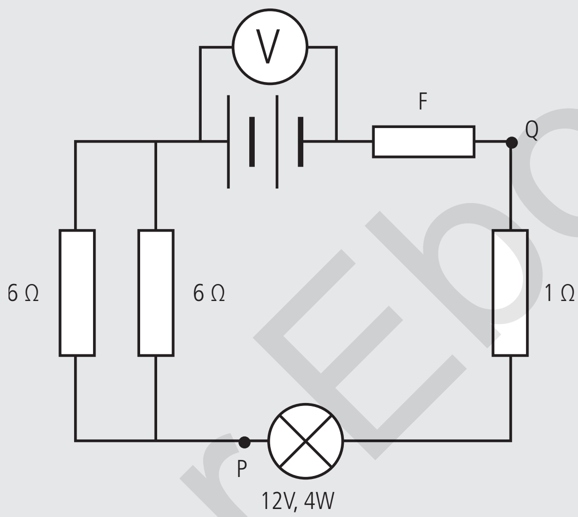

Figure 4.9 Circuit diagram for Question 13

a) $I = \frac{P}{V}$

$= \frac{4\text{ W}}{12\text{ V}}$

$= 0.33$ A✓✓✓ (3)

b) The sum of the currents passing through the parallel resistors is 0.33 A. Because the resistors have equal resistance, each of them will have the same current, which is 0.5 × 0.33 A = 0.165 A.

The p.d. across each resistor is then:

$V_{6\Omega} = I_{6\Omega}R_{6\Omega} = (0.165\text{ A} \times 6\ \Omega)$

$= 0.99$ V, which is also the p.d. across the parallel resistors.✓✓✓ (3)

c) The reading on the voltmeter is the sum of all the potential differences in the circuit. The p.d. across the 1 Ω resistor is :

$V_{1\Omega} = I_{1\Omega}R_{1\Omega} = (0.33\text{ A} \times 1\ \Omega)$

$= 0.33$ V

The reading on the voltmeter is:

$V = 0.33\text{ V} + 12\text{ V} + 0.99\text{ V}$

$= 13.32$ V✓✓✓ (2)

d) If P is joined to Q, then the 1 Ω resistor and the light bulb will be short circuited, and we will have only the two 6 Ω resistors connected to the battery which will still supply 13.32 V to the circuit. The current through each of the parallel resistors will now be:

$I_{6\Omega} = \frac{V_{6\Omega}}{R_{6\Omega}} = \frac{13.32\text{ V}}{6\ \Omega} = 2.22\text{ A}$

The total current in the circuit will be: 2 × 2.22 A = 4.44 A. Because this current is larger than the rating of the fuse (4 A), the fuse will blow (burn out).✓✓✓ (3)

Total marks: 60

THEME 5

Energy quantization and duality of matter

TOPIC 1: Particulate nature of matter

Performance objectives

1.1 Formulate simple hypotheses and test them before drawing conclusions based on specific information.
1.2 Explain how the molecules of a substance move relative to other molecules of the same substance.
1.3 Describe the atomic structure of matter.
1.4 State the constituents of the atom.
1.5 Use molecular theory to explain the three states of matter.
1.6 Describe the structure of simple crystals.
1.7 Distinguish between crystalline and amorphous substances.
1.8 Use the concept of the photon to explain that light behaves like particles.

Introduction

This topic focuses on the particulate nature of matter, which is also known as the kinetic theory of matter. You should first explain to the students what a hypothesis is and how to test a hypothesis. Recall also the black box experiments that the students did in Junior Secondary School. The experiments conducted to test hypotheses about the structure of matter are similar to the black box experiments.

A YouTube video on this topic can be found at: <https://www.youtube.com/watch?v=N9OL6AwyM5I> and <https://www.youtube.com/watch?v=ndw9XYA4iF0>.

Here are two links to YouTube videos on Brownian motion: <https://www.youtube.com/watch?v=brRLLObw30Y> and <https://www.youtube.com/watch?v=UDj7BXA1CHU>.

This topic also briefly discusses molecules and a classic experiment to determine the size of a molecule using an oil film. This experiment involves the dropping of an oil drop onto the surface of water containing lycopodium powder. The oil drop spreads itself out on the surface of the water into a circular oil film of one molecule thickness. A brief introduction to crystal structure, showing the different crystal shapes, is followed by a discussion on amorphous solids. The students are then introduced to the photoelectric effect by way of experimentation using electroscopes and light of different colours. The photoelectric effect will be studied in more detail in Senior Secondary 3.

Demonstrating the particle nature of matter

The ideas concerning the particle nature of matter can be reinforced with the aid of a rectangular tray with wooden vertical sides and about 20 marbles of the same colour and one of a different colour.

Place the marbles in the tray, and shake the tray from side to side (see Figure 5.1 on page 48). The random movement of the marbles can be clearly seen by observing the motion of the different coloured marble. This is an analogy for the random motion of gas particles.

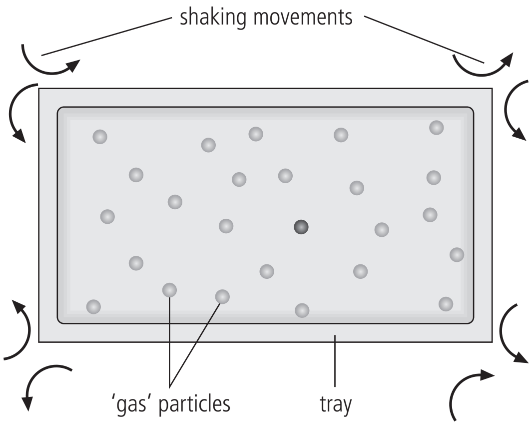

Figure 5.1 A demonstration of the random motion of gas particles

By placing a piece of timber across the diagonal of the tray, and then shaking the tray of marbles, the restricted motion of a compressed gas can be demonstrated (see Figure 5.2 below).

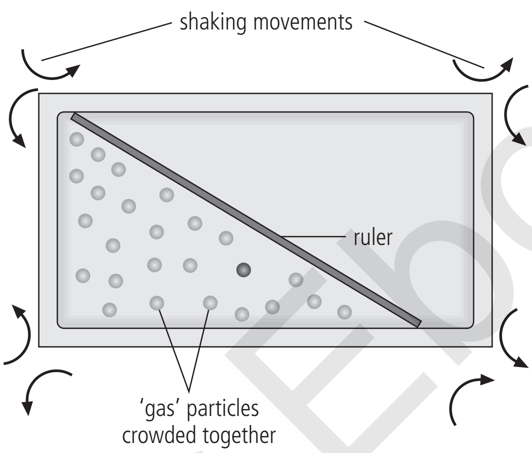

Figure 5.2 A demonstration of the restricted random motion of gas particles in a compressed gas

The motion of liquid particles can be demonstrated by tilting the tray at an angle (the marbles will fall to the bottom of the tray) and then shaking the tray.

Solids can be represented by using an atomic model set made of polystyrene or plastic balls attached to each other by wire coiled in the form of a spring. Shaking the model replicates the vibratory motions of the solid particles.

Investigation 1: Testing Hypothesis 1: All matter is made up of atoms

DEMONSTRATION (SB p. 126)

Resources

sharp knife, some yams

Investigation 2: Testing Hypothesis 2: There are forces between the particles of matter

DEMONSTRATION (SB p. 126)

Resources

a glass rod and three flasks (as in Figure 5.3, SB p. 126): one with a metal cube inside, one half-filled with a liquid and one covered and filled with a gas, such as carbon dioxide

Investigation 3a: Testing Hypothesis 3: The particles in matter are in continuous motion

DEMONSTRATION (SB p. 127)

Resources

a long glass combustion tube, metal tongs, cotton wool, two retort stands, two rubber stoppers, concentrated hydrochloric acid, ammonium hydroxide

Investigation 3b: Testing Hypothesis 3: The particles in matter are in continuous motion

DEMONSTRATION (SB p. 128)

Resources

a microscope, a smoke cell, a torch or any light source, a thin rope or semi-dried grass, a box of matches

Investigation 4: Testing Hypothesis 4: There are spaces between the particles of matter

DEMONSTRATION (SB p. 129)

Resources

a 100 ml measuring cylinder,
a 100 ml beaker, water, alcohol

Investigation 5: Determining the diameter of a molecule

DEMONSTRATION (SB p. 132)

Resources

olive oil, a shallow basin (with a bottom coated with blackened wax), a rod coated with wax, water, lycopodium powder, a small loop of wire attached to a piece of cardboard, filter paper, a travelling microscope or magnifying glass, a millimetre ruler

Investigation 6: The photoelectric effect

DEMONSTRATION (SB p. 135)

Resources

an electroscope, a sheet of lead, a glass rod, a polythene rod, a woollen cloth, a red laser pointer, an ultraviolet lamp

How are you doing?

(SB p. 137)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

allotrope – different structures of the same chemical element

amorphous solids – solids without a definite geometric shape and no defined melting and boiling points; formed by the sudden cooling of their liquid state

atom – the smallest particle of matter which can exist by itself

boiling point – the temperature at which a substance changes from the liquid state to the gas state

Brownian motion – the random, jerky motion of particles

condensation point – the temperature at which a gas changes to a liquid

crystals – solids with a characteristic geometric shape and well-defined melting and boiling points

diffusion – the process in which particles move from regions of higher concentrations to regions of lower concentrations

freezing point – the temperature at which a liquid changes to a solid

gas – a state of matter in which the particles move around randomly; gases take the volume and shape of their container and can be compressed

liquid – a state of matter in which the particles have a less orderly arrangement with small spaces between them; liquids have a fixed volume, but take the shape of their container and can be compressed slightly

melting point – the temperature at which a substance changes from the solid state to the liquid state

molecule – a group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction

particles – very small pieces of matter

photon – a bundle of light energy

solid – a state of matter in which the particles have an orderly arrangement with very few spaces between them; solids have a fixed shape and volume and cannot be compressed

sublimation – a direct change of state from a solid to a gas

Practice test: Answers

1. C✓✓ (2)
2. D✓✓ (2)
3. B✓✓ (2)
4. D✓✓ (2)
5. C✓✓ (2)
6. D✓✓ (2)
7. D✓✓ (2)
8. B✓✓ (2)
9. B✓✓ (2)
10. A✓✓ (2)

11.

Property	Solids	Liquids	Gases
Size of spaces between molecules	Very small spaces	Small spaces	Large spaces
Type of motion of particles	Vibratory and perhaps rotatory about fixed positions	Glide randomly over each other at low speed	Move randomly with high speeds
Degree of compressibility	Cannot be compressed because of very strong repulsive forces and very little spaces between particles	Very slightly compressible because of strong repulsive forces and small spaces between particles	Easily compressible because of very weak repulsive forces and large spaces between particles
Strength of attractive forces	Strong attractive forces	Moderately strong attractive forces	Very weak or no attractive forces

(12×0.5 marks) (6)

12. a) The process is diffusion.✓ (1)
    b) The molecules glide over each other at low speeds.✓✓ (2)
    c) The crystal has a characteristic orthorhombic structure.✓ The particles are highly ordered in three-dimensional units.✓ It has well-defined melting and boiling points.✓ (3)
13. Hexagonal.✓ The unit cell has three equal sides✓ and one unequal side,✓ which is the height.✓ The top and bottom are hexagonal (six-sided).✓ (5)
14. a) The crystalline structure of the two allotropes of sulphur are rhombic and monoclinic.✓✓ (2)
    b) To form plastic sulphur, heat the crystalline sulphur✓ to its melting point✓ and then pour the molten sulphur into cold water.✓ (3)
    c) The particles in plastic sulphur are randomly arranged✓ and it does not have well-defined melting or boiling points.✓ (either one) (1)
15. Make sure that the students can differentiate between the oil drop, with diameter d and the circular oil film on the surface of the water whose diameter is D and whose thickness, l, is the diameter of a molecule of oil.

$l = 2 \times 10^{-9}$ m
$d = 0.5 \times 10^{-3}$ m
$D = ?$

The volume of the oil drop is:

$$V_1 = \frac{4}{3}\pi r_1^3$$
$$= \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$$
$$= \frac{4}{3}\pi\left(\frac{0.5 \times 10^{-3}\text{ m}}{2}\right)^3$$
$$= 6.545 \times 10^{-11}\text{ m}^3 ✓$$

The volume of the oil film (with thickness l) is:

$V_2 = Al$

$= \frac{4}{3}\pi(\frac{D}{2})^2 l$

$= \pi(\frac{D}{2})^2 \times 2 \times 10^{-9}$ m

$= 1.57 \times 10^{-9}$ m $\times D^2$✓

Equating the two volumes we have:

$V_1 = V_2$✓

6.545×10^{-11} m^3 $= 1.57 \times 10^{-9}$ m $\times D^2$

$D^2 = \frac{6.545 \times 10^{-11} \text{ m}^3}{1.57 \times 10^{-9} \text{ m}}$✓

$= 0.042$ m^2

The diameter of the oil film is:

D = 0.204 m

= 20.4 cm✓ (5)

16. A photon is a bundle or quantum of light energy.✓ The particle property of light can be explained using photons.✓ (2)

Total marks: 50

TOPIC 2: Fluids at rest and in motion

Performance objectives

2.1 Define surface tension in liquids.
2.2 Classify fluids according to their viscous properties.
2.3 Give at least two examples of the application of surface tension and viscosity.

Introduction

It may be useful to point out to students that some aspects of this topic are also taught in chemistry courses – the branch of chemistry called physical chemistry. Students should realise that the divisions between the different 'disciplines' of science are not completely sharp. There are amounts of overlap in some areas.

Activity 5.1: Observing surface tension

GROUPS (SB p. 140)

Resources

for each group: cup or spoon, water

Guidelines

Facilitate: The students should have no difficulty in demonstrating for themselves the 'overfilling' of a cup or spoon.

Activity 5.2: Investigating surface tension

GROUPS (SB p. 145)

Resources

for each group: a cupful of clean water, a small piece of aluminium foil, a sewing needle, a razor blade

Guidelines

Facilitate: The activity of resting small pieces of aluminium foil, needles or razor blades, works well and is usually a cause of amused interest. Emphasize to the students that these bodies are not 'floating' on the surface of the liquid.

The tightly crumpled ball of foil will generate some debate. Why does it return to the surface after being pushed under when the flat piece of foil sinks? Some students will probably arrive at the correct answer: the crumpled ball of foil has a small amount of air trapped in it. This reduces the effective density of the ball to less than that of water and the ball floats due to the trapped air. Once the students have grasped this point, they should be told, or encouraged to realise, that in this case the ball is genuinely floating on the water.

Activity 5.3: Investigating viscosity and temperature

GROUPS (SB p. 147)

Resources

for each group: two small volumes of honey or syrup, access to a fridge

Guidelines

Facilitate: This activity could also be done as a class demonstration. Students should notice that the honey or syrup placed in the fridge has a much higher viscosity (is much harder to pour) than that at ambient temperature. Of course, the difference in viscosity will be more obvious on a hot day than on a cold day.

Activity 5.4: Investigating viscosity

GROUPS (SB p. 148)

Resources

for each group: a long glass tube (such as a measuring cylinder of at least two litre capacity); a stopwatch; some steel balls; some water (for comparison); some viscous ('thick'), transparent liquids (such as cooking oil, paraffin, kerosene, glycerine or syrup)

Guidelines

Facilitate: Again, the students should work in pairs or small groups, depending on laboratory space and the amount of equipment. Each group will need a long, narrow glass tube, sealed at one end, or a large measuring cylinder; four to five steel balls of about 1 cm diameter and a stopwatch. They will also need some liquids. In addition to water, each group should have, or have access on a central bench, to at least three of the following: glycerine, clear syrup, paraffin/kerosene, cooking oil. (Clear syrup can be made by dissolving white sugar in hot water, at a concentration of at least half a kilogram per litre of water.) Each group will need sufficient amounts of each liquid to fill the measuring cylinder or tube.

Activity 5.5: Discussing viscosity

GROUPS (SB p. 148)

Guidelines

Facilitate: Students are asked to discuss why paint for spray application is diluted to 'thin' it. Painting with a spray gun requires that the paint be broken up (in the nozzle of the spray gun) into very small droplets. A thick (viscous) liquid will not pass easily through a small nozzle and will not break up into very small droplets. In short, it is not possible to spray a 'thick' liquid.

How are you doing?

(SB p. 149)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

adhere (adhesion) – to stick to other things; forces of adhesion act between the molecules of a liquid and the molecules that make up the solid body (surface) with which the liquid is in contact

adhesive forces – forces of attraction in liquids between molecules of a different type

capillarity – the tendency of a liquid to rise up a narrow tube; the amount by which the liquid rises depends on the surface tension of the liquid, the diameter of the tube and the nature of the liquid and the tube itself

cohere (cohesion) – sticking to things of its own type; forces of cohesion act between the molecules of the liquid

cohesive forces – forces of attraction in liquids between molecules of the same type

hydrophilic – 'water-loving'

hydrophobic – 'water-hating'

laminar flow – the most efficient way in which fluids may flow; when all the particles of the fluid are moving in straight lines with minimal 'interference' between the particles

pascal (Pa) – the SI unit of pressure (pressure = force per unit area; a pressure of 1 pascal is a force of 1 newton acting on an area of 1 square metre)

pascal-second (Pa·s) – the SI unit of viscosity

rheology – the study of flow in liquids and gases

surface tension – a force acting at the surface of liquid so that the liquid behaves as if its surface were covered by an invisible, stretched membrane

turbulent flow – the type of flow in which the particles of the fluid are not moving in straight, 'orderly' paths; the particles tend to move around randomly and 'interfere' with each other; it takes more energy to move fluids when they are moving in a turbulent manner, so turbulent flow is an inefficient way of moving fluids

viscosity – the property of fluids that causes them to resist deformation during movement; the more viscous a fluid, the more difficult is it to get the fluid moving

wetting effect – a description of how much a liquid will spread out on a surface

Practice test: Answers

1. A fluid is a gas or a liquid: anything that flows.✓✓ (2)
2. Surface tension is due to attractive forces✓ between molecules at the surface of a liquid.✓✓ In gases, the molecules have almost no attraction towards each other,✓ thus there is no 'surface tension' effect.✓ (5)
3. The very thin film of water making up the soap bubble has surface tension.✓✓ It tends to reduce its surface area.✓ This 'shrinking effect' squeezes (i.e. applies pressure to) the air inside the bubble,✓ thus the pressure rises inside the bubble.✓ (5)
4. Forces of cohesion are the forces that operate between the molecules✓ of one substance.✓ Forces of adhesion are those between molecules✓of different substances.✓✓ (5)
5. Surface tension decreases as the temperature of the liquid rises.✓✓ (2)
6. 'Viscostatic' means that the viscosity of a particular liquid does not change in response to a change in temperature. (In fact, 'viscostatic' liquids do change their viscosities as their temperatures change, but the viscosity change per unit of temperature change is less than it is with 'ordinary' liquids.)✓✓ (2)
7. The 'lumen' is the channel inside a tube through which flow can occur. It is the 'hole' along the inside of a pipe.✓✓ (2)
8. The contact angle between pure water and clean glass is zero degrees.✓✓ (2)
9. If the contact angle between a liquid and a solid were 90°, the liquid would neither rise nor fall inside the tube in relation to the surrounding liquid level. There would be no curvature ('meniscus') to the surface of the liquid in the tube: it would be flat.✓✓(2)
10. The surface tension of the liquid on the surface of the lungs tends to 'shrink' them – it reduces their surface area and the lung surface resists being stretched when we breathe in.✓ If this surface tension is too high,✓ the lungs will not expand (stretch) sufficiently for proper gas exchange to take place across the lung membrane (i.e. between the gases in the lungs and the gases in the blood).✓ This is especially important in newborn babies. Before birth, the lungs secrete a substance which dissolves in the water layer on the lung surface and reduces the surface tension.✓ This makes it easier to breathe in. If the baby's lungs do not secrete this substance, drawing air into the lungs is so difficult that the baby is in danger of dying.✓ (5)
11. a) Viscosity is the 'thickness' of a fluid.✓ It can be described as the 'internal friction' of a fluid.✓ It influences the ways in which a fluid moves in response to a force.✓ (3)
    b) The SI unit of viscosity is the pascal-second (Pa·s).✓ (1)
12. Viscometers work by slowing down the rate at which a standardized spherical body falls through the fluid in question.✓ The amount of 'drag' is related to the viscosity of the fluid.✓ The rate at which the body falls is measured✓ and this gives an indication of the viscosity of the fluid through which the body falls.✓ (In fact, there are other types of viscometer, but the method described here is probably the most commonly used, and is also the simplest.) (4)

Total marks: 40

THEME 6

Physics in technology

TOPIC 1: Units of measurement

Performance objective

1.1 Identify units used in industry.

Introduction

This topic is to introduce students to non-SI units which are commonly used in industry and commerce to measure some common physical quantities, such as temperature, volume of crude oil, area of land, power of industrial machines and electrical energy. The students are also taught to convert between these units and SI units.

How are you doing? (SB p. 154)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

acre – a non-SI unit of area (1 acre = 4 047 m^2)

barrel (bbl) – a non-SI unit of volume used in the petroleum oil industry (1 bbl = 42 gallons = about 159 litres)

Celsius scale (T_C) – a non-SI unit of temperature derived from the SI unit kelvin; at standard temperature and pressure, water boils at 100 °C and freezes at 0 °C

Fahrenheit scale (T_F) – a non-SI unit of temperature; at standard temperature and pressure, water boils at 212 °F and freezes at 32 °F

horsepower (hp) – a non-SI unit for power (1 hp = 746 W)

Kelvin scale (T_K) – the SI unit of temperature; at standard temperature and pressure, water boils at 373 K and freezes at 273 K (note: not degrees K)

kilowatt-hour (kWh) – the unit used by power utilities to determine the amount of electricity consumed

mbd (million barrels per day) – a term used as a unit of measurement in oil production

Practice test: Answers

1. C✓✓ (2)
2. C✓✓ (2)
3. B✓✓ (2)
4. B✓✓ (2)
5. a) $T_K = T_C + 273$

   $T_C = \frac{5}{9}(T_F - 32)$

   $\therefore T_K = \frac{5}{9}(T_F - 32) + 273$

   $= \frac{5}{9}(50 - 32) + 273$

   = 283 K✓✓ (2)

   b) $T_F = \frac{9}{5}T_C + 32$

   $= \frac{9}{5}30\ ^\circ\text{C} + 32$

   = 86 °F✓✓ (2)

   c) 1 acre = 4 047 m^2

   ∴1.7 acres = (4 047 × 1.7) m^2

   = 6 879.9 m^2✓✓ (2)

   d) 1 hp = 746 W

   ∴ 85 hp = (85 × 746) W

   = 63 410 W

   = 63.41 kW✓✓ (2)

   e) 1 kWh = 3.6×10^6 J

   ∴ 1 J = 2.78×10^{-7} kWh

   ∴ 5 000 J = (5 000 × 2.78 × 10^{-7}) kWh

   = 1.39×10^{-3} kWh✓✓ (2)

   f) 1 hp = 746 W

   ∴ 212 hp = (212 × 746) W

   = 158 152 W

   = 158.152 kW✓✓ (2)

6. Cost = 99.96 kWh × $\frac{₦18.46}{\text{kWh}}$

   = ₦1 845.26✓✓✓✓ (4)

7. a) Value of voucher after VAT

   = ₦4 500 × 95%

   = ₦4 275✓✓

   ∴ Total kWh purchased

   $= \frac{₦4\ 275}{₦19.44 \text{ per kWh}}$

   = 219.9 kWh✓✓ (4)

   b) Total number of days

   $= \frac{219.9 \text{ kWh}}{8 \text{ kWh per day}}$

   = 27.49 days✓✓✓✓ (4)

8. a) Total volume (m^3) per day

   = 2.07 mbd

   $= 2.07 \times 10^6 \frac{\text{bbl}}{\text{day}} \times \frac{0.159 \text{ m}^3}{\text{bbl}}$

   = 329 130 m^3/day

   = 3.29×10^5 m^3/day

   Total volume (m^3) per month

   = 3.29×10^5 m^3/day × 31 days

   = 10.2×10^6 m^3

   Total volume (l) for March

   0.159 m^3 = 159 l

   ∴ 10.2×10^6 m^3

   = 1.02×10^{10} l✓✓ (2)

   b) Earnings

   $= \frac{₦}{\text{barrel}}$ × number of barrels × number of days

   $= 1\ 1281.31 \frac{₦}{\text{barrel}} \times 1.62 \times 10^6 \frac{\text{barrels}}{\text{day}} \times 31 \text{ days}$

   = ₦5.67×10^{11}✓✓ (2)

   c) Domestic use volume for March

   = (2.07 – 1.62) mbd × 31 days

   = 0.45 mbd × 31 days

   = 13.95 million barrels

   $= 13.95 \times 10^6 \text{ barrels/day} \times \frac{0.159 \text{ m}^3}{\text{bbl}}$

   = 2.22×10^6 m^3✓✓✓✓ (4)

Total marks: 40

TOPIC 2: Electrical continuity testing

Performance objective
2.1 Construct a simple electrical continuity tester.

Introduction

In this topic, students build an electrical continuity tester using simple equipment and use the tester to check faults in electrical circuits. There are not very many different types of simple circuit testers because multimeters serve this function. The students should be able to use the tester that they build to check faults in circuits. You may have to set up circuits with faults in them for the students to achieve this part of the objective.

This YouTube link shows how to use a multimeter (using the function mode similar to the continuity tester to be used): <https://www.youtube.com/watch?v=InJhgwmj2So>. You can skip the first part of the video because it deals with AC versus DC, which is taught in Senior Secondary 3.

Activity 6.1: Building a continuity tester

GROUPS or CLASS (SB p. 156)

Resources

for each group: two AA batteries and a battery holder, conducting leads with crocodile clips, an indicator (buzzer or light), a 3 V light bulb and holder, insulation tape

Guidelines

The activity is self-explanatory. Students may omit the buzzer if it is too costly to purchase. Warn the students of the hazards of testing faulty AC appliances, and that these appliances must be disconnected from the mains supply before being tested. Restrict the students to testing simple circuits, such as those in light bulbs, fuses, batteries and so forth.

How are you doing?

(SB p. 157)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key word

continuity tester – a device used to find electrical faults

Practice test: Answers

1. A continuity fault occurs in an electrical circuit when no current flows in it when the circuit is switched on. This could occur: (i) when there is a break in the conducting wires or (ii) because of a loose contact or (iii) because of a faulty resistor, light bulb, switch, ammeter or any other electrical device connected in the circuit.✓✓ (2)
2. The two essential features of a continuity tester are a battery✓ and a light bulb (or buzzer).✓ (2)
3. a) Connect A and E to test the bulb.✓✓ (2)
   b) Connect B and H to test Cell 1.✓✓ (2)
   c) Connect H and J to test Cell 2.✓✓ (2)
   d) Connect G and J to test the slide switch.✓✓ (2)

Total marks: 12

TOPIC 3: Solar collectors

Performance objectives

3.1 Construct a solar collector.
3.2 Explain the use of solar energy panels for energy supply.

Introduction

This topic is about solar collectors and solar panels. Solar collectors are made of large rectangular plastic- or glass-covered boxes which contain pipes transporting water. The main function of a solar collector is to heat water. Solar panels are made of small solar cells (also called photovoltaic cells) and they are used to generate electricity. Solar cells use the phenomenon of the photoelectric effect combined with the creation of electron-hole pairs in semiconductors, such as silicon. The electric current generated is used to charge batteries, and the battery current is converted into alternating current by inverters so that the current can be used for domestic and business purposes.

Activity 6.2: Building a simple solar collector to heat water

GROUPS or CLASS (SB p. 159)

Resources

per group: four pieces of timber or polystyrene (each 25 mm wide, 76 mm high and 600 mm long), Masonite board or any flat timber (600 mm wide by 600 mm long), irrigation hose (25 mm in diameter and 10 m long), two large metal coffee cans, matt black spray paint, a clear Perspex sheet (600 mm wide by 600 mm long), nails, a hammer, silicone adhesive, a roll of duct tape, a drill, a small drum for collecting the hot water

Guidelines

Facilitate: The activity would best be done on a sunny day. Depending on the resources available, this activity could either be done in groups or as a class.

How are you doing?

(SB p. 161)

Take this opportunity to ask learners if there is anything that they do not understand. You can check their understanding by asking them some questions about the information covered in the unit. Explain anything that learners do not understand.

Key words

charge controller – used to determine the amount of current needed to charge the batteries in a solar panel
inverter – a device which converts direct current (DC) into alternating current (AC)
solar cell – devices made of silicone materials which can easily release electrons under sunlight
solar collector – a device that collects solar energy
solar energy – energy from the sun
solar panel – sets of solar cells which collect solar energy

Practice test: Answers

1. D✓✓ (2)
2. C✓✓ (2)
3. A✓✓ (2)
4. D✓✓ (2)
5. a) Solar cell: to generate current using solar energy.✓ (1)
   b) Charge controller: to determine the amount of current needed to charge the storage batteries.✓ (1)
   c) Back-up batteries: to provide electrical energy in times of low sunlight or at night.✓ (1)
   d) Inverter: converts the direct current to alternating current.✓ (1)
6. Use the rubric (marking scheme) below to allocate marks for the report. (18)

	Electricity grid✓	**Diesel or petrol generators✓**	**Solar panel system✓**
Start-up costs	Electricity deposit paid by homeowners or cost of prepaid meters✓ (1)	Cost of purchasing or leasing generator✓ (1)	Cost of purchasing and installing the components✓ (1)
Cost per day of power	Electricity tariff set by local company or cost of prepaid cards✓ (1)	Cost of fuel used per day✓ (1)	Should be zero✓ (1)
Maintenance costs	Minimal for contract and prepaid users✓ (1)	Cost of repairs of generators✓ (1)	Should be zero✓ (1)
Reliability	Depends on area✓ (1)	Should be good✓ (1)	Depends on amount of sunlight in area✓ (1)
Effects on environment	Air pollution, water pollution, etc.✓ (1)	Noise and air pollution✓ (1)	None✓ (1)

Total marks: 30