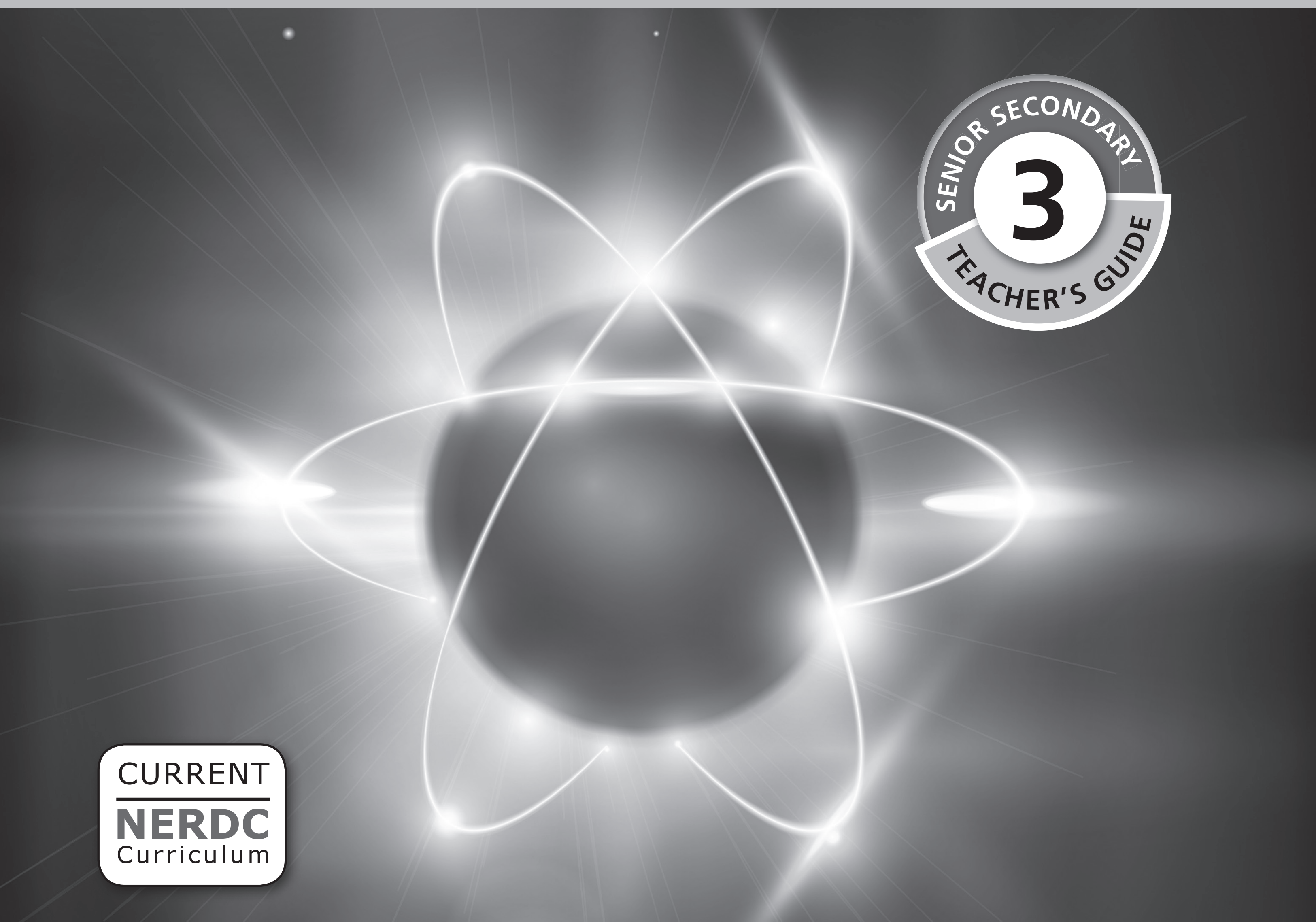
Excellence in Physics



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Excellence in
Physics

SENIOR SECONDARY
3
TEACHER'S GUIDE

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Contents

Introduction

The purpose of the curriculum

The general objectives of the curriculum are to:

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

The goals

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 120 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 slide shows, workstations, videos, discussion groups, worksheets, question–answer sessions, debate, and 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 do a written/typed plan for each lesson. This must include aims, objectives, resources, time frames, content for the lesson, activities, homework, assessment, and ideas and 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 actively involve your students 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 questions related to your lesson (approximately five). This will settle them into the lesson. You can use different types of questions in your lessons:

- for enabling you to determine prior knowledge on the topic (**diagnostic**)

- for **consolidation** of challenging concepts during the lesson
- for **stimulation** of interest in the subject
- for **concluding** the lesson.

This will assist you to find out whether students have understood the concepts and 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 purpose of this *Teacher's Book* is to assist you to use the *Student's Book* and be more thoroughly prepared so that your teaching is be more meaningful to your students. This book supports a hands-on approach.

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

The book is divided into 23 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, which are essential vocabulary for the topic
- practise test questions for revision of the topic.

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 3 to 11.

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 3 terms. Each term is divided into 13 weeks. There are six topics in Term 1, seven topics in Term 2 and ten 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 number of suggested lessons for each topic. This has been divided according to the content of the topic. These vary from 2 to 11 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? How can we use physics in daily life? What is the scientific method?

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 less discipline issues if you are: punctual, well prepared, follow a plan (write this on the board at the start of the lesson), keep your word (do not 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.

Physics teaching schemes of work for SS3

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
Term 1				
1	Conservation principles	1. Energy and society (SB p. 1)	1. Identify the sources of energy. 2. Distinguish between renewable and non-renewable sources of energy. 3. Identify the various ways energy is used. 4. Explain the importance of energy in the development of society. 5. Explain the impact/ effect of energy use on the environment. 6. Identify energy sources that are environmentally friendly and those that are hazardous to the environment.	1. Sources of energy 2. Renewable and non-renewable energy 3. Uses of energy 4. Energy and development 5. Energy diversification and conservation 6. Environmental impact of energy use: • global warming and greenhouse effect • oil spillage 7. Energy crisis

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
2		2. Conservation of energy (SB p. 10)	1. Identify the different forms of energy and state how these forms of energy can be converted from one form to another. 2. Use simple devices to convert one from of energy to another.	1. Conversion of: • mechanical energy to heat, mechanical light energies, etc • electrical energy to heat, mechanical light energies, etc • radiation energy to electrical, heat, etc • chemical energy to electrical and mechanical energies (vice versa), etc 2. Devices used in energy conversion in (1) above
3	Waves, motion without material transfer	1. Properties of waves (SB p. 14)	1. State and explain four properties of waves. 2. Demonstrate interference of waves. 3. Demonstrate polarisation of light waves. 4. Demonstrate diffraction of waves.	1. Interference of waves (light and sound) 2. Diffraction of waves (light and sound) 3. Polarisation of light (application on Polaroid only)
4		2. Electromagnetic waves (SB p. 23)	1. Distinguish between electromagnetic waves and mechanical waves. 2. List the six radiations in the electromagnetic spectrum in order if increasing wavelength and increasing frequency. 3. State some uses of electromagnetic waves. 4. Apply the formula $v = f\lambda$ to solve simple problems relating to electromagnetic waves.	1. Electromagnetic spectrum

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
5–6	Fields at rest and in motion	1. Gravitational field (SB p. 34)	1. Calculate the gravitational force between two masses. 2. Calculate the gravitational force between two planets. 3. Explain the meaning of *G* and show that *g* is the force per unit mass on the Earth's surface. 4. Relate Kepler's laws to the motion of the solar system. 5. Distinguish between natural and artificial satellites. 6. Explain how artificial satellites are launched. 7. Explain the concept of escape velocity.	1. Gravitational force between two masses (Newton's LAW of Universal Gravitation) 2. *G* as a universal constant 3. Solar system 4. Kepter's laws 5. Natural and artificial satellites 6. Escape velocity
7–10		2. Electric field (SB p. 47)	1. Identify all the components parts of simple cells and accumulators. 2. Solve problems involving series and parallel connections of resistors and cells. 3. Convert a galvanometer to an ammeter and to a voltmeter. 4. State the factors on which the resistance of a wire depends. 5. State and demonstrate the conditions for a balanced wheatstone bridge and deduce the condition for the balance metre bridge circuit. 6. Explain the basic principle of the potentiometer circuit.	1. Production of continuum charges (primary and secondary cells) 2. Electric circuit: series and parallel arrangement of cells and resistors 3. Shunt and multiplier 4. Resistivity and conductivity 5. Principle of the potentiometer: • metre bridge • wheatstone bridge 6. Measurement of • electric current • potential difference • resistance • emf of a cell

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
7–10		2. Electric field (SB p. 47)	7. Explain the behaviour of charges or charge carriers in liquids and gases in the electric field. 8. Describe an application each of electrical conduction through liquids and gases. 9. Calculate the electric force between two charges. 10. Explain electric field intensity and electric potential. 11. Explain the word capacitance. 12. Calculate the equivalent capacitance for series and parallel arrangements of capacitors. 13. Determine the energy stored in a capacitor.	7. Electrical conduction through liquids and gases: • electrolytes and non-electrolytes • conduction of charged electrolytes • voltammeter • electroplating • hot cathode emission • applications 8. Faraday's Law of Electrolysis 9. Electric force between point charges (Coulomb's Law) 10. Concept of: • electric field • electric field intensity • electric potential 11. Capacitance: • definition • arrangement of capacitors on a circuit • energy stores in a charged capacitor
11	Revision			
12–13	Examinations			
Term 2				
1–2	Fields at rest and in motion (continued)	3. Magnetic fields (SB p. 97)	1. Plot the magnetic field around: • a bar magnet • a straight conductor carry current • a solenoid. 2. Make a magnet from a soft iron bar. 3. Make an electromagnet. 4. Describe the working principles of an electric bell and a telephone earpiece.	1. The concept of a magnetic field 2 Magnetic field around: • a bar magnet • a straight conductor carry current • a solenoid 3. Magnets: • temporary and permanent • making magnets

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
1–2	Fields at rest and in motion (continued)	3. Magnetic fields (SB p. 97)	5. Locate the Earth's magnetic north–south direction 6. Explain the magnetic force on a moving charge. 7. State the relation between magnetic force and the motion of a charge in a magnetic field.	4. Application of electromagnetic fields 5. Earth's magnetic field: • description and use • mariner's compass 6. Magnetic forces on a moving charge
3–4		4. Electromagnetic field (SB p. 106)	1. Identify the directions of current, magnetic field. 2. Explain the action of a loop wire carrying current in a magnetic field. 3. Explain the basic working principle of the galvanometer and the electric motor. 4. State and explain Faraday's law of electromagnetic induction. 5. State and explain the implications of Lenz's law. 6. Explain how the conversation principle is involved in both laws with regard to: • charge • energy. 7. Explain the principle underlying the production of direct and alternating current. 8. State the use of induction coils and transformers. 9. Explain why the cores of the induction coil and the transformers are laminated.	1. The concept of an electromagnetic field 2. Interaction between magnetic field and current in • a current-carrying wire in a magnetic field • a current-carrying solenoid in a magnetic field 3. Applications of electromagnetic fields: • electric motor • moving coil galvanometer • induction coil 4. Electromagnetic induction: • Faraday's Law • Lenz's Law • motor generator effect 5. Eddy currents

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
5–6		5. Simple a.c. circuits (SB p. 129)	1. Explain the peak and vms values of current and pd. 2. Establish the phase relationship between current and pd in an a.c. circuit. 3. Explain reactance and impedance. 4. Determine current in circuits containing: • resistance and capacitance • resistance, inductance and capacitance. 5. Determine power in an a.c. circuit.	1. Alternating current circuits: • nomenclature in a.c circuits • peak and rms values • series circuits containing resistance, inductance and capacitance • reactance and impedance 2. Power in an a.c. circuit
7	Energy quantisation and duality of matter	1. Models of the atom (SB p. 146)	1. State and discuss what chemical evidence there is for the existence of an atom. 2. State and discuss what experimental evidence there is for believing that matter is electrical in nature. 3. Describe Rutherford-Bohr models of the atom. 4. Explain nucleon numbers and their relationship.	1. Concept of the atom 2. The various models of the atom: • Thomson • Rutherford • Bohr • Electron-cloud models 3. Limitations of physical models
8		2. Nucleus (SB p. 153)	1. Identify the radiation from radioactive substances using their characteristics. 2. Solve simple problems involving the half-life of radioactive substances. 3. State some uses of radioactive substances.	1. Natural and artificial radioactivity: • isotopes • radioactive elements • radioactive emission • half-life and decay constant

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
8		2. Nucleus (SB p. 153)	4. Use the concept of nuclear fission and fusion for the development of nuclear energy for Nigeria.	2. Nuclear reaction: • fission • fusion • nuclear energy • nuclear power and the atomic bomb 3. Nigeria's nuclear energy programme
9		3. Energy quantisation (SB p. 169)	1. Explain the concept of energy quantisation. 2. Use the photon concept to explain the effect of electrons in the photoelectric effect. 3. Describe X-ray production and state its characteristics, properties and uses.	1. Energy levels in atom: • ground state • excited state • emission of light energy on return to ground state 2. Photoelectric effect 3. Einstein's photoelectric equation and its explanation 4. X-ray: • production • characteristics and properties • uses
10		4. Duality of matter (SB p. 186)	1. Identify phenomenon which are only satisfactorily explained by assuming that matter behaves like: • waves and • particles.	1. Wave–particle duality
11	Revision			
12–13	Examinations			
Term 3				
1	Physics in technology	1. The battery (SB p. 191)	1. Construct a battery.	1. Battery
		2. Electroplating (SB p. 200)	1. Electroplate a suitable electrode.	1. Electroplating
2		3. Application of electromagnetic field (SB p. 202)	1. Construct and use: • a galvanometer • an electric motor • a generator.	1. Galvanometer 2. Electric motor 3. Generators

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
3		4. Transmission systems (SB p. 207)	1. Construct a simple transmission system. 2. Explain why it is preferred to have a high pd instead of a high current transmission over a long distance.	1. Transformer
4		5. Uses of machines (SB p. 209)	1. State the need for the use of machines. 2. State instances where machines are used.	1. Need for use of machines in doing work: • easier • quicker • more convenient 2. Instances of the use of machines: • at home • in offices • in industry • in agriculture • in transportation
5		6. Repairs and maintenance of machines (SB p. 212)	1. State the need to identify faults in machines and get them repaired. 2. State the need for regular maintenance of machines. 3. Identify and follow a maintenance schedule for a machine.	1. The need for repairs of machines 2. The need for regular maintenance of machines 3. Maintenance schedule of machines
6		7. Dams and energy production (SB p. 216)	1. Identify dams for producing electricity in Nigeria. 2. Describe how electricity is produced from a dam.	1. The location of dams for producing electricity in Nigeria 2. The principle of the production of electricity from dams
		8. Rockets and satellites (SB p. 220)	1. Identify the component parts of rockets and satellites. 2. Describe the functions of rockets and satellites. 3. State the uses of rockets and satellites.	1. Component parts of rockets and satellites 2. Functions of rockets and satellites 3. Uses of rockets and satellites

Week	Theme	Topic	Performance objectives (students should be able to:)	Content
7		9. NigerSAT-1 (SB p. 227)	1. State the features of NigerSAT-1. 2. Describe the operation of NigerSAT-1. 3. State its uses to Nigeria and its neighbours.	1. Features of NigerSAT-1 2. Operation of NigerSAT-1 and its uses
		10. NigComSAT-1 (SB p. 231)	1. State the features of NigComSAT-1. 2. Describe the operation of NigComSAT-1. 3. State its uses to Nigeria and its neighbours.	1. Features of NigComSAT-1 2. Operation of NigComSAT-1 and its uses
8–9	All practicals			
10	Revision			
11–13	Examinations			

THEME 2 Conservation principles

TOPIC 1: Energy and society
Performance objective
1.1 Identify the sources of energy. **1.2** Distinguish between renewable and non-renewable sources of energy. **1.3** Identify the various ways energy is used. **1.4** Explain the importance of energy in the development of society. **1.5** Explain the impact/effect of energy use on the environment. **1.6** Identify energy sources that are environmentally friendly and those that are hazardous to the environment.

Introduction

Students should be encouraged to see the energy crisis as a global situation, rather than as being restricted to any one country or continent. Energy has been a part of the syllabus for the two earlier years of study, and informal revision of this and other topics should be a routine part of the lessons.

It is important that students see the energy crisis as a part of the larger problem of overpopulation and continuing growth of human numbers. Seen from this larger perspective, they should realise that the energy crisis is not a single problem. It happens to dominate the world stage because of habitat destruction and global warming, but the only satisfactory, long-term solution to the various problems is a holistic one.

Activity 2.1 Hot springs INDIVIDUAL (SB p. 3)

Resources

Library or Internet

Guidelines

Ask students to look up the meaning of 'geyser'.

Countries with warm or hot springs: Japan, Iceland, Peru, USA, Canada, New Zealand, Chile.
Ikogosi Warm Springs: Ikogosi is a small town in Ekiti State, in south-west Nigeria. It is a local tourist attraction, and it was first developed by a missionary, John McGee, in 1952. Two points of interest and significance: It seems to be the only warm (or hot) spring in Nigeria. Second, there are two springs, side-by-side, one warm (70 °C), the other cold. They run parallel for some distance and then join. Ask the class to find out what 'confluence' means.

Activity 2.2 Albedo INDIVIDUAL (SB p. 7)

Resources

Dictionary or Internet

Guidelines

The students are asked to look up the word 'albedo' and write a paragraph on its relevance to global warming. Albedo is the proportion of light reflected from a surface – especially a planet. Thus, in relation to global temperatures and warming, as the white ice caps melt, the overall reflectivity of the planet (its albedo) is reduced, thus less light (energy) is bounced off the planet, and the more heat remains on the planet's surface to add to the warming effect.

Activity 2.3 Iceberg test

GROUP (SB p. 7)

Resources

For each group: a small bucket of ice blocks (not crushed ice), a container with a capacity of 2–4 litres and a thermometer

Guidelines

If this is done as a thought experiment, give the class a few minutes to discuss it amongst themselves in small groups, then open the discussion to the class.

The students should find that there is no difference in the water levels in the bucket before and after the ice blocks have melted. They may argue that the water level should rise as the ice melts, because about 10% of the ice is above the surface, thus when this melts the 10% will go into the water and increase its volume. In fact, the reason why ice floats is that its density is lower than that of liquid water above 4° Celsius. As the water melts and warms up, its volume actually decreases. When all the water has melted and it is back to ambient temperature, the volume will be the same as it was while the ice was floating.

Activity 2.4 The energy crisis

GROUP (SB p. 8)

Guidelines

Students discuss the energy crisis in small groups. You may consider asking for volunteer speakers from each group to briefly address the class on their findings.

Activity 2.5 The hunt for oil

INDIVIDUAL (SB p. 8)

Guidelines

The can be a homework activity. Tell the students that only a paragraph or two is required. They should understand – and convey in their reports – that there are two sides to the problem of drilling for oil in environmentally sensitive areas. There is pressure to preserve the environment, but the pressure of a globally and nationally expanding human population gives us little option about where we get our energy resources from. There is also the need to obtain the oil as cheaply as possible, and that consideration must be weighed against environmental destruction. The students should realise that one of the main causes of the problem is one of human numbers.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

demographic trap – A state of poverty from which a community cannot escape because the size of the population is increasing faster than the rate at which it generates wealth

global warming – Increasing temperature of earth's atmosphere

greenhouse gases – Gases (mainly carbon dioxide and methane) which form a blanket around the planet, and reduce the rate of heat loss. The rate of heat loss from the planet is therefore less than the rate at which heat arrives from the Sun, and the temperature of the atmosphere rises. It is the same effect that causes a greenhouse to be warmer than its surroundings, hence the name

photosynthesis – The building (synthesis) of substances (such as sugars) using the energy of light

Practice test: Answers (SB p. 9)

1. 'Geothermal' means 'earth heat'. Water at surrounding (surface) temperature is pumped, in pipes, deep underground. Below the surface the temperature is high, and the water is therefore heated. When it returns to the surface, also in pipes, it has picked up some of the earth's thermal (heat) energy. (5)
2. Fuel is a source of energy. Breakdown products are produced when the fuel is burnt to release some of its energy, but these breakdown products are not important to the machine that is using the energy. Food, on the other hand, releases energy, and produces breakdown products, but food also provides substances that are important to the organism. (1)
3. In many countries and societies people multiply faster than it is possible to increase their standard of living. They are therefore trapped in a state of continuing poverty. This situation has been described as a demographic trap. (2)
4. Much of the sun's energy gets through the earth's atmosphere and warms the surface of the planet. The atmosphere, however, prevents some of the radiant energy from escaping back into space. Thus the temperature of the earth's surface rises. This is the same principle that keeps a greenhouse warmer than the surroundings. (5)

Total marks: 13

Checklist for Self-evaluation

Theme 2 Topic 1

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify the sources of energy.					
2	Distinguish between renewable and non-renewable sources of energy.					
3	Identify the various ways energy is used.					
4	Explain the importance of energy in the development of society.					
5	Explain the impact/effect of energy use on the environment.					
6	Identify energy sources that are environmentally friendly and those that are hazardous to the environment.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 2: Conversion of energy
Performance objective
2.1 Identify the different forms of energy and state how these forms of energy can be converted from one form to another. **2.2** Use simple devices to convert one from of energy to another.

Introduction

Students should have a good general awareness and understanding of energy conversions, and class discussion should be used extensively as a means of revision and progress. Members of the class will probably enjoy reporting on energy economy and conversions within their domestic environs.

Activity 2.6 Converting light to heat

PAIR/GROUP (SB p. 10)

Resources

For each group: Two 250 ml beakers half-filled with clean sand; one laboratory thermometer, a sheet of black plastic or black cloth; sheet of aluminium foil or white plastic sheet.

Guidelines

The students should put the beakers near each other in direct sunlight, so that both beakers are receiving the same amount of solar radiation. If the day is hot and bright, there should be a noticeable difference between the two sand temperatures after about half an hour. This allows you to conduct the experiment within one class period. The students unwrap their beakers and record the temperatures of the two sand samples, by pushing the thermometer a few centimetres beneath the sand surface in each beaker. They should measure the temperature in the white-covered beaker before measuring the temperature in the black-covered beaker, because the latter is likely to be higher.

Activity 2.7 Converting mechanical energy to heat

INDIVIDUAL (SB p. 10)

Guidelines

This is a very quick, simple and informal exercise, done by the students individually. Rubbing their hands together produces a feeling of warmth, thus showing that mechanical energy is converted, through friction, into heat energy.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

armature – Any moving part of an electrical apparatus in which a voltage is induced by a magnetic field, or which closes a magnetic circuit

Practice test: Answers (SB p. 13)

1. Shivering is a process in which our muscles make small, rapid contractions without moving our bodies. Muscular contraction involves the use of energy, and when energy is used in any process, some of the energy escapes as heat. Shivering muscles produce more heat than muscles that are completely relaxed. Therefore, shivering helps to supply our bodies with a little extra heat when we are cold. (4)
2. 'Photo' means 'light', and 'voltaic' means 'relating to electricity'. Photovoltaic therefore refers to electricity produced from light energy. (2)
3. An electric motor is an armature that rotates in a magnetic field when electric current passes through the armature. A generator is an armature that produces electric current when it is forced to rotate in a magnetic field. (2)
4. A transducer is a machine that converts one form of energy to another form. (2)
5. An armature is a wire coil (actually many wire coils) that rotates in a magnetic field and carries electric current. (2)
6. A semiconductor is a substance that is b etween electrical conductors and insulators, in terms of the arrangement of electrons in the atoms of the substance. A source of energy, such as light, can make electrons move from one semiconductor to another, and thus produce an electric current. Silicon and germanium are semiconductors. (2)

Total marks: 14

Checklist for Self-evaluation

Theme 2 Topic 2

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify the different forms of energy and state how these forms of energy can be converted from one form to another.					
2	Use simple devices to convert one from of energy to another.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

THEME 3

Waves, motion without material transfer

TOPIC 1: Properties of waves
Performance objectives
1.1 State and explain four properties of waves. **1.2** Demonstrate interference of waves. **1.3** Demonstrate polarisation of light waves. **1.4** Demonstrate diffraction of waves.

Introduction

Class discussions might involve students with an interest in photography. Probably all of them will be familiar with sunglasses, and the rotation of polarising lenses makes a very impressive and memorable demonstration. If your science laboratory does not have any polaroid filters you should consider obtaining a few sets before the lesson. A ripple tank is also a very useful piece of apparatus for the school to acquire.

Activity 3.1 Whistle test CLASS (SB p. 16)

Resources

A whistle

Guidelines

Get a volunteer to sit or stand in one place and blow continuously on the whistle. The other members of the class move around the room and try to detect differing levels of loudness. These differences are due to interference – both constructive and destructive.

Activity 3.2 Ripple tank demonstration CLASS (SB p. 16)

Resources

Apparatus for a ripple tank

Guidelines

If your school laboratory has a ripple tank, you can set this up and perform it as a demonstration for the class. It works well.

Activity 3.3: Producing coherent light beams CLASS (SB p. 17)

Resources

A monochromatic light source

Activity 3.4 Polaroid test PAIR (SB p. 24)

Resources

Two polaroid filters or two pairs of polaroid sunglasses

Guidelines

Experiment with polaroid filters, or polaroid sunglasses. If sufficient equipment is available, students should work in small groups. Genuine polaroid sunglasses work well, but many dark glasses that call themselves polaroid do not really polarise the light passing through them. Also, you need two pairs of genuine polaroid glasses to demonstrate the effect of cutting out all light transmission by appropriately rotating the glasses.

How are you doing?

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

acronym – Word made up from the first letters of a group of words – for example: LASER and SCUBA

coherent waves – Waves that are aligned, or in register. The crests and troughs of coherent waves arrive at, or pass, any given point at the same time

constructive interference – Waves of the same wavelength interfere constructively when their crests and troughs are lined up

diffraction – The bending of waves (light and sound waves) when they pass the edge of an obstacle or through small openings

Practice test: Answers (SB p. 22)

1. Superposition is the situation that exists when two or more waves cross each other and have their crests in exactly the same place at the same time. The amplitudes of the waves are added. Superposition explains the properties of interference and diffraction. (4)
2. Coherent waves are waves in which all the crests and all the troughs are lined up. The waves are said to be in phase. (2)
3. Laser stands for: Light Amplification by Stimulated Emission of Radiation. (2)
4. Lasers were invented by Theodore Maiman. (2)
5. Lambda = $\frac{\text{speed}}{\text{frequency}}$ and speed = frequency × lambda (3)
6. One hertz (Hz) is the unit of frequency. It is equal to one cycle per second. (2)
7. Diffraction is an edge effect. If light passes through a small aperture, interference/diffraction causes a series of concentric light-and-dark circles (diffraction rings) to form on a screen in front of the aperture. The effect is increasingly noticeable as the diameter of the aperture comes close to the wavelength of the waves. In a camera with a very small aperture, diffraction reduces the quality of the image produced by the lens. The bigger the aperture, the less the effect of diffraction and, in a perfect lens, the better is the image. (5)
8. Light may be polarised by being passed through certain types of crystal (tourmaline).
   It becomes polarised at certain angles of reflection.
   It is polarised in the process of scattering.
   (The proprietary substance 'polaroid' also polarises light waves.) (3)
9. a) About 4.2 mm (5)
   b) No. The wrap round effect of longer wavelengths would give the bats less effective echo-locating ability. (4)
10. B (2)

Total marks: 34

Checklist for Self-evaluation

Theme 3 Topic 1

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	State and explain four properties of waves.					
2	Demonstrate interference of waves..					
3	Demonstrate polarisation of light waves.					
4	Demonstrate diffraction of waves.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 2: Electromagnetic waves

Performance objectives

2.1 Distinguish between electromagnetic waves and mechanical waves.
2.2 List the seven radiations in the electromagnetic spectrum in order of increasing wavelength and increasing frequency.
2.3 State some uses of electromagnetic waves.
2.4 Apply the formula $v = f\lambda$ to solve simple problems relating to electromagnetic waves.

Introduction

This topic is a brief introduction to electromagnetic waves. The students are first shown how electromagnetic waves differ from the mechanical waves previously studied. They are then shown the electromagnetic spectrum. Microwaves are treated as separate waves from radio waves, and hence the book has seven and not six parts of the electromagnetic spectrum. Some of the uses of the electromagnetic waves are then discussed.

The following are links to Internet websites that can be used by the teacher to enhance teaching of this topic:

https://www.youtube.com/watch?v=cfXzwh3KadE

https://www.youtube.com/watch?v=m4t7gTmBK3g

https://www.youtube.com/watch?v=hXe7EVv1y0Q.

How are you doing?

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

electron vacuum tubes – Glass or metal tubes in which electrons move from the negative electrode to the positive electrode through a vacuum

infrared waves – Part of the electromagnetic spectrum formed by rotating or vibrating molecules and with wavelengths larger than that of visible light

ionosphere – The layer of the atmosphere that consists of gases that have been ionised by the Sun

microwaves – Part of the electromagnetic spectrum and are very short wavelength radio waves

radio waves – Part of the electromagnetic spectrum with the longest wavelength and used for communication

Practice test: Answers

(SB p. 32)

1. 1.1 B (2)
   1.2 D (2)
   1.3 C (2)
   1.4 B (2)
   1.5 D (2)
2. Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays (2)
3. The wavelength of the waves is $\lambda = \frac{60}{3}$ µm = 20×10^{-6} m
   The frequency of the waves is given by
   $f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{20 \times 10^{-6} \text{ m}} = 1.5 \times 10^{13}$ Hz (3)
4. Similarities: both are electromagnetic waves, both travel at the same speed in air or a vacuum, both are transverse waves, both can be polarised (any two)(2)
   Differences: gamma rays carry more energy per photon than X-rays, gamma rays are produced by radioactive decay while X-rays are produced by fast-moving electrons being stopped by a metal target. (2)
5. For the wavelength $\lambda = 380$ nm $= 380 \times 10^{-9}$ m the frequency is:
   $f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{380 \times 10^{-9} \text{ m}} = 7.89 \times 10^{14}$ Hz
   For the wavelength $\lambda = 750$ nm $= 750 \times 10^{-9}$ m the frequency is:
   $f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{750 \times 10^{-9} \text{ m}} = 4.00 \times 10^{14}$ Hz
   The range of frequencies is between 4.00×10^{14} Hz and 7.89×10^{14} Hz. (3)
6. a) The frequency of the remote signals is:
   $f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{0.075 \text{ m}} = 4.00 \times 10^9$ Hz
   Since this frequency is less than the radio station frequency of 99.9×10^{14} Hz, there will be no interference. (2)

   b) The wavelength of the waves broadcast by Beat FM:
   $\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{99.9 \times 10^6 \text{ Hz}} = 3.00$ m
   The wavelength of the waves broadcast by Radio Nigeria 1 is:
   $\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{6.57 \times 10^5 \text{ Hz}} = 456.62$ m
   Since the wavelengths of the Radio Nigeria 1 station are larger than those of Beat FM, they can be more easily diffracted (bend) around hills and valleys and can be received in low lying areas. (3)
7. a) Infrared waves: used in optical fibres for the telecommunication industry, remote controls for electronic devices and in infrared imaging (2)
   b) X-rays: used in medical imaging, X-ray scanners and in X-ray crystallography (2)
8. Infrared waves.
   The wavelength of the waves is 20 µm = 20×10^{-6} m.
   The frequency is:
   $f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m·s}^{-1}}{20 \times 10^{-6} \text{ m}} = 1.5 \times 10^{13}$ Hz (4)
9. Microwaves are preferred to radio waves because they are not affected by the ionosphere; their smaller wavelengths result in less spreading out of the waves and less energy loss; their higher frequency allows microwaves to transmit much more information than radio waves. (3)
10. Plastic and paper contain very few molecules of water. Microwaves cause water molecules to oscillate, which generates the heat. (2)

Total marks: 40

Checklist for Self-evaluation

Theme 3 Topic 2

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Distinguish between electromagnetic waves and mechanical waves.					
2	List the six radiations in the electromagnetic spectrum in order if increasing wavelength and increasing frequency.					
3	State some uses of electromagnetic waves.					
4	Apply the formula $v = f\lambda$ to solve simple problems relating to electromagnetic waves.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

THEME 4

Fields at rest and in motion

TOPIC 1: Gravitational field

Performance objectives

1.1 Calculate the gravitational force between two masses.
1.2 Calculate the gravitational force between two planets.
1. 3 Explain the meaning of G and show that g is the force per unit mass on the Earth's surface.
1.4 Relate Kepler's laws to the motion of the solar system.
1.5 Distinguish between natural and artificial satellites.
1.6 Explain how artificial satellites are launched.
1.7 Explain the concept of escape velocity.

Introduction

Calculating a person's weight by using the masses of the earth and the person and the universal gravitational constant, is a highly satisfying exercise when students have learnt to perform the necessary manipulations. The solar system, and the question of life on other planets, makes a compelling area of discussion for most young people.

Activity 4.1 Gravitational force

INDIVIDUAL (SB p. 36)

Guidelines

Students calculate the force of attraction between Mars and Earth, when the two planets are in opposition (that is, nearest to each other). They should be able to do this individually, but you may decide to let them do the calculation in pairs.

Students are given the relevant information: the value of G (6.673×10^{-11} $N \cdot m^2 \cdot kg^{-2}$), the mass of Mars: 6.42×10^{23} kg, the mass of Earth: 6×10^{24} kg, and the separation between them in opposition: 54.6×10^6 km.

Students may need to be reminded to check that their units are correct (they must be S.I. units). This will mean changing the distance to the equivalent value in metres. They should know how to make the conversion by adjusting the power function appropriately: 10^6 km to 10^9 m.

Answer

The magnitude of the force is 8.8×10^{16} newtons.

Activity 4.2 Gravitational force on you

INDIVIDUAL (SB p. 37)

Guidelines

Students are asked to calculate their own body weight by calculating the force of attraction between themselves and the centre of the earth. (They should of course realise that this is what they are calculating. They should not need to be reminded that weight is a force, and the gravitational attraction between a body and the earth is the weight of the body.)

For a body of mass 60 kg the force of attraction to earth is about 605 N.

Answer

They should realise that they can check their result by dividing the force by 9.8 and arriving at their mass in kg. If they get it correct they should find the exercise very satisfying.

Activity 4.3 Launching satellites

PAIR/GROUP (SB p. 44)

Resources

Guidelines

This is a 'think about it' activity.

The point about launching satellites from places near the equator is that the surface speed of the planet is highest at the equator, thus a rocket leaving Earth in the equatorial region will have a big advantage in the speed with which it is already moving. In fact the surface of Earth, on the equator, is moving at about 1 670 $km{\cdot}h^{-1}$ – simply due to Earth's rotation. You might ask the students whether the launch should be in an easterly or a westerly direction. If they need help, ask them in which direction the Earth revolves on its axis. The answer is that our planet turns towards the east (which is why the sun rises in the east), and the rocket would need to be launched in that direction so that the Earth's rotational speed helps it. If the rocket were launched in a westerly direction, the rocket's own speed in that direction would cancel some of Earth's rotational speed.

How are you doing?

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

celestial bodies – Bodies in the sky, such as stars and planets

fusion – In atomic physics, fusion is the 'sticking together' of two or more atomic nuclei to produce a single nucleus. The mass of the fusion nucleus is slightly less than the sum of the masses of the nuclei from which it is formed. The mass difference is released as an enormous amount of energy

Kuiper belt – A belt of particles (some very large) orbiting the Sun at a great distance – beyond Neptune's orbit. Some comets are believed to have left the Kuiper belt and taken on flattened orbits, which carry them close to the Sun

Oort cloud – A belt, or cloud, of solid matter orbiting the Sun at a great distance, similar to the Kuiper belt, but even further away from the Sun. Some comets may have been displaced from the Oort belt and taken on long, flattened orbits passing near the Sun

Practice test: Answers

(SB p. 46)

1. Copernicus put forward the idea, based on observational evidence, that Earth and other planets revolve around the sun. This is known as the heliocentric model of the solar system. (2)
2. 'Heliocentric' means 'sun at centre'. (2)
3. 'Geocentric' means 'Earth at centre'. It was widely believed, in the middle ages, and the Church taught, that the sun and all other celestial bodies revolved around the Earth: a geocentric model. (2)
4. Every body in the universe attracts every other body with a force directly proportional to the product of their masses, and inversely proportional to the square of the distance between them. (5)
   $F \propto \frac{m_1 m_2}{d^2}$
5. The sun is a Population l star. It is also a G-type star, and is further categorised as a yellow dwarf. (2)
6. Population ll stars are the first to have formed in the young universe. When Population ll stars reached the end of their lives and exploded, they distributed various heavy atoms through surrounding space. (These heavy atoms were produced inside the Population ll stars, due to the immense temperatures and pressures.) Population l stars were formed after the Population ll stars, and contain some of the atoms that were produced inside the Population ll stars. (2)
7. The immense pressure and temperature inside the Sun causes the nuclei of hydrogen atoms to combine, to form helium nuclei. This process causes some mass to be turned directly into energy. Even a very small amount of mass releases an enormous amount of energy when it is destroyed. (4)
8. A dwarf planet does not have a strong enough gravity field (because it is not massive enough) to have swept its orbital path clear of chunks of matter. Pluto, Eris and Ceres are dwarf planets. (4)
9. An 'astronomical unit' is a distance unit used for distances within the solar system. It is the average distance between Earth and the Sun, and is defined as 150 million km. In S.I. units this is 1.496×10^{11} metres. (2)
10. Comets are believed to come from two parts of the solar system. One is a belt of small bodies, known as the Kuiper belt. This belt lies beyond the orbit of Neptune. Another source of comets is the Oort cloud, which is a spherical cloud of small bodies at the outermost edge of the solar system. (2)
11. The most famous comet is Halley's comet. Its period is about 76 years. (2)
12. Kepler's first law of planetary motion states that the orbits of planets are ellipses. (3)

Total marks: 32

Checklist for Self-evaluation

Theme 4 Topic 1

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Calculate the gravitational force between two masses.					
2	Calculate the gravitational force between two planets.					
3	Explain the meaning of G and show that g is the force per unit mass on the Earth's surface.					
4	Relate Kepler's laws to the motion of the solar system.					
5	Distinguish between natural and artificial satellites.					
6	Explain how artificial satellites are launched..					
7	Explain the concept of escape velocity.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 2: Electric field	
Performance objective	
2.1	Identify all the components parts of simple cells and accumulators.
2.2	Solve problems involving series and parallel connections of resistors and cells.
2.3	Convert a galvanometer to an ammeter and to a voltmeter.
2.4	State the factors on which the resistance of a wire depends.
2.5	State and demonstrate the conditions for a balanced Wheatstone bridge and deduce the condition for the balance metre bridge circuit.
2.6	Explain the basic principle of the potentiometer circuit.
2.7	Explain the behaviour of charges or charge carriers in liquids and gases in the electric field.
2.8	Describe an application each of electrical conduction through liquids and gases.
2.9	Calculate the electric force between two charges.
2.10	Explain electric field intensity and electric potential.
2.11	Explain the word 'capacitance'.
2.12	Calculate the equivalent capacitance for series and parallel arrangements of capacitors.
2.13	Determine the energy stored in a capacitor.

Introduction

This topic is a continuation of that done in Senior Secondary on charges at rest and charges in motion. It is therefore important that the teacher reviews these concepts before teaching this topic. We start this topic by looking at the structure of cells and batteries and then proceed to circuits containing cells and resistors. Although the syllabus does not specifically mention emf and internal resistance, these two are essential components of any discussion on electric circuits. The students are taught how to convert galvanometers into ammeters and voltmeters, and then the concept of resistivity and factors affecting resistance are revisited. The principles involving meter bridges and potentiometers are then discussed. Conduction in gases and liquids is briefly discussed before charges at rest are revisited. The interaction between charges via forces and fields is then brought to the attention of the students. This topic concludes with introducing the concept of capacitors and capacitance, which play an important part in all electronic equipment.

Activity 4.4 Cells in series and parallel

GROUP (SB p. 49)

Resources

Three similar cells, each 1.5 V, conducting leads, a voltmeter

Guidelines

It is important that all the cells used in this activity are similar in that they have the same emf and internal resistance. The equivalent emf of cells connected in series is the sum of the individual emfs, whilst the equivalent emf of cells connected in parallel is the individual emf of any of the cells. It will be useful to get the students to connect the cells in series with one of the cells connected the other way around (positive terminal of one cell connected to the positive terminal of a neighbouring cell) to observe the effect on the net emf. (The emfs of two such cells will cancel each other.)

Activity 4.5 Resistors in series and parallel

GROUP (SB p. 50)

Resources

Three resistors of different resistances, a 6 V battery, connecting wires, a switch, an ammeter, a voltmeter

Guidelines

The results of this activity will depend upon how accurately the students read the ammeter and voltmeter. Do not allow the current to be switched on for too long to minimise heating affects.

Activity 4.6 Determining the temperature coefficient of resistance of copper

GROUP (SB p. 60)

Resources

A small-diameter insulated copper wire of approximate length 0.4 m, an ammeter, a voltmeter, a 6 V battery, connecting wires, a rheostat, a beaker of water, a test tube of oil, a three-holed rubber stopper, a retort stand, wire gauze, and a Bunsen burner. Any other wire besides copper can be used for this activity.

Guidelines

Note that the oil used must be transparent in order to clearly read the thermometer. It is important that the oil and coil reach equilibrium with each other before the readings are taken. As an alternative to using a coil in a test tube of oil, the teacher can use the coiled wire of a joule calorimeter and a beaker of distilled water. If time permits, a second set of readings can be taken as the water (and oil) cools.

Answers

Some sources of error could be: errors in reading the ammeter and voltmeter, the temperature of the oil not being the same as that of the coiled wire, inaccuracies in temperature readings.

Activity 4.7 Determining the resistance of a resistor using a metre bridge

GROUP (SB p. 63)

Resources

A metre bridge with accessories, a 2 V battery, connecting wires, a standard resistor, a resistor of unknown resistance, two key switches, a centre-zero galvanometer, a rheostat, digital multimeter or ohmmeter

Guidelines

If your school does not have a resistance box of standard resistors, you can use a carbon film resistor whose resistance is close to that of the unknown resistance. The resistance of the standard resistor can be determined accurately with the aid of a digital multimeter or an ohmmeter. The unknown resistor can also be a carbon film resistor with a masking tape used to conceal its colour code.

The resistor connected in series with the galvanometer is essential to protect the galvanometer when the students are searching for the null point of the current. Ensure that this resistor is removed when the actual length of the metre is being determined. You can determine more than one reading for the unknown resistance, by varying the standard resistance.

Some sources of error in this experiment could be: heating of slide wire, errors in reading the length of the wire.

The following website gives an account of the metre bridge and how to use it:

https://www.youtube.com/watch?v=OWIpKd3FWUU.

Activity 4.8 Determining the emf of a cell using a slide-wire potentiometer

GROUP (SB p. 66)

Resources

A slide-wire potentiometer with metre rule, a 6 V battery, connecting wires, a standard cell, a cell of unknown emf, two key switches, a centre-zero galvanometer, a rheostat

Guidelines

The sources of error are similar to that of Activity 6.4.

The following websites give an account of the slide-wire potentiometer and how to use it:

https://www.youtube.com/watch?v=OF9UmZIeJlE

https://www.youtube.com/watch?v=UfujxxYo1f8

Activity 4.9 Conduction of electricity by liquids

GROUP (SB p. 67)

Resources

A 6 V battery, two carbon electrodes, a light bulb and holder, an ammeter, connecting wires, distilled water, salt solution, sugar solution, vinegar, dilute hydrochloric acid, paraffin, lemon juice, alcohol

Guidelines

If the light bulb is of high voltage it may not light up for some of the liquids, but the ammeter will indicate if the liquid is a conductor. Use as many liquids as you have available to test for conduction. Determine a value of the current to use for classification into types of electrical conductors.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

accumulator – A device for storing electricity, consisting of one or more secondary cells

alkaline cell – A primary cell in which the cathode is manganese dioxide and the anode is zinc, with the electrolyte being a potassium hydroxide paste

anode – The positive electrode of an electrolytic cell or discharge tube, but the negative electrode of an electrical cell or battery

cathode – The negative electrode of an electrolytic cell or discharge tube, but the positive electrode of an electrical cell or battery

cathode ray tube (CRT) – An electronic tube shaped like a funnel. It enables electrical signals to be displayed on a fluorescent screen and consists of an electron gun directing a beam of cathode rays (electrons) onto the screen

cathode rays – A stream of fast-moving electrons emitted from the cathode of a discharge tube or vacuum tube

dielectric constant – A constant which relates the capacitance of a vacuum filled capacitor to the capacitance of the same capacitor with a dielectric between its plates

electrochemical equivalent – The mass of an element liberated during electrolysis by one coulomb of charge

electrolysis – The positive cations and negative anions move towards the cathode and anode respectively, where substances are either deposited or liberated when the ions give up their electric charges by gaining or losing electrons

electrolyte – A liquid or molten solid that is able to conduct an electric current when the terminal of a battery are placed in it

electroplating – The depositing of a metal coating on the cathode of a cell during electrolysis

equivalent resistance The single resistor that effectively replaces two or more resistors in an electrical circuit

fluorescence – The emission of light by atoms in the coating of a Crookes's tube returning to the ground state after being excited by cathode rays in tube

galvanometer – A sensitive instrument for detecting and measuring very small electric currents

metre bridge – A simplified Wheatstone bridge that uses a standard resistor and a uniform wire connected to a cell via a galvanometer to determine the resistance of an unknown resistor

permittivity of free space – The ability of vacuum to sustain a magnetic field

potentiometer – A simplified Wheatstone bridge that uses a standard cell and a uniform wire connected to a driver cell via a galvanometer to determine the emf of an unknown cell

primary cell – An energy storage device that converts chemical energy into electrical energy, which cannot be recharged after use

resistivity – A property of an electrical conductor indicating the amount of resistance offered to current flow through the conductor

secondary cell – An energy storage device that converts chemical energy into electrical energy, which can be recharged for use again

shunt resistor – The resistor of very small resistance used in parallel with an a galvanometer to convert the galvanometer into an ammeter

superconductor – A conductor that has zero resistance at temperatures above zero kelvin

temperature coefficient of resistance – The constant that relates the resistance of a conductor at a particular temperature to the resistance of the same conductor at a reference temperature

terminal potential difference (terminal voltage) – The potential difference between the terminals of a real battery or cell when it is delivering current to a load

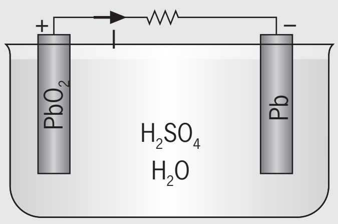
voltameter – A cell with an electrolyte connected to the terminals of a battery

Wheatstone bridge – A circuit containing three known resistors which are used with a galvanometer to determine the resistance of a fourth unknown resistor

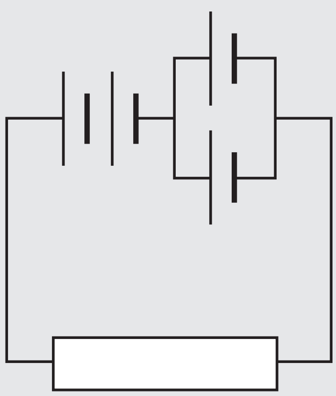
zinc chloride cell – A primary cell in which the cathode is manganese dioxide and the anode is zinc with the electrolyte being an ammonium chloride paste

Practice Test: Answers (SB p. 89)

1. 1.1 A
   1.2 D
   1.3 D
   1.4 D
   1.5 A
   1.6 C
   1.7 B
   1.8 C
   1.9 D
   1.10 A
   1.11 D
   1.12 C
   1.13 C
   1.14 B
   1.15 D
   1.16 C
   1.17 B
   1.18 C
   1.19 C
   1.20 A (40)
2. A lead accumulator cell has a negative anode made of lead metal and a positive cathode made of lead dioxide. The electrolyte is a mixture of sulphuric acid and water. The lead dioxide reacts with the sulphuric acid with electrons being removed and the electrode becoming positive. The lead reacts with the sulphuric acid with electrons being added and the electrode becoming negative. These reactions use up chemical energy. The electrons move through the external circuit because of the conversion of the chemical energy into electrical energy. (5)



3.



a) The total emf is given by

$\varepsilon_{total} = \varepsilon_{series} + \varepsilon_{parallel}$
$= (2\text{ V} + 2\text{ V}) + 2\text{ V} = 6\text{ V}.$

The total internal resistance is:

$r_{total} = r_{series} + r_{parallel}$
$= (1\ \Omega + 1\ \Omega) + (\frac{1}{1\ \Omega} + \frac{1}{1\ \Omega})^{-1}$
$= 2.5\ \Omega$

The total resistance in the circuits is:

$R_{total} = 3.5\ \Omega + 2.5\ \Omega = 6.0\ \Omega$

The current that flows through the resistor is:

$I = \frac{\varepsilon_{total}}{R_{total}} = \frac{6\text{ V}}{6.0\ \Omega} = 1\text{ A}$

The current through the series cells will be 1 A and through each of the parallel cells will be 0.5 A. (5)

b) The resistance of the light bulb:

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

$R = \frac{V^2}{P} = \frac{(6\text{ V})^2}{10\text{ W}} = 3.6\ \Omega$

The current that must pass through the bulb for maximum brightness is:

$I = \frac{V}{R} = \frac{6\text{ V}}{3.6\ \Omega} = 1.667\text{ A}$

The total resistance of the circuit with the light bulb is:

$R_{total} = 3.6\ \Omega + 2.5\ \Omega = 6.1\ \Omega$

The current through the light bulb will be:

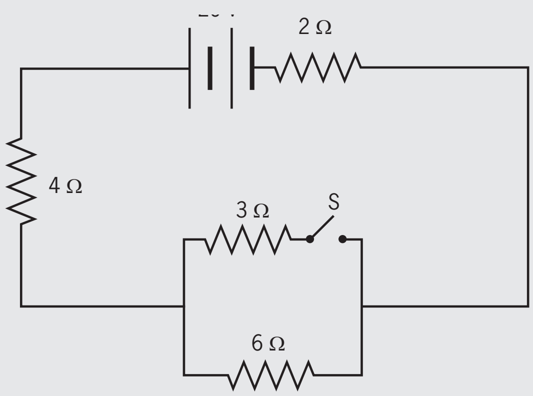
$I = \frac{\varepsilon_{total}}{R_{total}} = \frac{6\text{ V}}{6.1\ \Omega} = 0.984\text{ A}$

Since this current is less than the required current, the bulb will not burn at its maximum brightness. (3)

Alternate solution:

The p.d. required for maximum brightness is 6 V. The emf of the battery is 6 V, and the terminal p.d. is always less than the emf, and thus the p.d. across the light bulb (terminal p.d.) will be less than the required 6 V for maximum brightness.

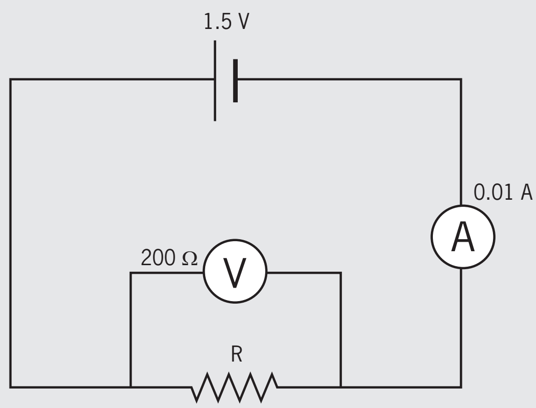
4. a) When the switch S is open:



The total resistance of the circuit is:
$R_{total} = 6\ \Omega + 4\ \Omega + 2\ \Omega = 12\ \Omega$
The current is given by:
$I = \frac{\varepsilon}{R_{total}} = \frac{20\ \text{V}}{12\ \Omega} = 1.67\ \text{A}$ (3)

b) When the switch is closed:
The total resistance of the circuit is:
$R_{total} = (\frac{6\ \Omega \times 3\ \Omega}{6\ \Omega + 3\ \Omega}) + 4\ \Omega + 2\ \Omega = 8\ \Omega$
The current is given by:
$I = \frac{\varepsilon}{R_{total}} = \frac{20\ \text{V}}{8\ \Omega} = 2.5\ \text{A}$ (3)

5. In this problem, the current through the voltmeter cannot be ignored because the voltmeter has a relatively small resistance.

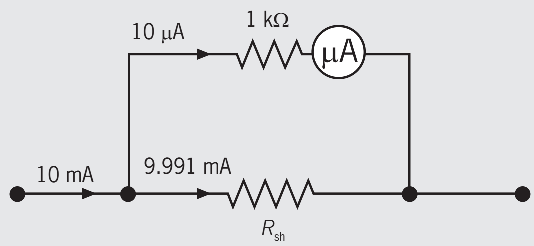


a) The p.d. across the voltmeter is 1.5 V and the current through the voltmeter is:
$I = \frac{V}{R_{voltmeter}} = \frac{1.5\ \text{V}}{200\ \Omega} = 0.0075\ \text{A}$
The current through R is
$IR = 0.01\ \text{A} - 0.0075\ \text{A} = 0.0025\ \text{A}$
The value of R is:
$R = \frac{V}{IR} = \frac{1.5\ \text{V}}{0.0025\ \text{A}} = 600\ \Omega$ (4)

b) The voltmeter would read the emf of the cell, which is 1.5 V and the reading on the ammeter will be:
$I = \frac{V}{R_{total}} = \frac{1.5\ \text{V}}{800\ \Omega} = 0.0019\ \text{A}$ (2)

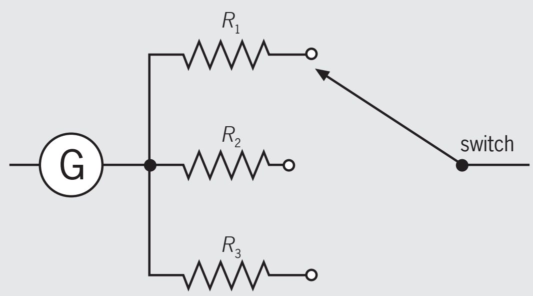
6. Let the emf and internal resistance of the cell be ε and r respectively. With the 6 Ω wire:
$I = \frac{\varepsilon}{R_{total}} = \frac{\varepsilon}{6\ \Omega + r} = 1.5\ \text{A}$
$\varepsilon = 0.5\ \text{A}(6\ \Omega + r)$ equation 1
With the second wire:
$I = \frac{\varepsilon}{R_{total}} = \frac{\varepsilon}{6\ \Omega + 8\ \Omega + r} = 0.25\ \text{A}$
$\varepsilon = 0.4\ \text{A}(14\ \Omega + r)$ equation 2
Equating the two equations:
$0.5\ \text{A}(6\ \Omega + r) = 0.25\ \text{A}(14\ \Omega + r)$
$r = 2\ \Omega$ and $\varepsilon = 4\ \text{V}$ (5)

7. The circuit diagram is as follows:



From the diagram:
$10\ \mu\text{A} \times 1\ \text{k}\Omega = 9.991\ \text{mA} \times R_{sh}$
$10 \times 10^{-6}\ \text{A} \times 1 \times 10^{3}\ \Omega$
$= 9.991 \times 10^{-3}\ \text{A} \times R_{sh}$
$R_{sh} = 1.00\ \Omega$ (4)

8. For R_1:



$1\ \text{mA} \times R_1 + 1\ \text{mA} \times 10\ \Omega = 1\ \text{V}$
$1 \times 10^{-3}\ \text{A} \times (R_1 + 10\ \Omega) = 1\ \text{V}$
$R_1 = 990\ \Omega$
For R_2:
$1\ \text{mA} \times R_2 + 1\ \text{mA} \times 10\ \Omega = 10\ \text{V}$
$1 \times 10^{-3}\ \text{A} \times (R_2 + 10\ \Omega) = 10\ \text{V}$
$R_2 = 9\ 990\ \Omega$

For R_3:

$1 \text{ mA} \times R_3 + 1 \text{ mA} \times 10\ \Omega = 100$ V

1×10^{-3} A $\times (R_3 + 10\ \Omega) = 100$ V

$R_3 = 99\,990\ \Omega$ (6)

9. For the first wire, the resistance is:

$A = \pi r^2 = \pi \frac{d^2}{4} = \pi \frac{(0.44 \text{ mm})^2}{4}$

$R = \rho \frac{L}{\text{A}} = \rho \frac{2.0 \text{ m}}{\pi \frac{(0.44)^2}{4}}$

$\rho \frac{2.0 \text{ m}}{\pi \frac{(0.44 \text{ mm})^2}{4}} = 8\ \Omega$ equation 1

For the second wire, the resistance is:

$A' = \pi r'^2 = \pi \frac{d'^2}{4} = \pi \frac{(0.3 \text{ mm})^2}{4}$

$R' = \rho \frac{L'}{\text{A}'} = \rho \frac{1.5 \text{ m}}{\pi \frac{(0.3 \text{ mm})^2}{4}}$

$R' = \rho \frac{1.5 \text{ m} \times 4}{\pi (0.3 \text{ mm})^2}$ equation 2

Dividing the two equations, we have:

$\frac{R'}{8\ \Omega} = \frac{\rho \frac{1.5 \text{ m} \times 4}{\pi (0.3 \text{ mm})^2}}{\rho \frac{2.0 \text{ m} \times 4}{\pi (0.44 \text{ mm})^2}}$

$R' = 12.91\ \Omega$ (3)

10. a) $R(T) = R_0 + \alpha(T - T_0)R_0$

$= 10\ \Omega + 0.0045\ (°\text{C})^{-1}$
$(25\ °\text{C} - 11.5\ °\text{C})\ 10\ \Omega$

$= 10.61\ \Omega$ (2)

b) $\rho = \frac{1}{1.90 \times 10^7\ (\Omega\text{m})^{-1}}$

$= 5.263 \times 10^{-8}\ \Omega$m

$A = \pi r^2 = \pi \frac{d^2}{4} = \pi \frac{0.1 \times 10^{-3} \text{ m})^2}{4}$

$= 7.854 \times 10^{-9}$ m^2

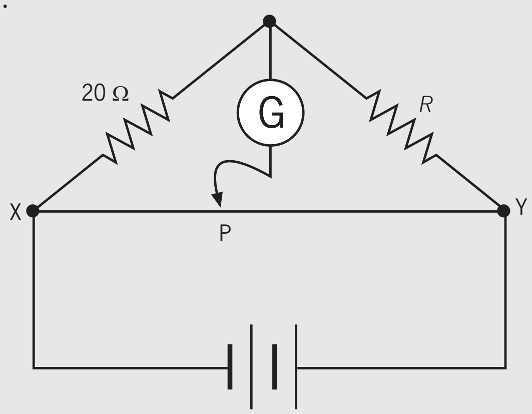
From $R = \rho \frac{L}{A}$ the length of the wire is then:

$L = \frac{RA}{\rho} = \frac{10.61\ \Omega \times 7.854 \times 10^{-9} \text{ m}^2}{5.263 \times 10^{-8}\ \Omega\text{m}}$

$= 1.58$ m (3)

c) $I = \frac{V}{R} = \frac{1.5 \text{ V}}{10.61\ \Omega} = 0.14$ A (1)

11.



For zero current in galvanometer:

$V_{20\Omega} = V_{XP}$

$I_{20\Omega} \times 20\ \Omega = I_{XP} \times \rho \frac{L_{XP}}{A}$

$= I_{XP} \times \rho \frac{32.4 \text{ cm}}{A}$ equation 1

$V_R = V_{PY}$

$I_R \times R = I_{PY} \times \rho \frac{L_{PY}}{A}$

$= I_{PY} \times \rho \frac{(100 - 32.4) \text{ cm}}{A}$ equation 2

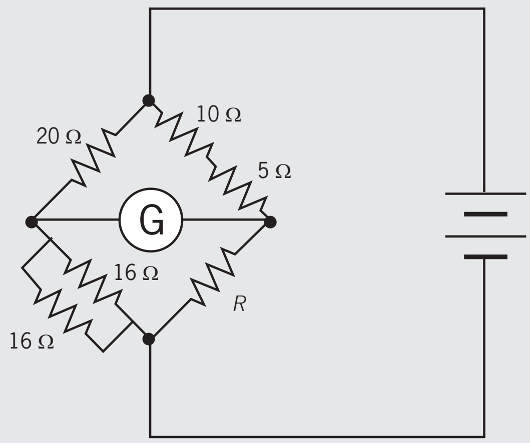
Dividing equation (2) by (1), we have:

$\frac{I_R \times R}{I_{20\Omega} \times 20\ \Omega} = \frac{I_{PY} \times \rho \frac{67.6 \text{ cm}}{A}}{I_{XP} \times \rho \frac{32.4 \text{ cm}}{A}}$

But $I_R = I_{20\Omega}$ and $I_{PY} = I_{XP}$, and we get:

$R = 41.73\ \Omega$ (4)

12.



We first determine the equivalent resistances of the multiple resistors in the two branches of the Wheatstone network.

$R_1 = 10\ \Omega + 5\ \Omega = 15\ \Omega$

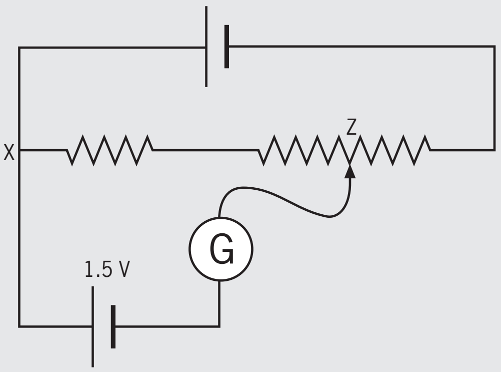
$R_2 = \left(\frac{16\ \Omega \times 16\ \Omega}{16\ \Omega + 16\ \Omega}\right) = 8\ \Omega$

Using the Wheatstone bridge formula, we have:

$\frac{R}{15\ \Omega} = \frac{8\ \Omega}{20\ \Omega}$

$R = 6\ \Omega$ (5)

13.



a) When the bridge is balanced for the known emf, we have:

$V_{XZ} = 1.5$ V

$\Rightarrow IR_{XZ} = 1.5$ V

$\Rightarrow I\frac{\rho L_{XZ}}{A} = 1.5$ V

$\Rightarrow I\frac{\rho \times 37.5\text{ cm}}{A} = 1.5$ V equation 1

When the bridge is balanced for the unknown emf, we have

$V_{XZ} = \varepsilon_X$

$\Rightarrow IR_{XZ} = \varepsilon_X$

$\Rightarrow I\frac{\rho L_{XZ}}{A} = \varepsilon_X$

$\Rightarrow I\frac{\rho \times 75\text{ cm}}{A} = \varepsilon_X$ equation 2

Dividing equation (2) by (1), we have:

$\varepsilon_X = \frac{75\text{ cm}}{37.5\text{ cm}} \times 1.5\text{ V} = 3.0\text{ V}$ (4)

b) When the bridge is balanced for the standard cell with the additional 1 Ω resistance we have:

$IR_{XZ} = 1.5$ V

$\Rightarrow \frac{4.0\text{ V}}{1.0\ \Omega + R_{XY}} R_{XY} = 1.5$ V,

where R_{XY} is the resistance of the full length wire XY.

$\Rightarrow \frac{4.0\text{ V}}{1.0\ \Omega + 4.0\ \Omega} R_{XZ} = 1.5$ V,

$R_{XZ} = 1.5\text{ V} \times \frac{5}{4}\ \Omega = 1.875\ \Omega$

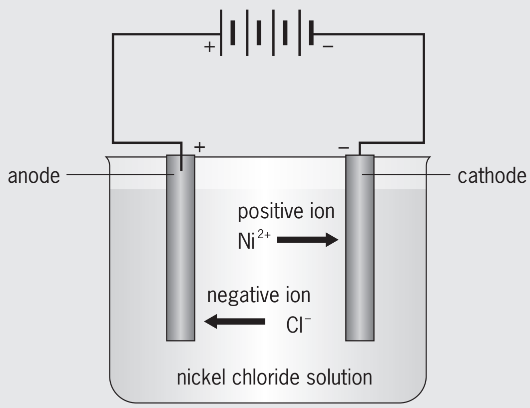
The length L_{XZ} is then given by:

$L_{XZ} = \frac{R_{XZ}}{R_{XY}} \times L_{XY}$

$= \frac{1.875\ \Omega}{4.0\ \Omega} \times 100$ cm

$= 46.9$ cm (4)

14. a) The diagram of the voltameter is shown below.



(3)

b) $m = zQ = zIt = 3.027 \times 10^{-4}$ g/C $\times 2.0\text{ A} \times 5 \times 60\text{ s} = 0.181$ g (2)

c) $m = zQ = zIt = 3.027 \times 10^{-4}$ g/C $\times 2.0\text{ A} \times 1 \times 60 \times 60\text{ s} = 2.179$ g (2)

Volume of nickel deposited is:

$V = \frac{m}{\rho} = \frac{2.179 \times 10^{-3}\text{ kg}}{8908\text{ kg/m}^3}$

$= 2.446 \times 10^{-7}\text{ m}^3$

The volume is also given by:

$V = l \times b \times t$

The thickness, t, is then given by:

$t = \frac{V}{l \times b} = \frac{2.446 \times 10^{-7}\text{ m}^3}{0.1\text{ m} \times 0.05\text{ cm}}$

$= 4.89 \times 10^{-5}\text{ m} = 0.0489$ mm (4)

d) Electroplating (1)

15. From Faraday's second law of electrolysis:

$$\frac{\text{mass of copper deposited}}{\text{mass of silver deposited}} = \frac{\dfrac{\text{relative atomic mass of copper}}{\text{valency of copper}}}{\dfrac{\text{relative atomic mass of silver}}{\text{valency of silver}}}$$

$$\Rightarrow \frac{\text{mass of copper deposited}}{2\text{ g}} = \frac{\frac{63\text{ g}}{2}}{\frac{108\text{ g}}{1}}$$

$= 0.583$ g (3)

16. a) The heater element heats the cathode, which then gives off electrons that form the electron beam. (1)

b) The anode accelerates the electrons towards the screen. (1)

c) When the plate D is made positive with respect to C, the spot on the screen is shifted vertically upward. When the plate D is made negative with respect to C, the spot on the screen is shifted vertically downward. (2)

d) When the plate A is made positive with respect to B, the spot on the screen is shifted horizontally to the left. When the plate A is made negative with respect to B, the spot on the screen is shifted horizontally to the right. (2)

e) The discharge tube has a gas under low pressure, while the CRT is evacuated; both ions and electrons are accelerated in a discharge tube, while only electrons are accelerated in a CRT; the direction of movement of the beam in a CRT can be controlled by deflection plates, while this is not possible in a discharge tube. (2)

17. The law states that the magnitude of the electric force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between the charges. Newton's law involves masses while Coulomb's law involves charges. In Newton's law the forces are only attractive, while in Coulomb's law the forces can be attractive or repulsive. They are similar in that both are inverse square laws relating forces to distances. (4)

18. a) $F = k\dfrac{|Q_1Q_2|}{r^2}$

$= 9 \times 10^9\ \text{N·m}^2\text{·C}^{-2}\dfrac{1.6 \times 10^{-19}\ \text{C}}{(0.053 \times 10^{-9}\ \text{m})^2}$

$= 8.2 \times 10^{-8}\ \text{N}$ (3)

b) $F = G\dfrac{m_1m_2}{r^2}$

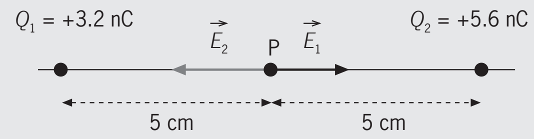
$= 6.67 \times 10^{-11}\ \text{N·m}^2\text{·kg}^{-2}\ \dfrac{1.67 \times 10^{-27}\ \text{kg} \times 9.11 \times 10^{-31}\ \text{kg}}{(0.053 \times 10^{-9}\ \text{m})^2}$

$= 3.61 \times 10^{-47}\ \text{N}$

$\dfrac{8.2 \times 10^{-8}\ \text{N}}{3.61 \times 10^{-47}\ \text{N}} = 2 \times 10^{39}$

The electrostatic force is 2×10^{39} stronger than the gravitational force. (3)

19. The diagram below shows the situation of the two charges.



We choose the direction to the left as positive.

$E_1 = k\dfrac{|Q_1|}{r_1^2}$

$= 9 \times 10^9\ \text{N·m}^2\text{·C}^{-2}\dfrac{3.2 \times 10^{-9}\ \text{C}}{(5 \times 10^{-2}\ \text{m})^2}$

$= 11\ 420\ \text{N·C}^{-1}$

$E_2 = k\dfrac{|Q_2|}{r_2^2}$

$= 9 \times 10^9\ \text{N·m}^2\text{·C}^{-2}\dfrac{5.6 \times 10^{-9}\ \text{C}}{(5 \times 10^{-2}\ \text{m})^2}$

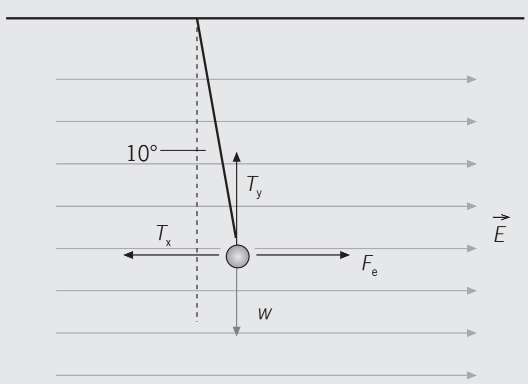
$= 20\ 160\ \text{N·C}^{-1}$

The resultant electric field is:

$E_{\text{result}} = \vec{E}_1 + \vec{E}_2 = -1.142 \times 10^4\ \text{N·C}^{-1} + 2.016 \times 10^4\ \text{N·C}^{-1} = 8.74 \times 10^3\ \text{N·C}^{-1}$

The resultant electric field is directed to the left since we took to the left as positive. (5)

20. The forces acting on the pith ball are shown in the diagram.



For equilibrium, we have:

$T_y = w$

$\Rightarrow T\cos 10° = mg$ equation 1

$T_x = F_e$

$\Rightarrow T \sin 10° = QE$ equation 2

Dividing equation (2) by (1), we have:

$$\frac{T \sin 10°}{T \cos 10°} = \frac{QE}{mg}$$

$$\Rightarrow \tan 10° = \frac{5.0 \times 10^{-6}\ \text{C} \times E}{0.5 \times 10^{-3}\ \text{kg} \times 9.8\ \text{m·s}^{-2}}$$

$$\Rightarrow E = 17.28\ \text{N·C}^{-1}$$

Since the direction of the force is the same as that of the electric field, the pith ball is positively charged. (6)

21. $V_1 = k\frac{Q}{r_1^2}$ and $V_2 = k\frac{Q}{r_2^2}$

Dividing the two equations, we have:

$$\frac{V_1}{V_2} = \frac{k\frac{Q}{r_1^2}}{k\frac{Q}{r_2^2}}$$

$$r_2 = \frac{V_1}{V_2} r_1 = \frac{5.6 \times 10^5\ \text{V}}{2.8 \times 10^5\ \text{V}} \times 45\ \text{cm}$$

$= 90$ cm (3)

22. a) A charge of 20 μC on the plates of the capacitor produces a potential difference of 1 V across the plates.
Or: the ratio of charge on the plates to the potential difference across the plates is equal to 20 micro-coulombs per volt. (1)

b) $Q = CV = 20 \times 10^{-6}\ \text{F} \times 12\ \text{V}$
$= 2.4 \times 10^{-4}$ C (1)

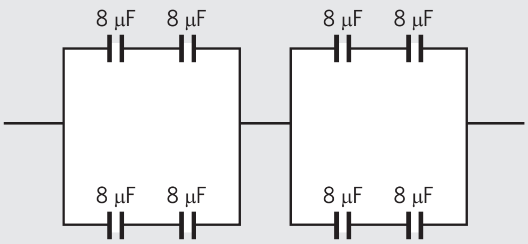
c) $W = \frac{1}{2} KCV^2$
$= \frac{1}{2} \times 1 \times 20 \times 10^{-6}\ \text{F} \times (12\ \text{V})^2$
$= 1.44 \times 10^{-3}$ J
$C' = KC = 3.7 \times 20\ \mu\text{F} = 74\ \mu\text{F}$
$Q' = C'V = 74\ \mu\text{F} \times 12\ \text{V}$
$= 888\ \mu\text{C}$ (1)

23. a) $C = \frac{Q}{V} = \frac{360 \times 10^{-12}\ \text{C}}{45\ \text{V}} = 8$ pF
$C = K\epsilon_0 \frac{A}{d} = \epsilon_0 \frac{A}{d}$
$\Rightarrow d = \epsilon_0 \frac{A}{C} = 8.85 \times 10^{-12}$
$\text{C}^2\text{·N}^{-1}\text{·m}^{-2}\ \frac{6.4 \times 10^{-4}\ \text{m}^2}{8 \times 10^{-12}\ \text{F}}$
$= 7.08 \times 10^{-4}$ m $= 0.71$ mm (3)

b) $W = \frac{1}{2} KCV^2 = \frac{1}{2} \times 1 \times 8 \times 10^{-12}$ F $\times (45\ \text{V})^2 = 8.1 \times 10^{-9}$ J (2)

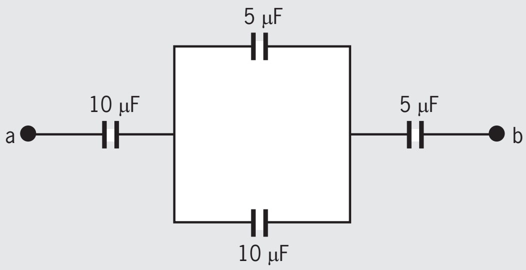
c) By doubling the distance between the plates, the capacitance is halved, and for constant charge, the p.d. must be doubled, therefore:
$V' = 90$ V or $V' = \frac{Q}{C}$
$$= \frac{360 \times 10^{-12}\ \text{C}}{\frac{1}{2} \times 8 \times 10^{-12}\ \text{F}} = 90\ \text{V}$$ (2)

24. The capacitors should be connected as follows:



Consider the first network of capacitors:
The equivalent capacitance in each of the parallel branches is 4 μF, and the equivalent of the two parallel branches is 8 μF.
The equivalent of the second network is also 8 μF.
These two networks are in series and their equivalent is 4 μF. The potential difference across each network is 500 V, and the combined p.d. is 1 000 V. (4)

25.



a) The equivalent of the two parallel capacitors:
$C_{//} = 5\ \mu\text{F} + 10\ \mu\text{F} = 15\ \mu\text{F}$
This capacitor is in series with the remaining two. Hence the equivalent capacitance of the network is given by:
$$C_{eq} = \left(\frac{1}{10\ \mu\text{F}} + \frac{1}{15\ \mu\text{F}} + \frac{1}{15\ \mu\text{F}}\right)^{-1}$$
$= 4.29\ \mu\text{F}$ (2)

b) The total charge is:

$Q = C_{eq}V_{ab} = 4.29\ \mu F \times 50\ V$

$= 214.2\ \mu C$

The p.d. across the parallel branch is:

$V_{//} = \frac{Q}{C_{//}} = \frac{214.2\ \mu C}{15\ \mu C} = 14.29\ V$

The charge on the 5.0 μF capacitor is then:

$Q_{5\mu F} = C_{5\mu F}V_{//} = 5.0\ \mu F \times 14.29\ V$

$= 71.42\ \mu C$ (3)

c) The energy stored in the 15 μF capacitor is:

$W = \frac{1}{2} K \frac{Q_2}{C}$

$= \frac{1}{2} \times 1 \times \frac{(214.2 \times 10^{-6}\ C)^2}{15 \times 10^{-6}\ F}$

$= 1.53 \times 10^{-3}\ J$ (2)

Total marks: 170

Checklist for Self-evaluation

Theme 4 Topic 2

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify all the components parts of simple cells and accumulators.					
2	Solve problems involving series and parallel connections of resistors and cells.					
3	Convert a galvanometer to an ammeter and to a voltmeter.					
4	State the factors on which the resistance of a wire depends.					
5	State and demonstrate the conditions for a balanced Wheatstone bridge and deduce the condition for the balance metre bridge circuit.					
6	Explain the basic principle of the potentiometer circuit.					
7	Explain the behaviour of charges or charge carriers in liquids and gases in the electric field.					
8	Describe an application each of electrical conduction through liquids and gases.					
9	Calculate the electric force between two charges.					
10	Explain electric field intensity and electric potential.					
11	Explain the word 'capacitance'.					
12	Calculate the equivalent capacitance for series and parallel arrangements of capacitors.					
13	Determine the energy stored in a capacitor.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 3: Magnetic fields
Performance objective
3.1 Plot the magnetic field around: • a bar magnet • a straight conductor carrying current • a solenoid. **3.2** Make a magnet from a soft iron bar. **3.3** Make an electromagnet. **3.4** Describe the working principles of an electric bell and a telephone earpiece. **3.5** Locate the Earth's magnetic north–south direction. **3.6** Explain the magnetic force on a moving charge. **3.7** State the relation between magnetic force and the motion of a charge in a magnetic field.

Introduction

This topic lends itself very well to simple but effective demonstrations and activities. The school laboratory should have several sets of bar magnets, a kilogram of iron filings and several magnetic compasses. You can appeal to students' imaginative faculties by talking about exploration of deserts and oceans, where a magnetic compass is essential to survival.

It is also important to emphasise the differences between the (electro)magnetic force and the force of gravity. Gravity is the weakest of nature's forces: the electromagnetic force is millions of times stronger. Also, gravity is an attractive force: it only pulls. The electromagnetic force is both attractive and repulsive.

Activity 4.10 Demonstrate the field around a bar magnet

PAIR (SB p. 97)

Resources

For each pair: a bar magnet, a piece of cardboard (about A4 size), a teaspoonful of iron filings, some newspaper

Guidelines

Get the pairs to cover their work surfaces with newspaper. This will aid in collecting spilt iron filings after the exercise.

The magnet is covered with the card and a small amount of iron filings is sprinkled uniformly over the card. By gently tapping the card the iron filings will move into alignment with the magnetic field.

Activity 4.11 Make a temporary magnet

PAIR (SB p. 100)

Resources

For each pair: a bar magnet, an (unmagnetised) piece of soft iron, about the same size as the bar magnet

Guidelines

The soft iron should be stroked in the same direction with each stroke. Make sure you have done this exercise satisfactorily yourself, and demonstrate it to the class before they begin.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

magnetite – A naturally-occurring magnetic substance: an oxide of iron, Fe3O4

Practice Test: Answers

(SB p. 105)

1. Magnetite is ferric oxide. (2)
2. Michael Faraday (2)
3. Hans Christian Oersted (2)
4. $F = qvB$ (3)
5. The tesla (T) (2)
6. The particle moves at 90° to the direction of the field, thus $\sin \theta = 1$, and the relevant equation simplifies to $F = qvB$.
   Thus $F = (1.60 \times 10^{-19}\ \text{C}) \times (1.7 \times 10^{5}\ \text{m·s}^{-1}) \times (20 \times 10^{-3}\ \text{T})$
   Therefore $F = 5.44 \times 10^{-16}$ N. (5)
7. $F = 9 \times 10^{-20}$ N (Force on the electron) (5)
8. a) F b) T c) T d) F (4)

Total marks: 25

Checklist for Self-evaluation

Theme 4 Topic 3

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Plot the magnetic field around: • a bar magnet • a straight conductor carrying current • a solenoid.					
2	Make a magnet from a soft iron bar.					
3	Make an electromagnet.					
4	Describe the working principles of an electric bell and a telephone earpiece.					
5	Locate the Earth's magnetic north–south direction.					
6	Explain the magnetic force on a moving charge..					
7	State the relation between magnetic force and the motion of a charge in a magnetic field.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 4: Electromagnetic field

Performance objectives

4.1 Identify the directions of current, magnetic field.
4.2 Explain the action of a loop wire carrying current in a magnetic field.
4.3 Explain the basic working principle of the galvanometer and the electric motor.
4.4 State and explain Faraday's law of electromagnetic induction.
4.5 State and explain the implications of Lenz's law.
4.6 Explain how the conversation principle is involved in both laws with regard to:
- charge
- energy.

4.7 Explain the principle underlying the production of direct and alternating current.
4.8 State the use of induction coils and transformers.
4.9 Explain why the cores of the induction coil and the transformers are laminated.

Introduction

This topic integrates Topic 2 on electricity with Topic 3 on magnetism. The students have been shown how a current can produce a magnetic field and that a force acts on a charge moving in a magnetic field. This topic discusses how the magnetic field of a current carrying conductor interacts with an external magnetic field to produce an electromagnetic force. The applications of this effect to motors and moving coil meters are then discussed. The converse effect of changing magnetic fields producing currents, known as electromagnetic induction is then explored. The applications of this to generators and induction coils is then discussed. This topic concludes with a discussion of transformers and eddy currents.

Activity 4.12 The force on a current–carrying conductor in a magnetic field

GROUP (SB p. 105)

Resources

A strip of aluminium foil of dimensions 1 cm × 15 cm, a flat cork board, pin tacks, a 6 V battery, an ammeter, a rheostat, a strong U-shaped magnet, conducting leads

Guidelines

The activity outlined in the student text uses simple material that can be easily obtained. This activity could also be conducted as illustrated by the following diagrams:

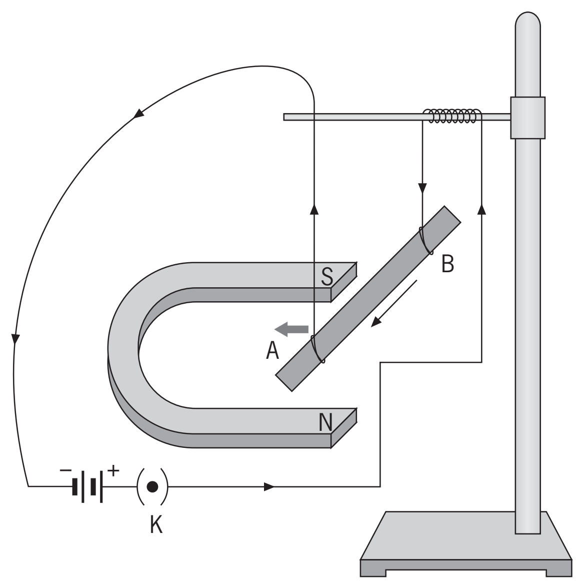


Figure A

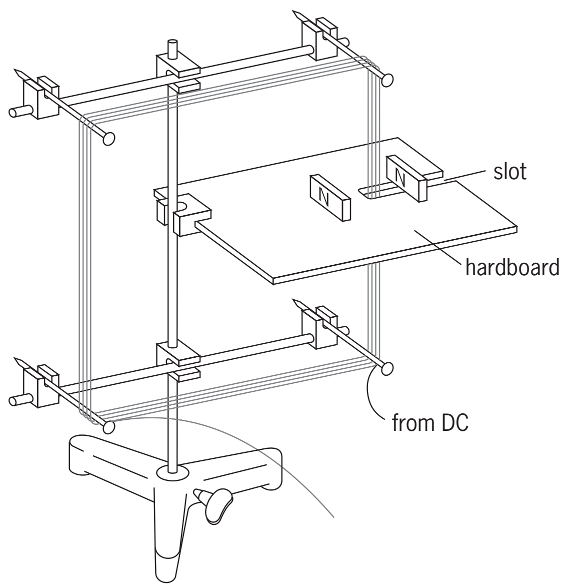


Figure B

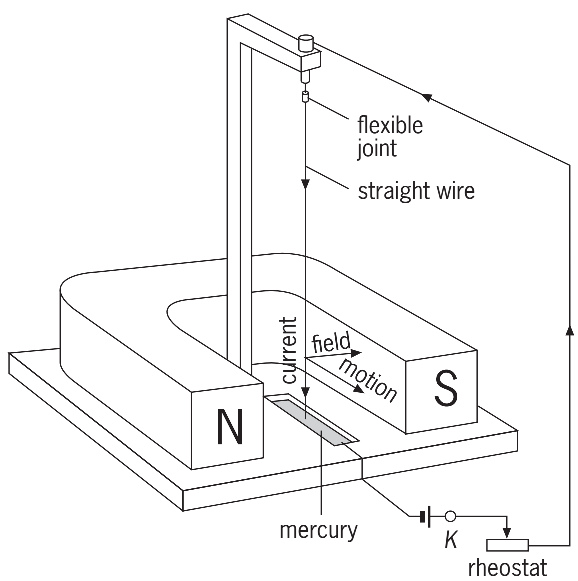


Figure C

More details about the apparatus in Figure (b) can be found at the following website:

http://www.nuffieldfoundation.org/practical-physics/catapult-magnetic-field

The following website demonstrates the force on conductor and Fleming's left hand rule

https://www.youtube.com/watch?v=vkZtsrgso2A

https://www.youtube.com/watch?v=8li1Vp8vLaI.

The following websites demonstrates the force on a conductor, but use the right hand rule:

https://www.youtube.com/watch?v=fHuhkNosSrg
https://www.youtube.com/watch?v=F1PWnu01IQg

Activity 4.13 Inducing a current

INDIVIDUAL (SB p. 112)

Resources

Two solenoids of different dimensions, a galvanometer, a magnet, a 6 V battery, a switch, conducting leads

Guidelines

The following websites are some of the many on YouTube on this section of motors and generators:

https://www.youtube.com/watch?v=8li1Vp8vLaI
www.youtube.com/watch?v=EHY_fWz3PaE.

The following links are related to this activity:

https://www.youtube.com/watch?v=S0wbEl7caTY
https://www.youtube.com/watch?v=hajIIGHPeuU
https://www.youtube.com/watch?v=KGTZPTnZBFE.

There are many videos on YouTube on Faraday's law of electromagnetic induction, generators, Lenz's law, eddy currents and transformers.

Answers

Answers to step 8 of the activity: direction and strength of the magnetic field, direction and strength of the current, length of the conductor, direction the conductor makes with the magnetic field.

https://www.youtube.com/watch?v=d_aTC0iKO68

https://www.youtube.com/watch?v=LAtPHANEfQo www.youtube.com/watch?v=elFUJNodXps

www.youtube.com/watch?v=Ux-QGhbjOA0.

Answer to step 15: A current will be induced in a solenoid/coil if:

- there is relative motion between the solenoid and a magnet
- there is a change of current in a neighbouring solenoid
- there is relative motion with a neighbouring current carrying solenoid.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

alternating current (a.c.) – An electric current that varies in strength and periodically reverses its direction

Fleming's left-hand rule – The thumb, first and second finger of the left hand are held at right angles to one another and represent the direction of motion of the conductor, magnetic field and conventional current respectively

generator (dynamo) – A machine for converting mechanical energy into electrical energy

magnetic flux – The scalar product of a magnetic field and the area vector through which the field passes

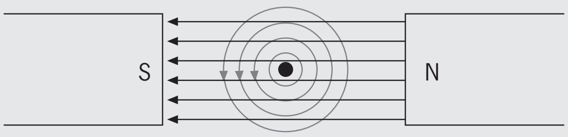
solenoid – A coil closely wound on a cylindrical insulated core

transformer – An electrical device that steps up or steps down an input a.c.

Practice test: Answers (SB p. 124)

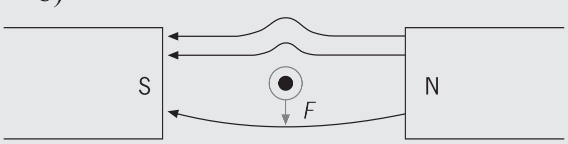
1. 1.1 C
   1.2 D
   1.3 D
   1.4 D
   1.5 B
   1.6 B
   1.7 D
   1.8 C
   1.9 A
   1.10 D
   1.11 B
   1.12 C
   1.13 D
   1.14 D (30)

2. a)



(2)

b)



(2)

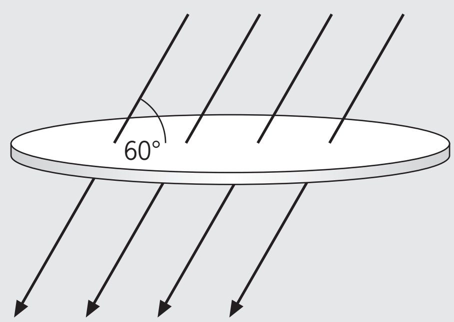
c) $bF = IB\ell \sin\theta$
$= 5\text{ A} \times 0.6\text{ T} \times 0.8\text{ m} \times \sin 90°$
$= 2.4\text{ N}$ (2)

3. The current in the wire is given by:
$I = \frac{V}{R} = \frac{6\text{ V}}{1.4\ \Omega} = 4.29\text{ A}$
The force on the wire is $F = IB\ell$, from which we get:
$B = \frac{F/\ell}{I \sin\theta} = \frac{0.9\text{ N·m}^{-1}}{4.29\text{ A} \times \sin 30°} = 0.42\text{ T}$ (4)

4. a) X is a split ring commutator, which is used to change the direction of the current in the coil.
Y is a brush, which is used to lead the current into and out of the coil. (3)
b) Downwards (1)
c) Increase the current and intensity of the magnetic field. (2)
d) It is done to confine the magnetic field to the coil. (1)

5. Only the long sides of the rectangular loop exert forces on the wire AB. The long side of the loop closest to AB exerts an attractive force on AB because the currents are in the same direction. The magnitude of this force is given by:
$F_1 = k\frac{I_1 I_2 \ell}{d_1}$
$= 2 \times 10^{-7}\text{ N·A}^{-2}\ \frac{5.0\text{ A} \times 12.0\text{ A} \times 0.20\text{ m}}{0.03\text{ m}}$
$= 8.0 \times 10^{-5}\text{ N downward}$
The long side of the loop furthest to AB exerts a repulsive force on AB because the currents are in the opposite direction. The magnitude of this force is given by:
$F_2 = k\frac{I_1 I_2 \ell}{d_1}$
$= 2 \times 10^{-7}\text{ N·A}^{-2}\ \frac{5.0\text{ A} \times 12.0\text{ A} \times 0.20\text{ m}}{0.13\text{ m}}$
$= 1.85 \times 10^{-5}\text{ N upward}$
The resultant force exerted by the loop on AB is:
$F = 8.0 \times 10^{-5}\text{ N} - 1.85 \times 10^{-5}\text{ N}$
$= 6.15 \times 10^{-5}\text{ N downward}$ (6)

6. The emf induced in the coil is:



$\varepsilon = IR = 12 \times 10^{-3}\text{ A} \times 15\ \Omega = 0.18\text{ V}$
The area of the coil is:
$A = (0.07\text{ m})^2 = 4.9 \times 10^{-3}\text{ m}^2$
From Faraday's law,
$\varepsilon = -N\frac{d\phi}{dt} = -NB\cos\theta\,\frac{dA}{dt}$
we have:
$\text{B} = -\frac{\varepsilon}{\cos\theta\,\frac{dA}{dt}}$
$= -\frac{0.18\text{ V}}{100 \times 1 \times \left(\frac{-4.9 \times 10^{-3}\text{ m}^2}{0.2\text{ s}}\right)}$
$= 0.075\text{ T}$ (4)

7. a) The angle between the normal to the coil and the magnetic field is 30°. The emf induced in the coil is:
$\varepsilon = IR = 4\ \text{A} \times 40\ \Omega = 160\ \text{V}$
The area of the coil is:
$A = \pi(0.55\ \text{m})^2 = 9.5 \times 10^{-3}\ \text{m}^2$
From Faraday's law:
$\varepsilon = -N\frac{d\phi}{dt} = -NA\cos\theta\,\frac{dB}{dt}$
we have:
$$\frac{dB}{dt} = -\frac{\varepsilon}{NA\cos\theta}$$
$$= -\frac{160\ \text{V}}{50 \times \cos 30° \times 9.5 \times 10^{-3}\ \text{m}^2}$$
$$= 3.89 \times 10^2\ \text{T·s}^{-1}$$ (4)

b) Since the magnetic field is decreasing (from the negative value in a)), the current induced in the loop is clockwise as viewed from above. (1)

8. a) When the switch is closed, the current and magnetic field in the primary solenoid (right) increase, with the left end of this solenoid being a north pole. To oppose this increase, the right end of the secondary solenoid becomes a north pole, and the current flows in a clockwise direction when looking in at the left end. Thus the current flows from A to B in the galvanometer. (3)

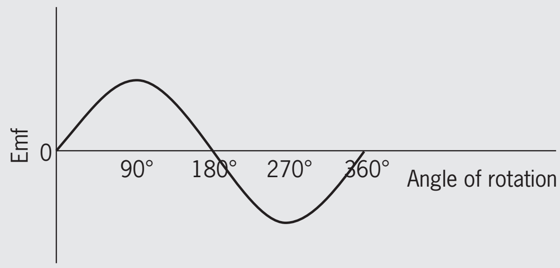
b) There is no current in the galvanometer since there is no rate of change of flux in the primary coil. (1)

c) When the switch is opened, the current and magnetic field in the primary solenoid (right solenoid) decrease, with the left end of this solenoid being a north pole. To oppose this decrease, the right end of the secondary becomes a south pole, and the current flows in an anti-clockwise direction when looking in at the left end. Thus the current flows from B to A in the galvanometer. (2)

9. a) They provide electrical contact with the brushes. (1)

b) Zero, since the rate of change of flux is zero. (2)

c) The graph is shown below: (2)



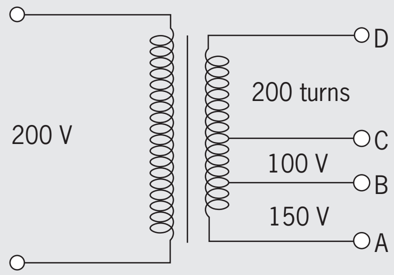
d) Increase the number of turns in the coil; increase the cross-sectional area of the coil; increase the speed of rotation of the coil. (2)

e) Replace the slip rings with a split-ring commutator. (1)

10. a) The current in the primary coil must change with time to produce a rate of change of flux in the secondary coil. The current in d.c. is constant with time, but in a.c. it changes in magnitude and direction with time. (2)

b) Lamination prevents eddy currents that cause heat and power losses. (4)

11.



Secondary coil	AB	BC	AC	AD
Primary emf, ε_p, in V	200	200	200	200
Secondary emf, ε_s in V	150	100	250	450
Secondary turns, N_s	75	50	125	225
Primary current, I_P, in A	1.125	0.5	3.125	10.125
Secondary current, I_S, in A	1.5	1.0	2.5	4.5

(8)

12. a) The function of the iron core is to become magnetised when a current is passed through the primary coil. (1)

b) The armature's function is to be attracted to the iron core when the core is magnetised, thus breaking the primary circuit. (1)

c) The capacitor's function is to prevent sparking at the contacts and to assist in the creation of the magnetic field. (1)

d) The secondary coil generates the large emf required for creating the sparks. (1)

13. a) Eddy currents are loops of current found in conducting sheets due to changes in magnetic flux in the conductors. (1)

b) Eddy currents cause power losses due to heating of the conductors. (1)

c) Eddy currents are used in braking systems, induction heating furnaces and to detect cracks and flaws in metal parts. (2)

14. In diagram A, the movement of the metal sheet of the pendulum in a magnetic field creates eddy currents. These eddy currents create opposing magnetic fields which retard the motion of the pendulum, and hence it comes to a stop rapidly. In diagram (b), the slits in the sheet of the pendulum minimise the formation of the eddy currents, and hence the pendulum swings for a longer time. (3)

Total marks: 100

Checklist for Self-evaluation

Theme 4 Topic 4

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify the directions of current, magnetic field.					
2	Explain the action of a loop wire carrying current in a magnetic field.					
3	Explain the basic working principle of the galvanometer and the electric motor.					
4	State and explain Faraday's law of electromagnetic induction.					
5	State and explain the implications of Lenz's law.					
6	Explain how the conversation principle is involved in both laws with regard to: • charge • energy.					
7	Explain the principle underlying the production of direct and alternating current.					
8	State the use of induction coils and transformers.					
9	Explain why the cores of the induction coil and the transformers are laminated.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 5: Simple a.c. circuits
Performance objectives
5.1 Explain the peak and root mean square (rms) values of current and potential difference. **5.2** Establish the phase relationship between current and potential difference in an a.c. circuit. **5.3** Explain reactance and impedance. **5.4** Determine current in circuits containing: • resistance and capacitance • resistance, inductance and capacitance. **5.5** Determine power in an a.c. circuit.

Introduction

This topic introduces the students to alternating current circuits. Alternating current plays an important part in our daily lives, with almost all the equipment at home, and in industries and businesses being plugged into the mains socket, which provides alternating current. In the previous topic we studied how alternating current is generated, while in this topic we will study how components, such as resistors and capacitors, behave in alternating current circuits. We will also introduce another electrical component called an inductor.

A new way of analysing circuits using phasors will be discussed. Finally, we will look at resonant circuits, which play an important part in devices such as radios and televisions.

There are many videos on a.c., and the following link is one of a series:

https://www.youtube.com/watch?v=FrR

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

impedance – The total effective resistance provided by a resistor, capacitor and inductor connected in an alternating current circuit

inductance – The inductance of a coil is a constant that relates the emf induced in the coil to the rate of change of current in the coil

inductive reactance – The resistance offered by an inductor to the change of current in it

leads – A physical quantity, such as an a.c. current, is said to lead another physical quantity if its phase angle is ahead of that quantity

peak potential difference – The maximum value of an alternating potential difference

phasor – A phasor is a rotating vector whose length is proportional to the peak value of the electrical quantity it represents

power factor – Is the cosine of the phase angle in an a.c. circuit

resonant frequency – The frequency at which the capacitive impedance is equal to the inductive impedance in a RLC a.c. circuit

self-induction – The process whereby an emf is induced in a coil due to the current in the changing with time

Practice test: Answers

(SB p. 143)

1.

1.1 B	1.2 D	1.3 C	
1.4 A	1.5 B	1.6 B	
1.7 D	1.8 A	1.9 B	
1.10 A	1.11 A	1.12 D	
1.13 C	1.14 D	1.15 D	(30)

2. $I_{rms} = \frac{P_{av}}{V_{rms}} = \frac{60\text{ W}}{240\text{ V}} = 0.25\text{ A}$

   $I_p = \sqrt{2} \times I_{rms} = 0.35\text{ A}$ (3)

3. The rms current in the loudspeaker is given by:

   $I_{rms} = \frac{V_{rms}}{R_{eq}} = \frac{15\text{ V}}{9.6\ \Omega + 8.5\ \Omega} = 0.829\text{ A}$

   The average power delivered to the speaker is then:

   $P_{av} = (I_{rms})^2R = (0.929\text{ A})^2 \times 9.6\ \Omega$

   $= 6.59\text{ W}$ (4)

4. $I_p = \omega CV_p$

   $= 2\pi fC\sqrt{2} \times V_{rms}$

   $= 2\pi \times 50\text{ Hz} \times 50 \times 10^{-6}\text{ F} \times \sqrt{2} \times 100\text{ V}$

   $= 2.22$ (3)

5. $I_{rms} = \frac{V_{rms}}{X_L} = \frac{V_{rms}}{2\pi fL}$

   $\Rightarrow \text{L} = \frac{V_{rms}}{2\pi fI_{rms}} = \frac{240\text{ V}}{2\pi \times 50\text{ Hz} \times 12.8\text{ A}}$

   $= 0.6\text{ H}$ (3)

6. a) The inductive capacitance is:

   $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

   $= \frac{1}{2\pi \times 400\text{ Hz} \times 12 \times 10^{-6}\text{ F}}$

   $= 33.16\ \Omega$

   The impedance is then given by:

   $Z = \sqrt{R^2 + X_C^2}$

   $= \sqrt{(150\ \Omega)^2 + (33.16\ \Omega)^2}$

   $= 153.62\ \Omega$

   $I_{rms} = \frac{V_{rms}}{Z} = \frac{200\text{ V}}{153.62\ \Omega} = 1.30\text{ A}$

   The peak current is given by:

   $I_p = \sqrt{2} \times I_{rms} = 1.84\text{ A}$ (3)

   b) The average power delivered by the source is same as that delivered to the resistor, and is given by:

   $P_{av} = (I_{rms})^2R = (1.84\text{ A})^2 \times 150\ \Omega$

   $= 508.5\text{ W}$ (2)

7. From $V_R = 40.0\text{ V} \sin((700\ \frac{\text{rad}}{s})t)$, we obtain:

   $V_p = 40.0\text{ V}$, $\omega = 700\frac{\text{rad}}{s}$

   a) The inductive reactance is:

   $X_L = \omega L = 700\frac{\text{rad}}{s} \times 250 \times 10^{-3}\text{ H}$

   $= 175\ \Omega$

   The impedance is then given by:

   $Z = \sqrt{R^2 + X_C^2}$

   $= \sqrt{(200\ \Omega)^2 + (175\ \Omega)^2} = 265.8\ \Omega$

   $I_p = \frac{V_p}{Z} = \frac{40.0\text{ V}}{265.8\ \Omega} = 0.15\text{ A}$ (4)

   b) $V_p = I_pX_L = 0.15\text{ A} \times 175\ \Omega$

   $= 26.34$ (1)

   c) The average power delivered by the source is same as that delivered to the resistor, and is given by:

   $P_{av} = \frac{1}{2}(I_p)^2R$

   $= \frac{1}{2}(\ (0.15\text{ A})^2 \times 200\ \Omega = 2.25\text{ W}$ (2)

8. a) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

   $= \frac{1}{2\pi \times 50\text{ Hz} \times 2 \times 10^{-6}\text{ F}}$

   $= 1\ 591.5\ \Omega$

   The inductive reactance is:

   $X_L = \omega L = 2\pi fL$

   $= 2\pi \times 50\text{ Hz} \times 250 \times 10^{-3}\text{ H}$

   $= 78.5\ \Omega$

   The impedance is then given by:

   $Z = \sqrt{R^2 + (X_L - X_C)^2}$

   $= \sqrt{(150\ \Omega)^2 + (78.5\ \Omega - 1\ 591.5\ \Omega)^2}$

   $= 1\ 520.4\ \Omega$

   The maximum or peak current is given by:

   $I_p = \frac{V_p}{Z} = \frac{210\text{ V}}{1\ 520.4\ \Omega} = 0.16\text{ A}$ (4)

   b) The phase angle is given by:

   $\Phi = \tan^{-1}(\frac{X_L - X_C}{R})$

   $= \tan^{-1}(\frac{78.5\ \Omega - 1\ 591.5\ \Omega}{150\ \Omega})$

   $= -84.3°$ (1)

c) The p.d. across each component is then:

$(V_p)_R = I_p R = 0.16\text{ A} \times 150\ \Omega$
$= 24.7\text{ V}$

$(V_p)_C = I_p R_C = 0.16\text{ A} \times 1\,591.5\ \Omega$
$= 254.6\text{ V}$

$(V_p)_L = I_p R_L = 0.16\text{ A} \times 78.5\ \Omega$
$= 12.6\text{ V}$ (3)

d) The power in the resistor is given by:

$P_{av} = \frac{1}{2}(I_p)^2 R = \frac{1}{2}((0.16\text{ A})^2 \times 150\ \Omega)$
$= 1.92\text{ W}$

The power in the capacitor and inductor are zero. (2)

9. a) The resonant frequency is the frequency of the radio station, which is:

$f_0 = \frac{1}{2\pi\sqrt{LC}} = 360 \times 10^3\text{ Hz}$

The capacitance is then given by:

$C = \frac{1}{(2\pi \times 360 \times 10^3\text{ Hz})^2 L}$
$= \frac{1}{(2\pi \times 360 \times 10^3\text{ Hz})^2 \times 14.8 \times 10^{-3}\text{ H}}$
$= 1.32 \times 10^{-11}\text{ F} = 12.2\text{ pF}$ (3)

b) At resonance, $X_C = X_R$ and hence $Z = R$.

The maximum current is given by:

$I_p = \frac{V_p}{Z} = \frac{150\text{ V}}{44.0\ \Omega} = 3.41\text{ A}$ (3)

10. a) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$
$= \frac{1}{2\pi \times 50\text{ Hz} \times 4.7 \times 10^{-6}\text{ F}}$
$= 677.3\ \Omega$

The impedance is then given by:

$Z = \sqrt{R^2 + (X_L - X_C)^2}$
$= \sqrt{(500\ \Omega)^2 + (131.9\ \Omega - 677.3\ \Omega)^2}$
$= 739.87\ \Omega$

The peak potential across the source is:

$V_p = I_p Z$
$= 250\text{ A} \times 10^{-3}\text{ A} \times 739.87\ \Omega$
$= 184.97\text{ V}$ (4)

b) The phase angle is given by:

$\Phi = \tan^{-1}(\frac{X_L - X_C}{R})$
$= \tan^{-1}(\frac{131.9\ \Omega - 677.3\ \Omega}{500\ \Omega}) = -47.48°$

The power factor is given by:

$\cos \Phi = \cos(-47.48°) = 0.68$ (2)

Total marks: 77

Checklist for Self-evaluation

Theme 4 Topic 5

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Explain the peak and root mean square (rms) values of current and potential difference.					
2	Establish the phase relationship between current and potential difference in an a.c. circuit.					
3	Explain reactance and impedance.					
4	Determine current in circuits containing: • resistance and capacitance • resistance, inductance and capacitance.					
5	Determine power in an a.c. circuit.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

THEME 5

Energy quantisation and duality of matter

TOPIC 1: Models of the atom
Performance objectives
1.1 State and discuss what chemical evidence there is for the existence of an atom. **1.2** State and discuss what experimental evidence there is for believing that matter is electrical in nature. **1.3** Describe Rutherford-Bohr models of the atom. **1.4** Explain nucleon numbers and their relationship.

Introduction

This topic and the next one take the student from classical physics into modern physics. This is in many ways an important point in their studies. Some students will already have developed a solid interest in physics. Amongst those who have not, there will be some who will be hooked by the subject matter of modern physics. Thus the latter half of this course is likely to put a few more young minds onto a career path in physics.

Activity 5.1 Atomic structure

GROUP (SB p. 150)

Guidelines

You should satisfy yourself that students understand the significance of the behaviour of alpha particles in passing through thin films.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

anion – An atom or group of atoms carrying a negative electrical charge

cation – An atom or group of atoms carrying a positive electrical charge

Ion – A very small particle carrying an electric charge

isotopes – Groups or families of atoms sharing the same atomic number, and therefore the same chemical properties, but differing in atomic mass, due to differing numbers of neutrons in their nuclei

quantum (plural: quanta) – A fixed bundle or packet of energy

Valency – A numerical measure of the combining power of an atom. Carbon, for example, can combine with, at most, 4 hydrogen atoms. Hydrogen has a valency of 1. Thus carbon has a valency of 4

Practice test: Answers (SB p. 152)

1. 'Atom' means indivisible, un-cuttable. (2)
2. The Law of Constant Proportions and the photoelectric effect (2)
3. JJ Thomson (in 1897) (2)
4. An alpha particle is the nucleus of a helium atom. It comprises two protons and two neutrons. (2)
5. Cations are formed when neutral particles (atoms or molecules) lose one or more electrons. Anions are formed when neutral particles (atoms or molecules) gain (take on) one or more electrons. (2)
6. Isotopes are atoms that have the same atomic number but different atomic masses. The mass difference is due to the fact that the different isotopes of an element have different numbers of neutrons in their nuclei. (3)
7. a) F b) T c) F d) T e) F (5)
8. The 1930s (2)
9. B (2)
10. Wave-particle duality makes it impossible to explain atomic structure in any simple way. (4)

Total marks: 26

Checklist for Self-evaluation

Theme 5 Topic 1

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	State and discuss what chemical evidence there is for the existence of an atom.					
2	State and discuss what experimental evidence there is for believing that matter is electrical in nature.					
3	Describe Bohr-Rutherford models of the atom.					
4	Explain nucleon numbers and their relationship.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 2: Nucleus

Performance objectives

2.1 Identify the radiation from radioactive substances using their characteristics.
2.2 Solve simple problems involving the half-life of radioactive substances.
2.3 State some uses of radioactive substances.
2.4 Use the concept of nuclear fission and fusion for the development of nuclear energy for Nigeria.

Introduction

This topic is about radioactivity and nuclear reactions. We live in a radioactive world in which about 50% of the radioactivity is present in the air around us in the form of radon gas. This form of radioactivity is harmless, with the harmful part coming from accidents in nuclear plants and the detonating of nuclear weapons. However, radioactivity has proved invaluable in the medical field. The students are introduced to the different types of radioactive particles, their properties and their uses. A brief introduction is given to nuclear fission and nuclear fusions, which are believed to be the energy sources of the future.

Here are some useful videos on radioactivity:

https://www.youtube.com/watch?v=oFdR_yMKOCw

https://www.youtube.com/watch?v=5oUagoF_viQ

https://www.youtube.com/watch?v=Zw0pHT47AAU

https://www.youtube.com/watch?v=z1ihC1I-bI0.

Here are some useful videos on half-life:

https://www.youtube.com/watch?v=opjJ-3Tkfyg

https://www.youtube.com/watch?v=HRwey6cwGHo.

Here are some useful videos on nuclear fission and fusion:

https://www.youtube.com/ watch?v=DvzXqasziUE

https://www.youtube.com/ watch?v=0B69RHqAfj8.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

activity – The activity of a radioactive sample is the number of decays that the sample undergoes per second

alpha particle – Alpha particles are emitted from the nuclei of certain radioactive elements. Each particle is the nucleus of a helium atom and having a double positive charge

antineutrino – The antiparticle of a neutrino, having no charge or mass

beta particle – An electron emitted from certain radioactive elements when a neutron is converted into a proton

chain reaction – A nuclear reaction in which energy is continuously released as a result of neutrons, emitted by the fission of an atomic nucleus of an element, each splitting another nucleus and causing the emission of more neutrons

control rods – The rods in a nuclear reactor, made of boron or cadmiumthat are used to control the power level of the reactor

decay constant – A constant that relates the rate of a nuclear decay to the number of undecayed nuclides in a radioactive sample

disintegration energy – The energy given off during a radioactive decay

electron capture – The capturing of an electron by a proton in the nucleus of a radioactive nuclide leading to the creation of a neutron

gamma ray – Electromagnetic radiation of very short wavelength emitted by certain radioactive atoms

half-life – The time taken for half of a radioactive sample to decay

moderator – The chemical substance, such as water, that is used in a nuclear reactor to slow down the fast moving electrons

neutrino – A massless and chargeless particle given off by the nucleus during a beta plus decay

nuclear fission – The splitting of a heavy unstable nucleus into two nuclei of smaller mass by bombarding it with a neutron

nuclide – A nucleus with a specific atomic number and mass number

positron – The positively charged electron emitted from a radioactive nuclide when a proton is converted into a neutron

radiation – Exposure to any electromagnetic wave

radioactivity – The process whereby an unstable nuclide gives off an electromagnetic radiation and or alpha and beta particles

strong nuclear force – The strong force that hold the nucleons (protons and neutrons) together in a nucleus

Practice test: Answers (SB p.166)

1. 1.1 D 1.2 C 1.3 B
   1.4 A 1.5 C 1.6 D
   1.7 B 1.8 B 1.9 D
   1.10 C (20)
2. The unstable nuclides either have too many protons relative to the number of neutrons or too many neutrons relative to the number of protons. They can become stable by radioactive decay or by nuclear fission. (4)
3. In electron capture a proton captures an electron from the orbit closest to the nucleus and converts into a neutron and a neutrino. The reaction is shown below:
   $p + e^- \rightarrow n + v$ (2)
4. a) (i) β (ii) ${}^{210}_{81}\text{Tl}$ (iii) β
   (iv) β (v) ${}^{210}_{84}\text{Po}$ (vi) α (6)
   b) After one day the fraction present of each nuclide is given by:
   $$\left(\frac{N}{N_0}\right) = e^{-\left(\frac{\ln 2}{T_{\frac{1}{2}}}\right) \times 1d}$$
   $$= 2^{-\frac{1}{T_{\frac{1}{2}}}} = \frac{1}{2}^{\frac{1}{T_{\frac{1}{2}}}}$$
   Thus this fraction is proportional to the half-life, expressed in days. The larger the half-life, the larger the fraction remaining. Since ${}^{210}_{82}\text{Pb}$ has a half-life of 22 years, it will have the largest fraction remaining. (2)
5. The decay constant is given by:
   $$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{5.2\text{ y}} = 0.133\text{ y}^{-1}$$
   a) The fraction remaining after 9 months ($= \frac{9}{12}$ y $= 0.75$ y) is:
   $$\left(\frac{N}{N_0}\right) = e^{-\lambda t} = e^{-(0.133\text{ y}^{-1}) \times 0.75\text{ y}}$$
   $$= 0.90$$ (2)
   b) The initial activity is:
   $$R_0 = \lambda N_0 e^{-\lambda t} = \lambda N_0 e^0 = \lambda N_0$$
   $$= \left(\frac{0.133}{365 \times 24 \times 3\,600}\text{s}^{-1}\right) \frac{m_0}{M} \times N_A$$
   $$= (4.22 \times 10^{-9}\text{ s}^{-1}) \frac{10\text{ g}}{58.9\text{ g}}$$
   $$\times 6.032 \times 10^{23}\text{ mol}^{-1}$$
   $$= 4.31 \times 10^{14}\text{ Bq}$$
   The activity after 1 year is:
   $$R = R_0 e^{-\lambda t}$$
   $$= 4.31 \times 10^{14}\text{ Bq} \times e^{-(0.133\text{ y}^{-1})1\text{ y}}$$
   $$= 3.78 \times 10^{14}\text{ Bq}$$ (3)
6. The decay constant is given by:
   $$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{8 \times 24 \times 3\,600\text{ s}} = 1.00 \times 10^{-6}\text{ s}^{-1}$$
   The initial activity is:
   $$R_0 = \lambda N_0 e^{-\lambda t} = \lambda N_0 e^0 = \lambda N_0$$
   $$= (1.00 \times 10^{-6}\text{ s}^{-1}) \frac{m_0}{M} \times N_A$$
   $$= (1.00 \times 10^{-6}\text{ s}^{-1}) \frac{500 \times 10^{-6}\text{ g}}{130.9\text{ g·mol}^{-1}}$$
   $$\times 6.032 \times 10^{23}\text{ mol}^{-1}$$
   $$= 2.31 \times 10^{12}\text{ Bq}$$
   The activity after 1 h is:
   $$R = R_0 e^{-\lambda t}$$
   $$= 2.31 \times 10^{12}\text{ Bq} \times e^{-(1.00 \times 10^{-6}\text{ s}^{-1})1 \times 3\,600\text{ s}}$$
   $$= 2.30 \times 10^{12}\text{ Bq}$$ (6)
7. Given $R/R_0 = \frac{1}{10} = 0.1$
   $$R = R_0 e^{-\lambda t}$$
   $$\Rightarrow e^{-\lambda t} = R/R_0 = \frac{1}{10} = 0.1$$
   $$\lambda = \frac{-\ln 0.1}{t} = \frac{-\ln 0.1}{6.5 \times 60\text{ s}} = 5.90 \times 10^{-3}\text{ s}^{-1}$$
   The half-life is given by:
   $$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{5.90 \times 10^{-3}\text{ s}^{-1}} = 117.4\text{ s}$$
   $$= 1.96\text{ m}$$ (4)
8. a) Proton (1)
   b) X has mass number 14 and atomic number 6, and is ${}^{14}_{6}\text{C}$. (1)
   c) The neutrons, being neutral, can get close to the nucleus, while a proton, being positively charged, will be repelled by the positive nucleus. (2)

9. a) $x = (236 - 93) = 143$
$y = (92 - 56) = 36$ (2)

b) $Q = \{M_U - (M_{Kr} + M_{Ba} + 2M_n)\} \times 931.5 \text{ MeV/u}$
$= \{235.04323 \text{ u} - (91.9262 \text{ u} + 140.9144 + 2 \times 1.008665 \text{ u})\} \times 931.5 \text{ MeV/u}$
$= 172.25 \text{ MeV}$ (4)

10. a) Uranium 235. (1)

b) The moderator slows down the neutrons.
Water or graphite (2)

c) The control rods absorb neutrons and control the power level of the reactor. (1)

d) The concrete prevents radioactive particles from escaping into the surroundings. (1)

e) The waste products are radioactive with long half-lives. (1)

Total marks: 65

Checklist for Self-evaluation

Theme 5 Topic 2

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify the radiation from radioactive substances using their characteristics.					
2	Solve simple problems involving the half-life of radioactive substances.					
3	State some uses of radioactive substances.					
4	Use the concept of nuclear fission and fusion for the development of nuclear energy for Nigeria.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 3: Energy quantisation

Performance objectives

3.1 Explain the concept of energy quantisation.
3.2 Use the photon concept to explain the effect of electrons in the photoelectric effect.
3.3 Describe X-ray production and state its characteristics, properties and uses.

Introduction

This topic covers three main aspects of energy quantisation: energy levels in an atom, the photoelectric effect and X-rays. A brief view is given of the quantisation of the energy levels in the hydrogen atom and the associated spectra. This is followed by the phenomena of the photoelectric effect, the Einstein explanation of the effect and the practical uses of the phenomenon. The topic concludes with a discussion of how X-rays are formed and the practical uses of X-rays.

Here is a list of a few of the many videos on line spectra available on YouTube:

https://www.youtube.com/watch?v=Kv-hRvEOjuA

https://www.youtube.com/watch?v=1uPyq63aRvg

https://www.youtube.com/watch?v=FrDZpnf1SEQ.

Here is a list of a few of the many videos on the photoelectric effect available on YouTube:

https://www.youtube.com/watch?v=v-1zjdUTu0o

https://www.youtube.com/watch?v=vuGpUFjLaYE

https://www.youtube.com/watch?v=0qKrOF-gJZ4

https://www.youtube.com/watch?v=v5h3h2E4z2Q.

Here is a list of a few of the many videos on X-rays available on YouTube:

https://www.youtube.com/watch?v=bkaECMbLy58

https://www.youtube.com/ watch?v=vYztZlLJ3ds

https://www.youtube.com/watch?v=3_bZCA7tlFQ

https://www.youtube.com/watch?v=hTz_rGP4v9Y.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

absorption spectrum – Produced when white light is passed through a cold gas and one or more wavelengths of the light are absorbed by the gas

braking radiation – The type of X-rays produced when an accelerating incident electron's velocity is changed by the nucleus of the target atom

characteristic radiation – The type of X-rays produced when an accelerating incident electron ejects an electron from the target atom

energy levels – Electrons orbiting the nucleus of an atom possess energy depending on their distance from the nucleus. The energy level of an electron indicates its distance from the nucleus

ground state – The lowest energy level of an atom

line emission spectrum – It is the spectrum consisting of a number of distinct lines of different colour against a black background that is given off by a low pressure gas when it is heated

photoelectric effect – The emission of electrons from the surface of a material when light is radiated on the material

photoelectric equation – The equation for which the photon energy is equal to the sum of the work function of the material on which the photon is radiated and the maximum kinetic of the ejected photoelectron

quantized – Existing in discrete fixed values and not continuous such as the energy levels in an atom

stopping potential – The reverse potential difference required to stop the fastest moving photoelectrons in a photoelectric cell

threshold frequency – The minimum frequency for which light can emit photoelectrons from the surface of a metal

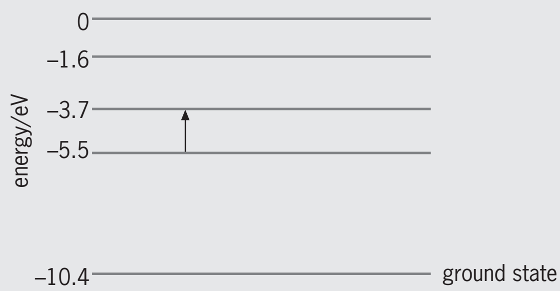
work function – The energy needed to overcome the forces that the atoms of a metal exert on electrons at the surface

X-ray – Electromagnetic spectrum waves that are given off when fast-moving electrons are incident on a metal target

Practice test: Answers

(SB p.182)

1. 1.1 C 1.2 B 1.3 D
   1.4 B 1.5 C 1.6 B
   1.7 A 1.8 C 1.9 B
   1.10 C (2)
2. A line emission spectrum consists of lines that correspond to the wavelengths of light emitted as photons. These photons of light are emitted when an atom makes a transition from a higher energy level to lower energy level. Since the spectrum consists of discrete lines instead of being continuous, this implies that the energy levels themselves must be discrete or quantised instead of being continuous. (4)
3. The energy of the third level in hydrogen is given by:
   $E_3 = -\frac{13.6}{n^2}$ eV $= -\frac{13.6}{3^2}$ eV
   $= -1.51$ eV,
   while the ground state energy is
   $E_1 = -13.6$ eV.
   The wavelength is then given by:
   $E_h - E_1 = hf = h\frac{C}{\lambda}$
   With:
   $-1.51 \times 1.6 \times 10^{-19}$ J $- (-13.6 \times 1.6 \times 10^{-19}$ J$)$
   $= \frac{6.63 \times 10^{-34}\ \text{J·s} \times 3.0 \times 10^{8}\ \text{m·s}^{-1}}{\lambda}$
   $\Rightarrow 12.09 \times 1.6 \times 10^{-19}$ J
   $= \frac{6.63 \times 10^{-34}\ \text{J·s} \times 3.0 \times 10^{8}\ \text{m·s}^{-1}}{\lambda}$
   $\Rightarrow \lambda = 1.03 \times 10^{-7}$ m $= 103$ nm (3)
4. a) $E = h\frac{C}{\lambda} = \frac{6.63 \times 10^{-34}\ \text{J·s} \times 3.0 \times 10^{8}\ \text{m·s}^{-1}}{691 \times 10^{-9}\ \text{m}}$
   $= 2.88 \times 10^{-19}$ J (2)
   b) This energy expressed in eV is:
   $E = \frac{C}{\lambda} = \frac{2.88 \times 10^{-19}\ \text{J}}{1.6 \times 10^{-19}\ \text{J}} = 1.8$ eV
   The transition will be from the second to the third energy level. (2)



5. a) $E = -10$ eV $- (-20$ eV$) = 10$ eV
   $= 10 \times 1.6 \times 10^{-19}$ J
   $= 1.6 \times 10^{-18}$ J (2)
   b) $f = \frac{E}{h} = \frac{1.6 \times 10^{-18}\ \text{J}}{6.63 \times 10^{-34}\ \text{J·s}}$
   $= 2.41 \times 10^{15}$ Hz (2)
6. a) The amount of energy required to remove an electron from the surface of sodium metal is $3.8 \times 1.6 \times 10^{-19}$ J. (1)
   b) From:
   $\Phi = hf_0 = h\frac{C}{\lambda_0}$
   we have
   $\lambda_0 = \frac{hC}{\Phi} = \frac{6.63 \times 10^{-34}\ \text{J·s} \times 3.0 \times 10^{8}\ \text{m·s}^{-1}}{3.8 \times 10^{-19}\ \text{J}}$
   $= 5.24 \times 10^{-7}$ m (2)
   c) $KE_{max} = hf - \Phi = h\frac{C}{\lambda} - \Phi$
   $= \frac{6.63 \times 10^{-34}\ \text{J·s} \times 3.0 \times 10^{8}\ \text{m·s}^{-1}}{306 \times 10^{-9}\ \text{m}}$
   $- 3.8 \times 10^{-19}$ J
   $= 2.7 \times 10^{-19}$ J (3)
7. a) From $KE_{max} = hf - \Phi$ we have:
   $\Phi = h\frac{C}{\lambda} - KE_{max} = h\frac{C}{\lambda} - \frac{1}{2}mv^2_{max}$
   $= \frac{6.63 \times 10^{-34}\ \text{J·s} \times 3.0 \times 10^{8}\ \text{m·s}^{-1}}{625 \times 10^{-9}\ \text{m}}$
   $- \frac{1}{2} \times 9.1 \times 10^{-31}$ kg
   $\times (4.6 \times 10^{5}\ \text{m·s}^{-1})^2$
   $= 2.22 \times \times 10^{-19}$ J (4)
   b) From $\Phi = hf_0$ we have (1)
   $f_0 = \frac{\Phi}{h} = \frac{2.22 \times 10^{-19}\ \text{J}}{6.63 \times 10^{-19}\ \text{J·s}}$
   $= 3.35 \times 10^{14}$ Hz

8. a) The maximum kinetic energy of the emitted electrons is given by:

$KE_{max} = hf - \Phi = h\frac{C}{\lambda} - h\frac{C}{\lambda_0}$

$= hC\frac{1}{\lambda} - \frac{1}{\lambda_0}$

$= 6.63 \times 10^{-34}$ J·s × 3.0 × 10^8 m·s^{-1}($\frac{1}{270 \times 10^{-9}\text{ m}}$ − $\frac{1}{350 \times 10^{-9}\text{ m}}$)

$= 1.68 \times 10^{-19}$ J (3)

b) Since the wavelength 360 nm is greater than the threshold wavelength, no photoelectrons will be emitted. (2)

9. a) Cathode (1)

b) $\Phi = hf_0 = h\frac{C}{\lambda_0}$

$= \frac{6.63 \times 10^{-34}\text{ J·s} \times 3.0 \times 10^8\text{ m·s}^{-1}}{592 \times 10^{-9}\text{ m}}$

$= 3.36 \times 10^{-19}$ J

The metal is caesium. (3)

c) Decreasing the wavelength results in an increase in the frequency, which increases the maximum kinetic energy of the ejected electrons but not the number of electrons. Therefore, there will be no change in the photoelectric current or the reading on the ammeter (2)

d) Since the wavelength used is below the threshold wavelength, there will be an ammeter reading. Increasing the intensity will increase the photons per second incident on the metal and hence the number of photoelectrons ejected per second, which cause the ammeter reading to increase. (2)

10. Similarity: In both the photoelectric effect and in the characteristic radiation of X-rays, electrons are ejected from metals.
Difference: In the photoelectric effect, electromagnetic waves produce electrons, while in X-rays, electrons produce electromagnetic waves. (3)

11. In characteristic X-rays, the accelerating electrons knock off electrons from the lower energy levels of the target metal. Electrons moving from higher energy levels to fill the vacant energy level emit X-rays in the process. In braking radiation, the accelerating electrons are slowed down by the target nucleus, and this lost kinetic energy of the electrons is released in the form of X-rays. (4)

12. a) From $W = \Delta KE = Vq_e$ we have:

$KE_f - 0 = Vq_e = 10 \times 10^3$ V × 1.6×10^{-19} C $= 1.6 \times 10^{-15}$ J

$KE_f = 1.6 \times 10^{-15}$ J (3)

b) $E = hf = h\frac{c}{\lambda}$

$\Rightarrow \lambda = \frac{hc}{E} = \frac{hc}{KE_f}$

$= \frac{6.63 \times 10^{-34}\text{ J·s} \times 3.0 \times 10^8\text{ m·s}^{-1}}{1.6 \times 10^{-15}\text{ J}}$

$= 1.24 \times 10^{-10}$ m = 124 pm (2)

13. a) From $E_h - E_l = h\frac{C}{\lambda}$ we have

$-6.4 \times 10^3 \times 1.6 \times 10^{-19}$ J − ($-74 \times 10^3 \times 1.6 \times 10^{-19}$ J)

$= \frac{6.63 \times 10^{-34}\text{ J·s} \times 3.0 \times 10^8\text{ m·s}^{-1}}{\lambda}$

$\Rightarrow 108.16 \times 10^{-16}$ J

$= 1.99 \times 10^{-25}$ J·m/λ

$\lambda = 1.84 \times 10^{-11}$ m = 18.4 pm (3)

b) The minimum energy of the incident electron must be 1.08×10^{-14} J (which is the difference in energy of the K and M shells). (1)

Total marks: 75

Checklist for Self-evaluation

Theme 5 Topic 3

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Explain the concept of energy quantisation.					
2	Use the photon concept to explain the effect of electrons in the photoelectric effect.					
3	Describe X-ray production and state its characteristics, properties and uses.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 4: Duality of matter
Performance objectives
13.1 Identify phenomenon which are only satisfactorily explained by assuming that matter behaves like: • waves and • particles.

Introduction

Wave-particle duality has fascinated many generations of young minds. It represents one of the points of departure, beyond which our ability to imagine the processes of nature often breaks down. Always remember to appeal to the students' sense of wonder and mystery. Fortunately, physics is an excellent subject for doing this.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Activity 5.2 Useful magnification

PAIR (SB p. 189)

Resources

Library or Internet

Guidelines

Useful magnification involves being able to see detail in the magnified image. Simple or empty magnification involves no more than making the image bigger: no greater detail is visible inside it, therefore the magnification is useless in terms of showing structure. With useful magnification the amount of visible detail increases with the magnification – thus one can learn more about the structure of what is being examined.

Practice test: Answers

(SB p. 190)

1. James Clerk Maxwell showed that light waves and electromagnetic waves belong to the same family of waves – the so-called electromagnetic spectrum. (4)
2. $E = hf$, where E is the energy of the packet, f is the frequency, and h is a constant that became known as Planck's constant. (4)
3. The photoelectric effect. The light particle was called the photon. (4)
4. Prince Louis de Broglie (2)
5. Because the electrons are so small that they would be deflected if they hit a molecule of gas (4)
6. At least 1 000 times more powerful. (2)
7. If light behaves as waves, then even low-energy light should build up enough energy eventually to knock electrons from the surface. If the light is particulate, the individual quanta may not have enough energy to knock out electrons. The low energy quanta will not build up with time. Short-wave light, if it behaves as particles, probably has enough energy in each package (quantum) to knock out electrons immediately – as is observed. (5)

Total marks: 25

Checklist for Self-evaluation

Theme 5 Topic 4

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify phenomenon which are only satisfactorily explained by assuming that matter behaves like: • waves and • particles.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

THEME 6

Physics in technology

TOPIC 1: The battery
Performance objectives
1.1 Construct a battery.

Introduction

Students should know from earlier work that batteries are energy stores, from which the energy is released as an electric current. This Topic extends their familiarity with the principles of battery design, and allows them to make a single electric cell with very simple components.

Activity 6.1 Building an electric cell

GROUP (SB p. 196)

Resources

For each group: Strips of zinc and of copper for the electrodes; two 250 ml beakers; electrolyte solution (this can be tap water to which some lemon juice or vinegar has been added), lengths of insulated copper wire, crocodile clips, a voltmeter, an ammeter or multimeter

Guidelines

Students build their own electric cell/ battery.

If adequate equipment is available, students should work in small groups. If this is not possible, you should consider doing the activity as a demonstration. If you do, attempt to gain as much class involvement as possible by means of questions and by calling for volunteers to help with assembly of the cell.

If you have not done this as a demonstration for previous classes you are urged to set up the system yourself beforehand to ensure that the system works satisfactorily, and to allow you to perform the demonstration with efficiency and confidence.

An advantage of having groups set up cells is that you will then have several cells, and it will be a simple matter to connect two or more cells in series to produce a battery. If you do the activity as a demonstration you should plan to assemble at least two cells so that students can see them assembled into a battery, and can see that the current from a two-celled battery is greater than that from a single cell.

Answer

A question that is put to the students in their books is: how might they determine whether a current is flowing in the external circuit of the cell/battery if they do not have a voltmeter or ammeter? The answer is; use a magnetic compass, placed near a straight section of the wire. Remind them that this was Oersted’s discovery.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

electrochemical series – Metallic elements arranged in order of their increasing electrode potentials, those highest in the series having large negative values

electrode potential – The potential difference between an element and a solution containing its ions

electrodes – A conductor for emitting, collecting or controlling the flow of electric charge carriers in an electrolyte, gas, vacuum, dielectric or semiconductor

redox – Word formed from *red*uction and *oxi*dation; refers to the gaining of electrons (reduction) or the loss of electrons (oxidation). The two processes go hand-in-hand: When one substance gains an electron, another substance must necessarily lose an electron

Practice test: Answers

(SB p. 199)

1. The electrochemical series is a ranking of elements in terms of the ease with which they gain or lose electrons. The series is based on hydrogen, which is given an electrode potential of zero volts. All the other elements are measured relative to the hydrogen electrode. (5)
2. Electric cells are also known as galvanic cells and voltaic cells. (2)
3. A redox reaction is one in which one substance is reduced (‘red-’) and another is oxidised (‘-ox’). Reduction is an addition of one or more electrons; oxidation is a removal of one or more electrons. (2)
4. A hydrogen electrode is used as a basis for comparison with the other elements, in terms of their willingness to take on or lose one or more electrons. (4)
5. At the cathode electrons are received (accepted). A cathode is a good electron acceptor. The cathode is positive. This is why electrons are attracted to it. (2)
6. Zinc, lithium (2)

Total marks: 17

Checklist for Self-evaluation

Theme 6 Topic 1

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Construct a battery.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 2: Electroplating
Performance objectives
2.1 Electroplate a suitable electrode.

Introduction

The student text outlines the theory and suggests how the students should approach the task. There are some good videos on this topic on the Internet.

Activity 6.2 Electroplating a suitable electrode

GROUP (SB p. 201)

Resources

A 6 V battery, connecting leads, a rheostat, an ammeter, a stopwatch, a switch, a suitable metallic anode or carbon anode, and a container for the electrolysis, chemicals needed will depend on the type of electroplating done

Guidelines

It is important to ensure that the metal to be electroplated is thoroughly clean before it is attached to the battery. The amount of current needed is also vital, and this can be done by trial and error or by using Faraday's law of electrolysis.

How are you doing?

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.

This is a project topic and there is no practice test.

Checklist for Self-evaluation

Theme 6 Topic 2

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Electroplate a suitable electrode.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 3: Application of electromagnetic field
Performance objectives
3.1 Construct and use: • a galvanometer • an electric motor • a generator.

Introduction

The student text gives some examples of how to make these devices. The internet has numerous other examples, which the teacher could use to advise the students. They are far too numerous to list here.

Activity 6.3 Constructing and using a galvonometer GROUP (SB p. 202)

Resources

A strong, U-shaped magnet, an aluminium frame (or a light plastic pill bottle), 1 m of very thin insulated copper wire, a cardboard pointer, connecting wires, about 20 cm of phosphor–bronze wire, a piece of soft iron, a vertical support, a current source, an ammeter, tacking glue

Activity 6.4 Constructing and using an electric motor GROUP (SB p. 203)

Resources

A size D-battery, a ceramic magnet or a magnet from a loudspeaker, 2 large safety pins, 1 m of enamel-coated #22 gauge copper wire, 2 plastic beads (about 6 mm in size), a 14 cm × 14 cm piece of timber, or polystyrene, 1 large rubber band, cutting tools

Activity 6.5 Constructing and using a conventional motor GROUP (SB p. 204)

Resources

A large cork, a hard plastic tube (for example from a ball point pen), a piece of thick wire to loosely fit the plastic tube, about 2 m to 3 m of fine insulated wire, rubber rings (for example cut from rubber tubing), a pair of magnets or a U-shaped magnet, drawing pins (thumb tacks), 2 paper clips, a wooden base board, connecting leads, a 6 V battery, a rheostat

Activity 6.6 Constructing and using a generator GROUP (SB p. 205)

Resources

1 m of enamel-coated thin wire, 4 ceramic block magnets, corrugated cardboard (from packing boxes), a large iron nail, a 1.5 V, 25 mA light bulb, scissors or a sharp knife

How are you doing?

Take this opportunity to ask students 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 students do not understand.

This is a project topic and there is no practice test.

Checklist for Self-evaluation

Theme 6 Topic 3

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Construct and use: • a galvanometer • an electric motor • a generator.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 4: Transmission systems
Performance objectives
4.1 Construct a simple transmission system. **4.2** Explain why it is preferred to have a high potential difference instead of a high current transmission over a long distance.

Introduction

The student text outlines how a power transmission system works and the need for one. The teacher can consult the local electricity utility company for any further details required. When the students are constructing the power transmission system, they must use low voltage a.c. transformers because of the dangers involved. Ensure that safety measures are taken when handling a.c. voltages.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

This is a project topic and there is no practice test.

Checklist for Self-evaluation

Theme 6 Topic 4

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Construct a simple transmission system.					
2	Explain why it is preferred to have a high potential difference instead of a high current transmission over a long distance.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 5: Uses of machines

Performance objectives

5.1 State the need for the use of machines.
5.2 State instances where machines are used.

Introduction

Students should be introduced to this Topic in the broad context of technology, because unlike earlier topics this is something of a hold-all – dealing as it does with a cross-section of machines with no unifying theme of principle. A point that should come through clearly is the need for scrupulous observance of protocols for the correct use of machines. The attitude behind successful maintenance is more important than an understanding of physics.

Activity 6.7 Everyday machines

INDIVIDUAL (SB p. 210)

Guidelines

The students will probably need guidance with the full range of machines the school owns. They should understand what the machines do, how they work, and what source of energy they use.

Activity 6.8 Agricultural machines

INDIVIDUAL (SB p. 211)

Guidelines

This activity can be done as homework.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

artificial intelligence (AI) – The ability of a machine to perform some functions that require intelligence

global village – The idea that our planet has become small – a 'village' – because of the ease and speed with which information can be distributed around the world

Practice test: Answers

(SB p. 211)

1. Arnold Schwarzenegger (2)
2. A machine is a device that uses energy and does work. Or: A device for converting energy into work. (2)
3. 'Splitting the atom' involves breaking the atomic nucleus into two or more pieces. The significance of this is that it releases enormous quantities of energy. (4)
4. Being excessively dependent on machines makes us lazy, tends to produce obesity, and associated with that is an increased risk of various diseases. (2)
5. GMO = Genetically Modified Organism (4)

Total marks: 14

Checklist for Self-evaluation

Theme 6 Topic 5

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	State the need for the use of machines.					
2	State instances where machines are used.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 6: Repairs and maintenance of machines
Performance objectives
6.1 State the need to identify faults in machines and get them repaired. **6.2** State the need for regular maintenance of machines. **6.3** Identify and follow a maintenance schedule for a machine.

Introduction

This topic is a direct continuation of the previous one, and should be closely connected to it in terms of teaching procedures. Attitude is more important, in these areas, than scientific knowledge. The students' knowledge of underlying principles should, of course, promote the necessary attitude.

Activity 6.9 Machine maintenance

GROUP (SB p. 214)

Resources

Guidelines

1. This activity continues from an activity in the previous topic, in which students made a list of machines owned by the school. Tell the students they should use these lists and proceed to discuss maintenance and repair of the machines. You might consider asking the students to make notes of their discussions.
2. Vehicles are common and expensive machines owned by most businesses, and by most schools. Suggest to the students that they should consider motor vehicles as a separate category from the machines dealt with in the previous activity.
3. Visiting a garage will provide students with useful information about the maintenance (servicing) of vehicles, and the disposal of old engine oil.
4. This activity involves interviewing the owner or manager of a shop dealing in electronic equipment. The students should enquire about maintenance and malfunction of electronic equipment, and about the disposal of any environmentally dangerous materials associated with any types of electronic equipment.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

accredited agent – A person with permission to do certain types of work

Practice test: Answers

(SB p. 215)

1. A log book shows the number of hours for which a machine has been used, and (possibly) the people who have used it. The log book is important in determining when the machine, or specific parts of it, should be replaced or serviced. (4)
2. Defective electrical equipment can cause fires – which might destroy an entire factory or home – and can cause lethal electric shocks to people who touch or use the equipment. (4)
3. Writing off: Firstly, it may no longer be possible to obtain parts for an old machine, and secondly, newer machines may be more efficient and therefore more cost-effective. This means it may be financially better to write off an old machine even before it breaks down. (4)
4. 'Planned obsolescence' means designing and building something in such a way that it will work for only so long before breaking down and requiring replacement. This means that the manufacturer can sell more of the machines, or parts – and thus make higher profits. Mild steel exhaust pipes for cars are the classical example of this. A typical exhaust pipe for a car is guaranteed for one year, and it breaks down after 13 months. (5)

Total marks: 17

Checklist for Self-evaluation

Theme 6 Topic 6

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	State the need to identify faults in machines and get them repaired.					
2	State the need for regular maintenance of machines.					
3	Identify and follow a maintenance schedule for a machine.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 7: Dams and energy production
Performance objectives
7.1 Identify dams for producing electricity in Nigeria. **7.2** Describe how electricity is produced from a dam.

Introduction

As in several previous topics, this one is directly concerned with aspects of energy on the industrial and social scales. More thoughtful students will perhaps reflect on the insatiable energy hunger of the global population, and the various complex consequences that follow from this. Technological and scientific expertise is best integrated with society by those young people who balance their specific education and training with intelligent social awareness.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

equilibrium – A balanced state of constant (continual) change of a system

Practice test: Answers (SB p.219)

1. The depth of the water escape duct below the water surface (roughly, the height of the dam) and the volume of water held in the dam (2)
2. A turbine is a propeller that is driven by water or gas moving past it. It differs from a true propeller in that a propeller is driven by a motor and pulls or pushes air or water past it. A propeller drives and a turbine is driven. (2)
3. The Kainji dam and power station are the biggest hydroelectric generating facilities in Nigeria. (1)
4. A dam is in equilibrium if its catchment brings in as much water, on average, as is lost from the dam. (4)
5. Just over 3 000 MW (1)

Total marks: 10

Checklist for Self-evaluation

Theme 6 Topic 7

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify dams for producing electricity in Nigeria.					
2	Describe how electricity is produced from a dam.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 8: Rockets and satellites
Performance objectives
8.1 Identify the component parts of rockets and satellites. **8.2** Describe the functions of rockets and satellites. **8.3** State the uses of rockets and satellites.

Introduction

This topic, while remaining within the area of technology, returns to some of the principles of mechanics that the students will have encountered earlier.

Activity 6.10 Satellites GROUP (SB p. 223)

Guidelines

Students discuss in small groups the question of why the mass of a satellite cannot be calculated even if you know its period and the radius of its orbit. This problem should remind them of similar matters in the topics they have already studied. In particular they should remember, or be reminded, that satellites are in free fall as they orbit their primary, and that all masses falling towards their parent planet accelerate at a rate that is independent of their masses. For example, all bodies near Earth accelerate towards the ground at a rate of 9.8 $m \cdot s^{-2}$, thus, from knowing this value, we have no basis for calculating the mass of the body. The situation is exactly this with free fall.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

geostationary orbit – The orbit of a satellite with a period of 24 hours, and lying in the same plane as Earth's equator. Such a body remains in a fixed position relative to an observer on the ground. Such an orbit is also called a geosynchronous orbit

Practice test: Answers

(SB p.226)

1. A hypergolic rocket fuel is one that ignites automatically when the fuel and oxidant are mixed. An ignition system is therefore not required. (2)
2. Newton's third law of motion (2)
3. A rocket engine carries not only a supply of fuel but also a supply of the substance necessary to burn it (the oxidant). A jet carries its fuel, but uses the surrounding air (specifically oxygen) to burn the fuel. (2)
4. The drag of the atmosphere. Friction against the air would cause the satellite to slow down and fall back to Earth. (2)
5. A geostationary orbit is an orbit above the equator at a height at which the period of the satellite is the same as Earth's rotation time. Thus the satellite does not move relative to Earth. A geostationary orbit is also called a Clarke orbit, after the man who suggested the idea of satellites orbiting in this way. (2)
6. A little less than 600 km above sea level (2)

Total marks: 12

Checklist for Self-evaluation

Theme 6 Topic 8

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	Identify the component parts of rockets and satellites.					
2	Describe the functions of rockets and satellites.					
3	State the uses of rockets and satellites.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 9: NigerSAT-1
Performance objectives
9.1 State the features of NigerSAT-1. **9.2** Describe the operation of NigerSAT-1. **9.4** State its uses to Nigeria and its neighbours.

Introduction

The first of Nigeria's satellites was intended mainly for monitoring conditions on Earth's surface. As it was in low orbit (and therefore not geosynchronous), it moved relative to the Earth's surface – passing completely around the Earth regularly – and was able to monitor conditions in a band around the planet.

The satellite could be called a remote sensing device, or simply a weather satellite. The alternative name of Disaster Monitoring Constellation was appropriate but perhaps a little negative in its connotation. It monitored more than disasters.

Activity 6.11 Satellite information

GROUP (SB p.229)

Guidelines

This activity should take place after the class has had an opportunity to read the topic – perhaps guided by you, the teacher. Encourage the class, before it breaks into groups for the discussion, to consider what types of disaster might be monitored, and what types of event might be seen as disasters. Flooding and drought are obvious examples of disasters. Less obvious, but far more insidious and serious, are the effects of habitat destruction due to the encroachment of humans on the environment.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

microsatellite – An artificial satellite with a mass between 10 and 100 kg

Practice test: Answers

(SB p. 230)

1. Alan Shepard, American (2)
2. Sputnik (October 1957) (2)
3. National Space Research and Development Agency (1)
4. Disaster Monitoring Constellation (2)
5. 10–500 kg (3)
6. 100 kg (1)
7. 2003 (1)
8. 9 years (1)
9. a) England (1)
   b) Russia (1)
10. No. The cameras could see (detect) objects as small as 32 m across. An object of 25 m diameter would be just below the ability of the optical systems to resolve it. (4)
11. Aircraft accident, 1968 (2)
12. Air resistance very slowly erodes the orbital speed of the satellite, and when it gets below a critical speed it falls back to Earth. (5)
13. A satellite in sun-synchronous orbit passes over any given place at about the same time each day, so the shadows at one place are about the same each day. (5)

Total marks: 31

Checklist for Self-evaluation

Theme 6 Topic 9

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	State the features of NigerSAT-1.					
2	Describe the operation of NigerSAT-1.					
3	State its uses to Nigeria and its neighbours.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

TOPIC 10: NigComSAT-1
Performance objectives
10.1 State the features of NigComSAT-1. **10.2** Describe the operation of NigComSAT-1. **10.3** State its uses to Nigeria and its neighbours.

Introduction

Following on from the previous topic, students need to be made aware of the importance of knowledge in the modern world. Information is the raw material of knowledge, and communication goes hand-in-hand with both. The greatest differences between modern and earlier societies lie in the scale of things, the volume of information and knowledge, the speed at which it is transmitted, and the rate and scale of change.

Modern technology is essential to the tempo of today's global society. Satellites, and the technology needed to produce and maintain them, are very expensive, but they make communication much cheaper than it would otherwise be.

How are you doing?

Take this opportunity to ask students 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 students do not understand.

Key words

geosynchronous orbit – An orbit with a period of 24 hours, but not in the plane of Earth's equator. A satellite in such an orbit moves across the sky, as seen from Earth, but returns to the same position every 24 hours

gigahertz – One thousand million cycles per second

L-band; C-band; Ku-band; Ka-band – Frequency bands on which satellites receive and transmit signals. The L-band is 1–2 GHz; Ka-band is 26–40 GHz

satellite bus – The frame on which the specific electronic equipment of a satellite is mounted

transponder – Electronic device that receives and sends signals. It may also amplify a signal before sending it

Practice test: Answers

(SB p. 235)

1. 35 000 km (1)
2. Insurance on NicomSat 1 (1)
3. 5 150 kg (1)
4. China (1)
5. May 2007 (1)
6. An electronic device that receives, amplifies and re-transmits signals (3)
7. DFH-4 (DFH = ‘Dong Fang Hong’) (1)
8. 15 years (1)
9. 1–10 cm (1)
10. Frequencies of 1–40 GHz (2)
11. To re-position occasionally (3)
12. To be geosynchronous, the satellite must circle the Earth once every 24 hours. To be geostationary, the (geosynchronous) orbit must lie in the plane of the Earth’s equator. All geostationary orbits are geosynchronous, but not all geosynchronous orbits are geostationary. (10)
13. 10^9 hertz – in other words: 1 000 million cycles per second (2)
14. NicomSat-1R has 40 transponders, instead of 28 on NicomSat 1. (4)
15. The amount of thruster fuel it carries Once the fuel is exhausted the satellite can no longer re-position itself. (4)
16. Nigerian Communications Satellite Ltd (2)

Total marks: 38

Checklist for Self-evaluation

Theme 6 Topic 10

EVALUATION GUIDE: Student should be able to:

	Criteria	4	3	2	1	Comments
1	State the features of NigComSAT-1.					
2	Describe the operation of NigComSAT-1.					
3	State its uses to Nigeria and its neighbours.					

Code for evaluation:			
4 – Very well	3 – Well	2 – Fairly well	1 – Not well at all

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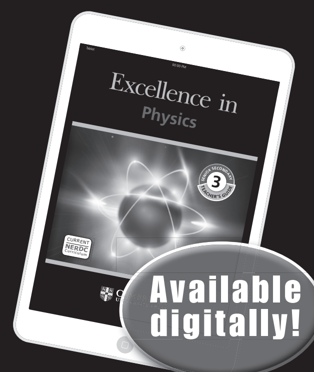

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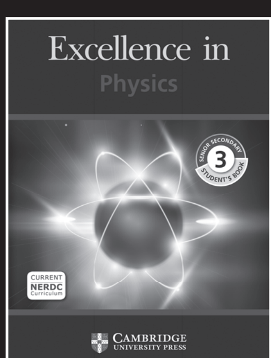

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