Notes to Physics Practical Work

Introduction

For meaningful inquiry-based learning of physics to occur, it is important that students should not just learn physics as a body of facts, models, and theories. Rather, they must also learn physics as an 'empirical' subject, which involves the use of observations and experiments for knowledge construction.

Based on the IGCSE syllabus by CAIE, practical work helps students to:

- use equipment and materials accurately and safely
- develop observational and problem-solving skills
- develop a deeper understanding of the syllabus topics and the scientific approach
- appreciate how scientific theories are developed and tested
- transfer the experimental skills acquired to unfamiliar contexts
- develop positive scientific attitudes such as objectivity, integrity, cooperation, enquiry and inventiveness
- develop an interest and enjoyment in science

[Taken from CAIE Syllabus Cambridge IGCSE Physics 0625]

This section will provide students with notes on:

- some common experimental contexts in practical work
- the safety pointers when performing experiments in the laboratory work
- the practical skills before engaging in the planning of experiments and investigations

Common Experimental Contexts

During experiments, the accurate measurement of physical quantities using instruments is a fundamental skill in practical work. Lord Kelvin (1824–1907), an eminent British scientist, once said, "When you can measure what you are speaking about, and express it in numbers, you know something about it, but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be."

Below are some notes to some common experimental contexts in physics practical work.

1 General Physics

Common Experimental Contexts	Common Instruments	Link to Chapters
Measuring physical quantities such as length, time, mass and volume	1. Metre rule (length) 2. Vernier calipers (length) 3. Stopwatch (time) 4. Beam balance (mass) 5. Electronic balance (mass) 6. Measuring cylinder (volume) 7. Displacement can (volume) 8. Burette (volume)	Chapter 1 Measurement of Physical Quantities Chapter 3 Mass, Weight and Density
Precautions		
1 Length • Avoid parallax error when using metre rule • Check for zero error when using vernier calipers		

Precautions

2 Time

When timing oscillations, take note of the following points:

- Repeat timings and take the average time for a more accurate measurement.
- To find the period of an oscillation, record the time taken for a large number of oscillations (e.g. 20) and calculate the average time for one oscillation. This average time is more accurate than a direct measurement of the time taken for just one oscillation.
- Ignore the first few oscillations. Start timing only when oscillations are steady and you have gotten used to the rhythm of the oscillation.
- When oscillations become 'abnormal' (e.g. elliptical oscillations in a pendulum), the timing of such oscillations must be ignored.

3 Mass

When you are using the beam balance or an electronic balance, take note of the following points:

- Zero the instrument before use, i.e., set the reading to zero when it is measuring nothing.
- Do not place wet objects on the pan of the scale.
- When weighing chemicals or granular solids, place them in a watch glass (or other suitable containers) of known mass.

4 Volume

- Ensure that your viewing eye is at the same level as the bottom of the meniscus when taking volume readings.

2 Thermal Physics

Common Experimental Contexts	Common Instruments	Link to Chapter
Cooling and heating, including measurement of temperature	1. Thermometer (temperature) 2. Bunsen Burner 3. Beaker 4. Boiling tube 5. Measuring cylinder (volume)	Chapter 9 Thermal Properties and Temperature Chapter 10 Transfer of Thermal Energy

Precautions

1 When using a mercury-in-glass thermometer, take note of the following:

- Avoid using the thermometer as a stirrer.
- Record temperature readings to the smallest half division.
- Avoid parallax errors when taking temperature readings by reading the scale with your line of sight perpendicular to the stem of the thermometer.
- If you are measuring the temperature of a liquid in a container, stir the liquid continuously with a stirrer to ensure that the temperature is uniform throughout the liquid.

2 When using a Bunsen burner, take note of the following:

- Close the air holes completely before lighting the burner. Lighting the burner with open air-holes may result in a "strike back".
- The temperature and the colour of the Bunsen flame is controlled by the size of the air-hole openings. For a very hot blue flame, open the air-hole slowly to allow air to mix with the gas.
- A Bunsen burner that is working properly will not produce a loud noisy hiss.
- If the burner is hissing loudly, turn off the gas supply and check that the jet is not choked. Do not touch the hot collar or barrel with your bare hands.
- The size of the flame can be controlled by adjusting the gas tap.

3 Optics

Common Experimental Contexts	Common Instruments	Link to Chapter
Measuring quantities such as angles of reflection	1. Illuminated object 2. Optical pins 3. Lenses 4. Transparent prisms and blocks 5. Protractor (incident, reflected and refracted angles)	Chapter 12 Light

Precautions

1 When using an illuminated object, ensure that the lights in the lab are switched off or dimmed with the curtains drawn.

2 When using optical pins, take note of the following:
- The two pins used to locate the path of the ray of light must be placed as far apart as possible when they are aligned.
- The pins must be placed vertically upright.

3 When performing experiments involving lenses, note the following points:
- The lens must be upright. If he lens is tilted, the image formed on a vertical screen may not be as sharp as it could be.
- Object and image distances should be measured along a line parallel to the principal axis.
- The centre of the illuminated object and the centre of the screen should be placed near the principal axis of the lens. Both the object and the screen should be positioned at right angles to this axis.

4 When using the protractor, avoid parallax error.

4 Magnetism

Common Experimental Contexts	Common Instruments	Link to Chapter
Finding the magnetic field pattern of a permanent bar magnet	1. Permanent bar magnets 2. Plotting compass	Chapter 15 Simple phenomena of Magnetism

Precautions

1 When handling magnets or plotting compass, remember the following points:
- Do not drop them or knock them unnecessarily.
- Avoid placing them near hot objects, such as a Bunsen burner or a beaker of hot water.

2 When storing magnets, store them in pairs with soft iron keepers when they are not in use.

5 Electricity

Common Experimental Contexts	Common Instruments	Link to Chapter
• Determining a derived quantity such as the value of a known resistance • Testing and identifying the relationship between two variables such as between the potential difference across a wire and its length • Connecting and reconnecting of electric circuits, and measuring of current and potential difference	1. Dry cell 2. Resistor 3. Ammeter 4. Voltmeter 5. Plug-key switch 6. Filament lamp 7. Wire 8. Crocodile clip	Chapter 16 Electrical Quantities Chapter 17 Electrical Circuits and Electrical Safety

Precautions
1 Avoid parallax error when using the ammeter or voltmeter.
2 Check for zero error when using the ammeter or voltmeter.
3 Minimise heating effects by breaking the circuit using the plug-key switch after taking the readings.

Safety Pointers

Carrying out any experiment in the laboratory can be dangerous if we do not follow basic safety guidelines. Here are some basic safety pointers that you should be aware of:

Before you begin …

1 Make sure your workbench is not cluttered with unnecessary items (such as your school bag, files, clothes and books). Keep your workbench neat and clean.
2 Read all the instructions in your practical workbook before you do anything.
3 Look out for possible dangers.

While you are conducting the experiment …

1 Follow the instructions in the practical workbook closely. Do not do anything you are not instructed to do without your teacher's permission.
2 Do not fool around and endanger people around you.
3 Wear or use protective devices provided for you. These protective devices include goggles, gloves and safety tongs.
4 Never leave heating apparatus unattended. Turn off Bunsen burners when you have to leave your workbench for a while or when you have completed your experiments.
5 If you have broken any glassware (beakers, test tubes and thermometers, etc.) or spilt any liquids, inform your teacher immediately.
6 Find out where fi re extinguishers are located in the laboratory and how to operate one.

After you have finished the experiment …

1 Clean your workbench.
2 Do not dispose of materials in the sink unless you are instructed to do so.
3 Wash your hands thoroughly.

The pointers above are only some of the important safety guidelines that you should follow to avoid accidents. The best preventive measure is to always be careful and alert. Take care of yourself and your neighbours. Above all, pay attention to your teacher.

Practical Skills

1 Planning an Investigation

Planning an investigation involves the four main steps shown below.

Step	Elaboration
1 Define the problem.	• Make a clear statement of the problem • Identify the independent and the dependent variables. **Example 1: Period of a Simple Pendulum** *Statement of the problem:* What is the relationship between the period and the length of a simple pendulum? *Variables:* (a) Independent variable: length of thread *L* (b) Dependent variable: time t for 20 oscillations **Example 2: Resistance of a Fixed Resistor** *Statement of the problem:* How to determine the resistance of a fixed resistor using the voltmeter-ammeter method? *Variables:* (a) Independent variable: potential difference *V* (b) Dependent variable: current *I*
2 Describe how data is to be collected.	Give a clear and logical account of the experimental procedure, including a description of • how the independent variable is to be varied; • how the independent and the dependent variables are to be measured; • how the other variables are controlled; • the arrangement of the apparatus that will be used.
3 Describe the analysis of the collected data.	Describe how the data collected should be processed to fulfil the purpose of the investigation. **Example 1: Period of a Simple Pendulum** 1. For each value length L and the corresponding time t for 20 oscillations, the period $T = \frac{t}{2}$ is calculated. 2. Plot a graph of *T*/s (y-axis) against *L*/cm (axis) to deduce the relationship between the period *T* and length of *L* of the pendulum. 3. Conclusion: The period of a pendulum increases with its length. **Example 2: Resistance of a Fixed Resistor** 1. By adjusting the position of the sliding contact on the rheostat, record three pairs of the potential difference *V* and the current *I* across the fixed resistor 2. For each pair of *V* and *I*, calculate the resistance of the fixed resistor using $R = \frac{V}{I}$ 3. Conclusion: The resistance of a fixed resistor can be determined by finding the average value of the three pairs of *R* in (2).
4 Think of the relevant safety precautions.	Suggest suitable safety precautions to be taken. **Example 1: Period of a Simple Pendulum** 1. Ensure that the pendulum oscillates steadily in a vertical plane before starting the timing. 2. To find the period of an oscillation, record the time taken for a large number of oscillations (e.g. 20) and calculate the average time for one oscillation. **Example 2: Resistance of a Fixed Resistor** 1. Check for zero error when using the ammeter or voltmeter. 2. Minimise heating effects by breaking the circuit using the plug-key switch after taking the readings of *V* and *I*.

2 Displaying Data on Graphs

Graphs are plotted to show the relationship between two quantities. The quantity that you choose to vary (independent variable) is usually plotted on the x -axis. You should vary this quantity in nearly regular intervals covering the entire range of the quantity available in the experiment. The quantity that is dependent on the quantity that you vary (dependent variable) is plotted on the y -axis.

The following points should be noted when drawing graphs:

1 Both axes should be labelled in this manner: name of quantity/unit, e.g., time/second, time/s or t/s.

2 Use a convenient scale to draw the graph as large as the available space allows.

3 Avoid using awkward scales such as 2 cm : 3 units. Such scales usually lead to errors in plotting and deduction.

4 Points must be clearly and accurately marked with small, sharp crosses (×).

5 Do not attempt to join all the plotted points on the graph. It is not likely that you will obtain a straight line or a smooth curve by joining all the points, as there are bound to be errors in the experimental readings. Instead, use a long (30 cm) transparent ruler to help you draw the best straight line, or a flexible curve ruler to draw a smooth curve. Remember to use a sharp pencil to draw the straight line or curve.

6 The best straight line (Figure 1) or the best smooth curve (Figure 2)
   (a) passes through the middle of the spaces between the points;
   (b) has about the same number of points on either side of the line over
   (c) its entire length;
   (d) does not necessarily pass through any plotted points or the origin.

7 For an irregular point that is far from the best straight line or curve, either
   (a) repeat the measurement and/or calculations for the point and correct it. OR
   (b) circle the point and indicate that the point has been rejected and ignored.

8 The gradient of a straight line should be calculated from a right-angled triangle drawn with dotted lines. The hypotenuse should be as long as possible, and no shorter than half of the straight-line graph. The ends of the hypotenuse must not be any of the plotted points.

9 Draw dotted lines to find a point on the x -axis corresponding to a point on the y -axis, and vice versa.

Figures 1 to 10 show examples of desirable and undesirable graphs.

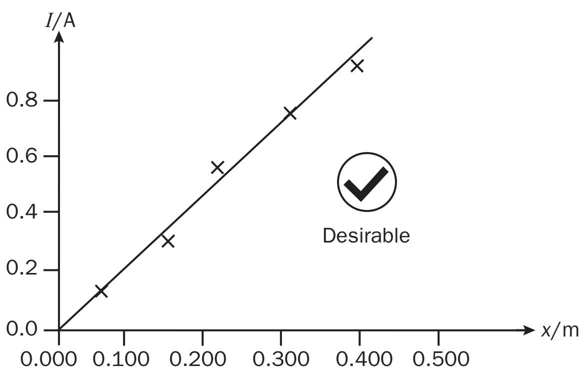

Figure 1

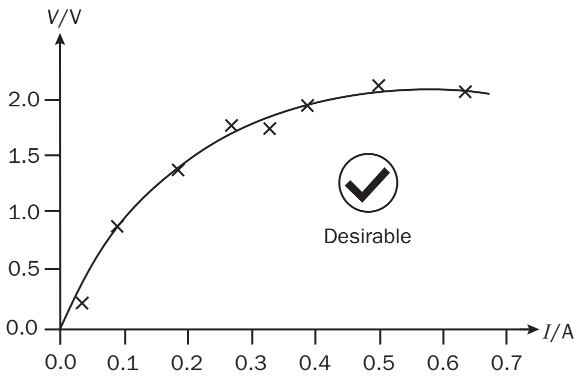

Figure 2

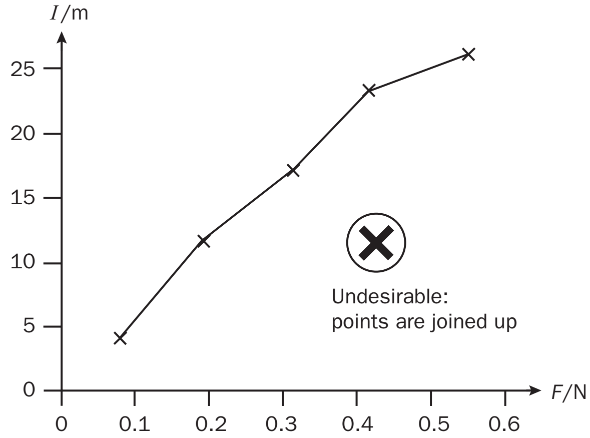

Figure 3

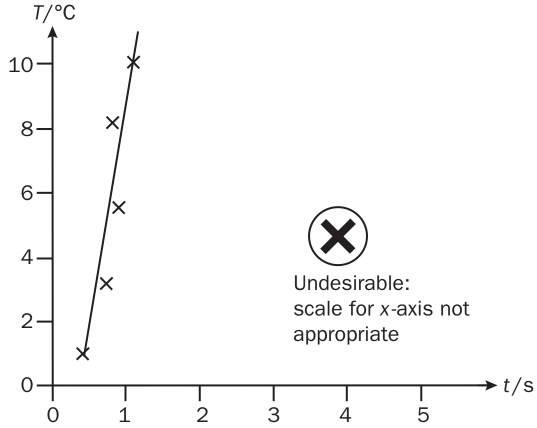

Figure 4

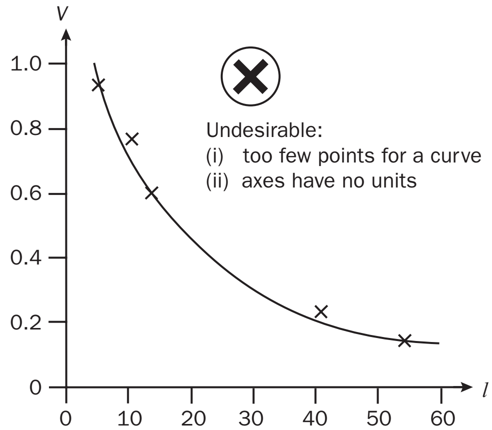

Figure 5

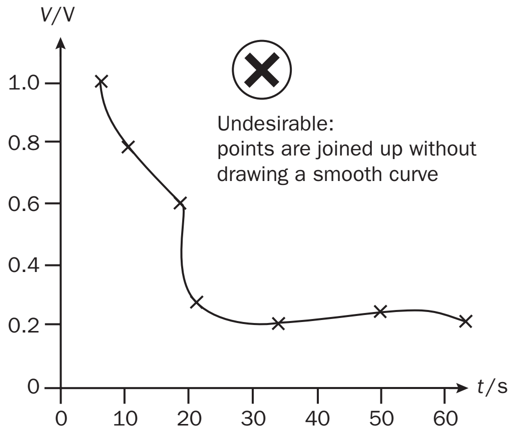

Figure 6

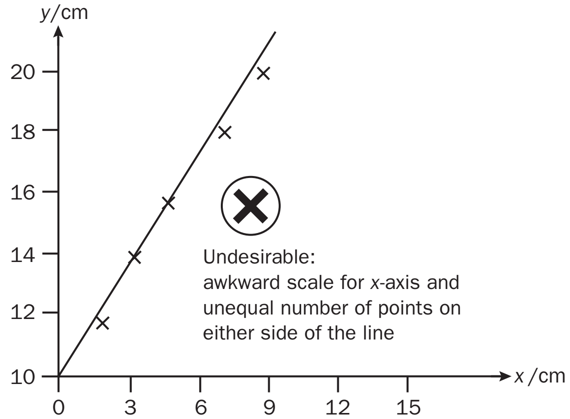

Figure 7

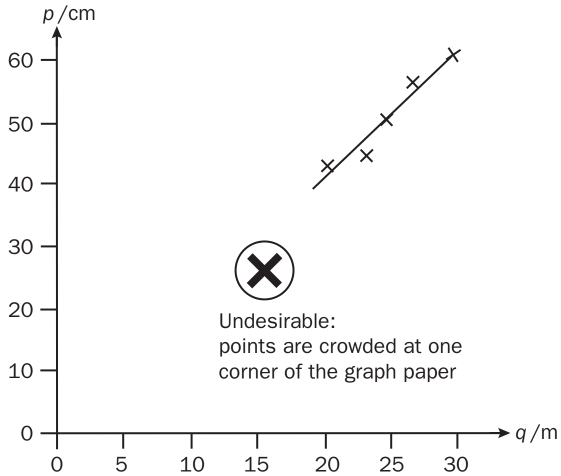

Figure 8

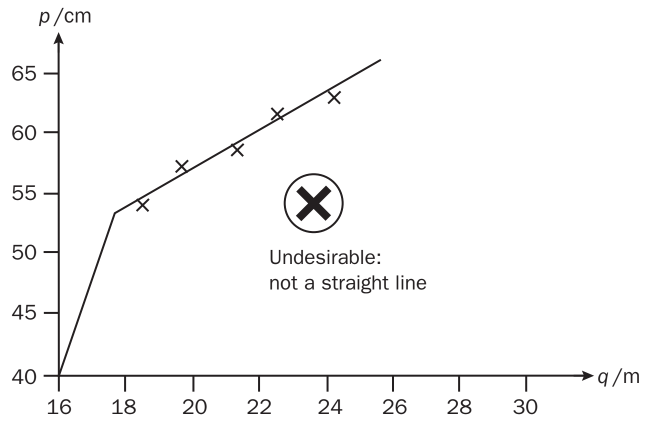

Figure 9

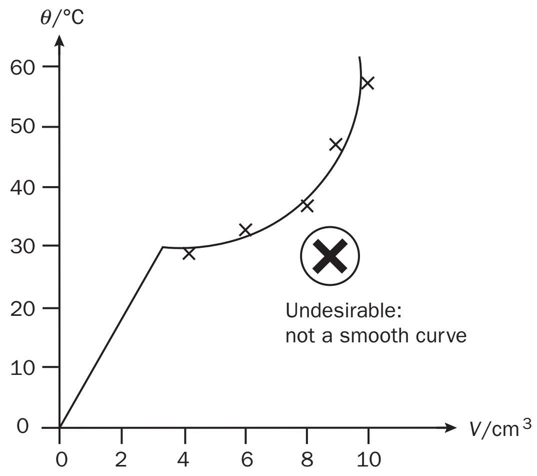

Figure 10

3 Interpreting Graphs

After you have gathered your data in an experiment, you may wish to know how two variables are related to each other. One simple way of examining the mathematical relationship between two variables is to plot a graph. The graph will indicate the general trend of the mathematical relationship between the two variables.

At the level of this course, there are two common mathematical relationships that you may encounter. If x and y are the variables that you are investigating, the two mathematical relationships are:

(a) $y = kx$ (y is directly proportional to x; k = constant);

(b) $y = \frac{k}{x}$ (y is inversely proportional to x; k = constant).

Figure 11 shows a $y = kx$ relationship. Notice that in this relationship,

- when x increases to $2x$, y increases by the same factor of 2;
- when x decreases to $\frac{1}{2}x$, y decreases by the same factor of $\frac{1}{2}$.

In this relationship, we say that y is (directly) **proportional** to x.

You may encounter some cases in which y is inversely proportional to x, i.e. $y = \frac{k}{x}$.

In such cases, the graph of y against x is a curve, which makes it difficult for us to determine the constant k. We will obtain a straight-line graph when we plot y against 1x instead of x.

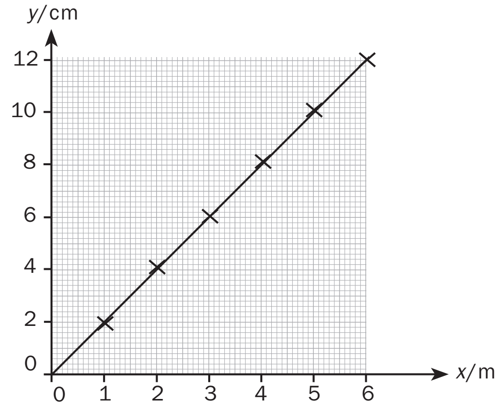

Figure 11

Quick Revision Guide

Chapter 1: Measurement of Physical Quantities

- A **physical quantity** is a quantity that can be measured. It consists of a numerical magnitude and a unit.
- **SI units** are the units of measurement in the widely used International System of Units.
- The smallest unit an instrument can measure is known as its **precision.**
- When using a metre rule, if eye level is not positioned perpendicularly to the rule, **parallax error** will be introduced.
- Taking several readings and calculating the **average** also minimises errors.
- When using the vernier calipers, we need to examine the instrument for zero error. This occurs when the zero marks on the two scales of the vernier calipers do not coincide.
- We can tell time by observing events that repeat at **regular intervals** or **periods**.
- Each complete to-and-fro motion is one oscillation.
- The **period** of a simple pendulum is the time taken for one complete oscillation.
- (S) A **scalar quantity** is a physical quantity that has **magnitude only.**
- (S) A **vector quantity** is a physical quantity that has both **magnitude and direction.**
- In a vector diagram, a vector quantity is represented by an arrow. The length of the arrow is proportional to the magnitude of the vector. The direction of the arrow indicates the direction of the vector.
- The single vector, called the **resultant vector**, must be equivalent to the individual vectors combined in terms of magnitude and direction.

Chapter 2: Motion

- **Speed** is the distance travelled per unit time.
- **Speed** $= \dfrac{\textbf{distance travelled}}{\textbf{time taken}}$
- **Average speed** $= \dfrac{\textbf{total distance travelled}}{\textbf{total time taken}}$
- **Distance** is the total length covered by a moving object regardless of the direction of motion.
- **Displacement** is the distance measured in a straight line in a specified direction.
- **Velocity** is speed in a given direction.
- **Velocity** $= \dfrac{\textbf{displacement}}{\textbf{time taken}}$
- (S) **Acceleration** is the change of velocity per unit time.
- **Acceleration,** $a = \dfrac{\textbf{change of velocity}}{\textbf{time}} = \dfrac{\Delta v}{\Delta t}$
- The gradient of a distance–time graph of an object gives the speed of the object.
- The area under a speed–time graph gives the distance travelled.
- (S) The gradient of a speed–time graph gives the acceleration of the object.
- **Acceleration due to gravity**, **g**, is a constant for objects close to the Earth's surface.
- An object can only be in **free fall** if the only force acting on it is its own weight.
- **Air resistance** is a form of frictional force.
- An object falling through air achieves a uniform velocity known as **terminal velocity** when its weight is equal to the air resistance against it.

Chapter 3: Mass, Weight and Density

- **Mass** is a measure of the quantity of matter in an object at rest relative to the observer.
- **Weight** is the gravitational force on an object that has mass.
- A **gravitational field** is a region of space in which a mass exerts a force of attraction on another mass.
- (S) The weight of an object is the effect of a gravitational field on a mass.
- **Gravitational field strength *g*** is defined as the gravitational force per unit mass.

  $g = \dfrac{W}{m}$ *where* *g = gravitational field strength (in N/kg)*
  W = weight (in N)
  m = mass of the object (in kg)
- The **density** of a substance is defined as its mass per unit volume.

  $\rho = \dfrac{m}{V}$ *where* ρ = density
  m = mass of the object
  V = volume of the object

Chapter 4: Forces

- Forces can change the size and shape of an object. They can change the motion of an object.
- We can plot the **load-extension graph** to show the relationship between the force and the extension of an elastic solid.
- (S) The **spring constant** is defined as the force per unit extension.

  $k = \dfrac{F}{x}$ where k = spring constant
  F = force
  x = extension
- (S) There is a point beyond which the extension is no longer directly proportional to the load. This point is called the **limit of proportionality**.
- A force is a vector quantity with both magnitude and direction. When more than one force acts on an object, we need to consider the direction of each force in order to determine the **resultant force**.
- A resultant force may change the velocity of an object by changing its direction of motion or its speed.
- An object either remains at rest or continues in a straight line at constant speed unless acted on by a resultant force.
- The resultant force F acting on an object of mass m is related to the acceleration of the object by the following equation:

  $F = ma$ where F = force (in N)
  m = mass (in kg)
  a = acceleration (in m/s^2)
- **Friction** is a force that impedes motion. It is a resistive force because it acts in the opposite direction to motion.
- Friction between two moving surfaces produces heating.
- **Moment of a force** is defined as the product of the force and the perpendicular distance from the pivot.

  Moment of a force $= F \times d$
  where F = force (in N)
  d = perpendicular distance from the pivot (in m)

- When the total clockwise moment is equal to the total anticlockwise moment, there is no resultant turning effect about a pivot. This is the **principle of moments**.
- When there is no resultant force and no resultant moment, an object is in **equilibrium**.
- The **centre of gravity** of an object is the point through which the weight of the object acts.
- To increase the stability of an object, its centre of gravity should be kept as low as possible and its base area should be kept as wide as possible.

Chapter 5: Momentum

- S **Momentum** is defined as the product of mass and velocity.
- **Momentum = mass × velocity**

  $p = mv$ where p = momentum
  m = mass
  v = velocity
- S **Impulse** is the product of force and the period of time for which force acts.
- S **Impulse = force × time = $F\Delta t$**
- S **Resultant force** on an object is the change in momentum per unit time.

  $F = \frac{\Delta p}{\Delta t}$
- S The **principle of conservation of momentum** states that the total momentum of two objects just before collision is the same as the total momentum of the objects immediately after the collision.

Chapter 6: Energy, Work and Power

- **Energy** is the capacity to do work.
- Energy may be stored as kinetic energy, gravitational potential energy, chemical energy, elastic (strain) energy, nuclear energy, electrostatic energy and internal (thermal) energy.
- S Kinetic energy can be calculated using

  $E_k = \frac{1}{2}mv^2$ where E_k = kinetic energy (in J)
  m = mass of the body (in kg)
  v = speed of the body (in m/s)
- S **Gravitational potential energy** can be calculated using

  $\Delta E_p = mg\Delta h$ where E_p = gravitational potential energy (in J)
  m = mass of the body (in kg)
  g = gravitational field strength (in N/kg)
  h = height (in m)
- The **principle of conservation of energy** states that energy cannot be created or destroyed. It can be converted from one form to another or transferred from one body to another. The total amount of energy remains constant.
- Energy conversions taking place can be shown using a **flow diagram**.
- S A **Sankey diagram** can be used to represent the energy conversions involving multiple stages.
- **Work done** by a constant force on an object is the product of the force and the distance moved by the object in the direction of the force.

  $W = F \times s$ where W = work done by a constant force F (in J)
  F = constant force (in N)
  s = distance moved by the object in the direction of the force (in m)
- We can obtain energy from fossil fuels, biofuels, hydropower, geothermal energy, solar energy and nuclear energy.
- S The Sun is our main source of energy for all our energy resources except for geothermal, nuclear and tidal resources.
- S The efficiency of a machine can be calculated using:

  $$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

  $$\text{Efficiency} = \frac{\text{useful power output}}{\text{power input}} \times 100\%$$
- **Power** is defined as the work done or energy transferred per unit time.

  $P = \frac{W}{t} = \frac{\Delta E}{\Delta t}$ where P = power (W)
  W = work done (J)
  ΔE = energy converted (J)
  t = time taken (s)

Chapter 7: Pressure

- **Pressure** is defined as force per unit area.

  $p = \frac{F}{A}$ where p = pressure (in Pa)
  F = force (in N)
  A = area (in m^2)
- S The change in pressure in a liquid is given by

  $\Delta p = \rho g \Delta h$ where p = pressure (in Pa)
  ρ = density (in kg/m^3)
  g = gravitational field strength (in N/kg)
  Δh = depth (in m)

Chapter 8: Kinetic Particle Model of Matter

- When a solid is heated, it **melts** into a liquid at its **melting point**. A liquid that is heated will **boil** and become a gas at its **boiling point.** When a gas is cooled to its boiling point, it will **condense** into a liquid. A liquid will **freeze/solidify** into a solid when cooled to its melting point.
- S The forces and distances between particles affects the properties of solids, liquids and gases.
- The **kinetic particle model of matter** states that the tiny particles that make up matter are always in continuous random motion.
- The lowest temperature where the particles have the least kinetic energy occurs at **–273°C**. This temperature is also known as **absolute zero.**
- **Brownian motion** refers to the *random movement* of microscopic particles in a fluid due to the collisions by the molecules of the fluid.
- The gas pressure of a gas at fixed volume and mass increases with temperature.
- The gas pressure of a fixed mass of gas at constant temperature increases when the volume decreases.
- S The decrease in the volume resulting in a proportional increase in pressure is known as **inverse proportionality**.
- For an inverse proportionality,

  $p \propto \frac{1}{V}$ or $p = \frac{k}{V}$ where p = pressure
  k = proportionality constant
  V = volume
- Temperature can also be measured using kelvin, K, which is the SI unit for temperature. The **Kelvin scale** of temperature has absolute zero as 0 kelvin, or 0K.
- To convert a temperature (θ) measured in °C into a temperature (T) in K:
- **T (in K) = θ (in °C) + 273**

Chapter 9: Thermal Properties and Temperature

- Solids, liquids and gases increase in volume or expand when heated. The greater the temperature rise, the greater the expansion. When cooled, the volume will decrease, i.e., it will contract.
- Liquids expand more than solids for the same temperature rise.
- Gases expand much more than liquids.
- The **internal energy** of a substance is the total energy of all of its particles.
- The higher the temperature of a substance (measured in °C or K), the greater the internal energy of the substance (measured in J).
- S **Specific heat capacity** c is defined as the amount of thermal energy required to raise the temperature of a unit mass (e.g. 1 kg) of a substance by 1°C (or 1 K).

  $$c = \frac{\Delta E}{m\Delta\theta}$$ where ΔE = thermal energy required (in J)
  $\Delta\theta$ = temperature change (in K or °C)
  m = mass of substance (in kg)
- The **melting point of pure water** at standard atmospheric pressure of 1 atmosphere is **0°C**.
- The **boiling point of pure water** at standard atmospheric pressure of 1 atmosphere is **100°C**
- **Evaporation** involves a change of state from liquid to gas.
- Evaporation causes cooling of a liquid.
- S Temperature, surface area and air movement over a surface affect evaporation.

Chapter 10:Transfer of Thermal Energy

- Thermal energy always flows from *a region of higher temperature* to *a region of lower temperature*. Net flow of thermal energy occurs only when there is a *difference in temperature*.
- **Conduction** is the transfer of thermal energy through solids.
- The **thermal conductivity** of a material is dependent on how quickly thermal energy is transferred from the hotter end to the colder end. Materials that can transfer thermal energy quickly are good thermal conductors, while materials that transfer thermal energy slowly are bad thermal conductors or insulators.
- **Convection** is the transfer of thermal energy in a fluid (liquid or gas) by means of convection currents due to a difference in density.
- **Thermal radiation** is the transfer of thermal energy in the form of invisible waves called infrared radiation which can travel through a vacuum.
- The amount of infrared radiation absorbed by or emitted from a surface is dependent on the **colour and texture** of the surface. Dull and black surfaces emit and absorb infrared radiation at a faster rate than shiny and silver surfaces. Shiny and silver surfaces reflect more infrared radiation.
- The higher the **surface temperature** of an object relative to the surrounding temperature, the higher the rate of emission of infrared radiation.
- When we compare two objects of the same mass and material, but with different surface areas, the object with the larger **surface area** will emit or absorb infrared radiation at a higher rate.
- The greenhouse effect is a natural process that warms the Earth's surface through a balance of absorption and emission of infrared radiation.

Chapter 11: General Properties of Waves

- **Wave motion** is made up of periodic motion or motion repeated at regular intervals.
- One complete cycle of such motion is known as an **oscillation** or a **vibration**.
- The source of a wave is a vibration or an oscillation.
- Waves transfer energy from one point to another.
- Waves transfer energy without transferring the medium.
- **Transverse waves** are waves that propagate perpendicular to the direction of the vibration.
- **Longitudinal waves** are waves that propagate parallel to the direction of the vibration.
- A **crest** is the highest point of a transverse wave.
- A **trough** is the lowest point of a transverse wave.
- The **amplitude** A of a wave is the maximum displacement of a point from its rest position.
- The **wavelength** λ of a wave is the shortest distance between any two points in phase.
- The **period** T of a wave is the time taken to produce one complete wave.
- The **frequency** f of a wave is the number of complete waves produced per second.
- **Wave speed** v is the distance travelled by a wave per second.

  $v = f\lambda$ where v = wave speed (in m/s)
  λ = wavelength (in m)
  T = period (in s)
- A **wavefront** is an imaginary line on a wave that joins all adjacent points that are in phase.
- When water waves hit a barrier, they undergo **reflection.**
- Waves undergo **refraction** when the they pass from one medium to another.
- S **Diffraction** involves the spreading out of waves when they encounter gaps and edges.

Chapter 12: Light

- **Reflection** is the rebounding of light at a surface.
- **Incident ray** is light ray that hits the reflecting surface.
- **Point of incidence** is the point at which the incident ray hits the reflecting surface.
- **Reflected ray** is light ray that bounces off the reflecting surface.
- **Normal** is the imaginary line perpendicular to the reflecting surface at the point of incidence.
- **Angle of incidence** i is the angle between the incident ray and the normal.
- **Angle of reflection** r is the angle between the reflected ray and the normal.
- The **law of reflection** states that the angle of incidence i is equal to the angle of reflection r (i.e. $i = r$).
- A plane mirror image is of the **same size** as the object, **laterally inverted**, **upright**, **virtual** and **same distance** from the mirror as the object.
- A **real** image can be captured on a screen and the light rays meet at the image position.
- **Refraction** is the bending of light as it passes from one optical medium to another.
- **Angle of refraction** r is the angle between the refracted ray and the normal.
- S The **law of refraction** states that, for two given media, the ratio of the sine of the angle of incidence, i, to the sine of the angle of refraction, r is a constant. This is also known as **Snell's Law**.

  $$\frac{\sin i}{\sin r} = \text{constant}$$
- S The **refractive index** n is the ratio of the speeds of a wave in two different regions.

- $n = \frac{\sin i}{\sin r}$ where i = angle of incidence in vacuum
  r = angle of refraction in the medium
- The **critical angle** *c* is defined as the angle of incidence in an optically denser medium for which the angle of refraction in the optically less dense medium is 90°.
- **Total internal reflection** is the complete reflection of a light ray inside an optically denser medium at its boundary with an optically less dense medium.
- **S** Relationship between the critical angle *c* and the refractive index *n* of an optical medium:

  $\sin c = \frac{1}{n}$
- A **converging lens** causes light rays to converge to a point. It is *thicker in the centre*.
- A **diverging lens** causes light rays to diverge from a point. It is *thinner in the centre*.
- **Focal length** *f* is the distance between the optical centre C and the focal point F.
- The **principal axis** is the horizontal line passing through the optical centre of the lens. It is perpendicular to the vertical plane of the lens.
- The **principal focus (or focal point)** is the point at which all rays parallel to the principal axis converge after refraction by the lens. A lens has two focal points, one on each side of the lens.
- The different colours of light observed is called a **spectrum**
- This change in refractive index across the spectrum is known as **dispersion**.
- **S** Any single frequency of light is described as **monochromatic**.

Chapter 13: Electromagnetic Spectrum

- Light from the Sun travels as electromagnetic waves. These waves are of different types and they make up the **electromagnetic spectrum**.
- Waves with higher wavelength have lower frequencies.
- All electromagnetic waves travel at the **same high speed** in a vacuum.
- **S** The speed of electromagnetic waves in a vacuum is $\mathbf{3 \times 10^8}$ **m/s**.
- **S** An **analogue signal** has continuous values in time.
- **S** A **digital signal** has fixed values. For example, it can have two values of 1 and 0.

Chapter 14: Sound

- **Sound** is a form of energy that is transferred from one point to another.
- Sound is produced by **vibrating sources** placed in a medium. The medium is usually air, but it can be any gas, liquid or solid.
- **S** **Compressions** are regions where air pressure is higher than the surrounding air pressure.
- **S** **Rarefactions** are regions where air pressure is lower than the surrounding air pressure.
- For humans, the audible sound range is from **20 Hz to 20 000 Hz**.
- Sound waves need a medium to travel from one point to another.
- **S** In general, sound travels faster in solids than in liquids and faster in liquids than in gases.
- An **echo** is a reflection of sound waves. It is formed when a sound is reflected off hard, flat surfaces.
- **Ultrasound** is sound with a frequency higher than 20 kHz.
- **S** Ultrasound is used in testing materials for quality control, medical scanning and sonar technologies.
- **Pitch** is related to the frequency of a sound wave — the higher the frequency, the higher the pitch.
- **Loudness** is related to the amplitude of a sound wave — the larger the amplitude, the louder the sound.

Chapter 15: Simple Phenomena of Magnetism

- **Magnetic materials** are materials that can be attracted to a magnet.
- **Non-magnetic materials** are materials that cannot be attracted to a magnet.
- Like poles **repel**, unlike poles **attract**.
- The process of magnetising a magnetic material is known as **magnetic induction**. When the magnetic material has become magnetised, we say that it has become an **induced magnet**.
- A **magnetically soft** material can be easily magnetised and also lose its magnetism easily. A **magnetically hard** material is difficult to magnetise, but once magnetised, retains its magnetism afterwards.
- Every magnet has a region of space around it called a **magnetic field.**
- A magnetic material or magnetic pole placed in the magnetic field will experience a force.
- The arrangement of a group of magnetic field lines is called a **magnetic field pattern**.
- The *direction* of the magnetic field lines at a point is the direction of the force on the N pole of a magnet at that point.
- **S** The *relative strength* of a magnetic field is dependent on how closely packed the magnetic field lines are.
- **S** Magnetic forces are due to interactions between magnetic fields.

Chapter 16: Electrical Quantities

- In an atom, there is a central **nucleus**. The nucleus is made up of **protons** and **neutrons**. Around the nucleus are the orbiting **electrons**. There are positive and negative charges in the atom. Protons are the positive charges while electrons are the negative charges.
- Positive charges repel other positive charges. Negative charges repel other negative charges. Positive charges attract negative charges.
- **S** An **electric field** is a region in which an electric charge experiences a force.
- **S** The direction of an electric field at a point is the direction of the force on a positive charge at that point.
- Electric current is related to the flow of charge.
- **S** **Electric current** is the charge passing a point per unit time.

  $I = \frac{Q}{t}$ where I = current (in A)
  Q = charge (in C)
  t = time taken (in s)
- **S** **Conventional current** is from positive to negative and that the flow of free electrons is from negative to positive.
- An **ammeter** is used to measure the magnitude and direction of an electric current in an electric circuit.
- **Direct current (d.c.)** flows in a single direction only, whereas **alternating current (a.c.)** changes direction frequently.
- **Electromotive force (e.m.f.)** is the electrical work done by a source in moving a unit charge around a complete circuit.

  S $E = \frac{W}{Q}$ where E = e.m.f (in V)
  W = work done (in J)
  Q = charge (in C)
- **Potential difference (p.d.)** is the work done by a unit charge passing through a component.

Ⓢ $V = \frac{W}{Q}$ where V = p.d. (in V)
W = work done (in J)
Q = charge (in C)

- A **voltmeter** is used to measure the e.m.f. of a dry cell or the p.d. across a component.
- The **resistance** R of a component is the potential difference V across it divided by the current I flowing through it.

Ⓢ $R = \frac{V}{I}$ where R = resistance of the component (in Ω)
V = p.d. across the component (in V)
I = current flowing through the component (in A)

- **Ohm's Law** states that the current passing through a metallic conductor is directly proportional to the potential difference across it, provided that physical conditions (such as temperature) remain constant.
- The resistance R of a conductor depends on its temperature, length l and cross-sectional area A (or thickness).
- **Electrical power** P can be expressed as follows:
  $P = IV$ where P = power (in W)
  I = current (in A)
  V = potential difference (in V)
- **Electrical energy** E can be expressed as follows:
  $E = Pt = IVt$ where E = electrical energy (in J)
  P = power (in W)
  t = time (in s)
  I = current (in A)
  V = potential difference (in V)

Chapter 17: Electric Circuits and Electrical Safety

- We use circuit diagrams to represents electric circuits.
- Ⓢ Diodes are components that allow current to flow through them in one direction only.
- In a **series circuit**, the components are connected one after another in a single loop. A series circuit has only one path through which electric charge can flow. The current at every point in a given series circuit is the same.
- Ⓢ For n resistors placed in series, the p.d. V_E across the whole circuit (i.e. across all of the components) is equal to the sum of the p.d.s across each component.
  $V_E = V_1 + V_2 + \ldots + V_n$
- For n resistors in placed in series, the combined resistance is the sum of all the resistances.
  $R = R_1 + R_2 + \ldots + R_n$
- In a **parallel circuit**, the components are connected to the e.m.f. source in two or more loops. A parallel circuit has *more than one path through which electric charge can flow*.
- For n branches in parallel, the main current I is the sum of all the current in each branch.
  $I = I_1 + I_2 + \ldots + I_n$
- Ⓢ The reciprocal of the combined resistance of resistors in parallel, $\frac{1}{R}$, is equal to the sum of the reciprocal of all the individual resistances.
  $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$
- A **potential divider** is a line of resistors connected in series. It is used to provide a fraction of the available p.d. from a source to another part of the circuit.
- The equation for two resistors used as a potential divider is as follows:
  $\frac{R_1}{R_2} = \frac{V_1}{V_2}$ where V_1 = p.d. across R_1 and V_2 = p.d. across R_2
- Potential dividers that are used to *vary* the output voltage from a source are called **variable potential dividers**.
- **Input transducers** are electronic devices that respond to changes in physical conditions, such as temperature and light. They can be used in potential dividers to vary the output voltage.
- A **thermistor** is a resistor whose resistance varies with temperature. An NTC thermistor has resistance that decreases as its temperature increases.
- A **light-dependent resistor (LDR)** has a resistance that decreases as the amount of light shining on it increases, and vice versa.
- **Trip switches** are safety devices that can switch off the electrical supply in a circuit when large currents flow through them.
- A **fuse** is a safety device added to an electrical circuit to prevent excessive current flow.
- **Switches** are designed to break or complete an electrical circuit.
- The **live wire** (brown) is connected to a high voltage and delivers current to the appliance. This is the wire to which trip switches, fuses and switches are fitted.
- The **neutral wire** (blue) completes the circuit by providing a return path to the supply for the current. It is usually at 0 V.
- The **earth wire** (green and yellow) is a low-resistance wire. It is usually connected to the metal casing of appliances.
- A fused plug connects an electrical appliance to the mains supply via the power socket. The fused plug commonly used in some countries is the **three-pin plug**.
- **Double insulation** is a safety feature that can replace the earth wire.

Chapter 18: Electromagnetic Effects

- **Electromagnetic induction** is the process through which an induced e.m.f. is produced in a conductor due to a *changing magnetic field*.
- **Faraday's Law** of electromagnetic induction states that the magnitude of the induced e.m.f. in a circuit is directly proportional to the rate of change of magnetic flux in the circuit.
- Ⓢ **Lenz's Law** states that the direction of the induced e.m.f., and hence the induced current in a closed circuit, is always such that its magnetic effect opposes the motion or change producing it.
- Ⓢ The **alternating current (a.c.) generator** uses alternating current to transform mechanical energy into electrical energy.
- In a simple a.c. generator, the direction of the induced current flowing in the coil can be found using **Fleming's right-hand rule**.
- In **a fixed coil a.c. generator**, the magnets rotate with respect to fixed coils.
- **Electromagnetism** is the relationship between electricity and magnetism.
- A current-carrying conductor produces a magnetic field around it. We can determine the direction of the magnetic field around the wire using the **right-hand grip rule**.
- Ⓢ The strength of the magnetic field of a current-carrying wire increases when the current is increased.
- Ⓢ We can deduce the direction of the force acting on a current-carrying conductor in a magnetic field using **Fleming's left-hand rule**.
- Conductors carrying currents in opposite directions repel.

- Conductors carrying currents in the same direction attract.
- The direction of the force on a beam of charged particles is reversed when we reverse the direction of the magnetic field.
- A current-carrying wire coil placed between two poles of a strong magnet experiences a **turning effect**.
- A **d.c. motor** is used to convert electrical energy to mechanical energy.
- A **transformer** is a device that can change a high alternating voltage (at low current) to a low alternating voltage (at high current), or vice versa. It has a **primary coil** and a **secondary coil** wound around a laminated soft iron core.
- Electrical energy is transferred from the primary coil to the secondary coil in a transformer. The voltages and the number of turns in the primary and secondary coils are related by this formula:

  $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ where V_S = secondary (output) voltage (in V)
  V_P = primary (input) voltage (in V)
  N_S = number of turns in secondary coil
- In a **step-up** transformer, the number of turns in the secondary coil is greater than that in the primary coil. This results in an output voltage that is higher than the input voltage.
- In a **step-down** transformer, the number of turns in the secondary coil is less than that in the primary coil, so that the output voltage produced is lower than the input voltage.
- S In an ideal transformer, there is no power loss (i.e. the efficiency is 100%). The power supplied to the primary coil is fully transferred to the secondary coil.

  $I_pV_p = I_sV_s$ where V_s = secondary (output) voltage (in V)
  V_p = primary (input) voltage (in V)
  I_s = current in secondary coil (in A)
  I_p = current in primary coil (in A)
- The efficiency of a transformer can be calculated using the following equation:

  Efficiency = $\frac{\textbf{output power}}{\textbf{input power}}$ **100%**

Chapter 19: Nuclear Model of the Atom

- An **atom** consists of a positively charged nucleus and negatively charged electrons in orbit around the nucleus.
- An atom which loses electrons has more positive charges – it becomes a **positive ion**.
- An atom which gains electrons has more negative charges – it becomes a **negative ion**.
- The scattering of alpha (α-) particles by a sheet of thin metal provide evidence to support the nuclear model of the atom.
- The **nucleus** of an atom consists of **protons** (positively charged) and **neutrons** (no charge).
- The **relative charge of an electron is –1** (because it is negative) and the **relative charge of a proton is +1**. As the neutron does not carry any charge, the **relative charge of a neutron is 0**.
- The number of protons in an atom is called the **proton number** or atomic number, represented by *Z*.
- The total number of neutrons and protons in a nucleus is called the **nucleon number**, represented by *A*.
- **The number of neutrons in a nucleus = nucleon number *A* – proton number *Z***.
- **Isotopes** of an element are the atoms that have the same number of protons but different number of neutrons in the nucleus.
- S **Nuclear fission** is a process in which the nucleus of an atom splits (usually into two parts) and releases a huge amount of energy.
- S The **relative charge on the nucleus** is the same as the proton number *Z* of the nucleus.
- S **Nuclear fusion** is a process in which two light atomic nuclei combine to form one heavier atomic nucleus, releasing a huge amount of energy.
- S The total number of nucleons before and after the a nuclear fission or fusion reaction is the same. The total relative charge before and after should also be the same.

Chapter 20: Radioactivity

- **Ionising radiation** is radiation with high energies that can *knock off electrons from atoms to form ions*.
- **Background radiation** is ionising nuclear radiation in the environment when no radioactive source is deliberately introduced.
- The background count rate is measured in **counts per minute (counts/min)**.
- When carrying out any measurements with radioactive sources, you should first measure the background radiation. Subtract this background count rate from your measurements to obtain the corrected count rate for the radioactive source.
- The radiation emitted by a radioactive nucleus is **spontaneous and random** in direction.
- An **α-particle** consists of two protons and two neutrons tightly bound together without any orbiting electrons. It is Identical to a helium nucleus.
- A **β-particle** is a fast-moving electron ejected from a radioactive nucleus.
- A **γ-ray** is an electromagnetic radiation emitted by a nucleus with excess energy.
- A change in an unstable nucleus can result in the emission of α-particles or β-particles and/or γ-radiation. This nuclear process is called **radioactive decay**.
- When a nucleus undergoes **α-decay**, it emits an α-particle. When a nucleus undergoes **β-decay**, it emits a β-particle.
- During α- or β-decay, the nucleus changes to that of a different element.
- The **half-life** of a radioactive isotope is the time taken for half the nuclei of that isotope in any sample to decay.
- The graph of count rate against time is called the **decay curve**.
- Applications of radioactivity include household fire alarm, sterilisation of food and equipment, measuring and controlling thickness of materials
- S Ionising nuclear radiation damages living cells. The energy carried by the radiation *can kill cells and cause mutation and cancer.*
- S Exposure to ionising radiation can be controlled by *reducing exposure time, increasing distance between source and living tissue* and *shielding*.

Chapter 21: Earth and the Solar System

- The Earth is a **planet**. Planets orbit a star. Our star is the Sun.
- The Earth takes about 365 days or one **year** to orbit the Sun.
- The Earth also rotates on its axis and it takes about 24 hours or one **day** *to rotate once*. The Earth's *axis is tilted* at an angle of about 23.5 degrees towards the plane of its orbit.
- The day and night cycle is due to the Earth's rotation about its tilted axis.
- On the Earth, we see the Sun move across the sky from East to West. This apparent movement is because the Earth is spinning about its axis as it orbits the Sun.

- Temperate countries have different weather patterns at different times of the year. These weather patterns are called the **seasons**.
- Seasons occur because the Earth orbits the Sun on a tilt.
- The Earth has one *natural satellite* called the **Moon**.
- The different appearances of the Moon in the sky are known as the **phases of the Moon**.
- S The Moon's **average orbital speed** around the Earth:

$$\boldsymbol{v = \frac{2\pi r}{Q}}$$

where v = average orbital speed (in m/s)
r = average orbital radius
T = orbital period

- The Solar System was formed from a swirling cloud of gas and dust in space called **nebula.**
- A hot spinning mass called a **protostar** was formed at the centre of a swirling disc of gas and dust. The swirling disc is called an **accretion disc**.
- **Accretion** is the accumulation of particles into a massive object by gravitational attraction.
- S Objects in the Solar System move in an **elliptical orbit**.
- S As the distance of planets from the Sun increases, the orbital speed decreases due to decreasing gravitational field of the Sun. This means the time to orbit the Sun also increases.

Chapter 22: Stars and the Universe

- The Sun is an average yellow star consisting of mostly hydrogen and helium.
- The Sun radiates the energy in the form of electromagnetic radiation — mostly infrared, visible light and ultraviolet.
- S Stars are powered by nuclear reactions that release energy.
- S In stable stars, the nuclear reactions involve the fusion of hydrogen into helium.
- The **Milky Way** is a group of many billions of stars or a galaxy to which our Sun belongs.
- S One **light-year** is equal to 9.5×10^{15} m.
- **Redshift** is the increase in the observed wavelength of electromagnetic radiation emitted from stars and galaxies which are moving away from the Earth.
- At some moment in the past, all of the matter in the Universe must have exploded outwards from this point and it is still expanding. This is known as the **Big Bang Theory** of the Universe.
- S If the Big Bang Theory is correct, the Universe should now be filled with microwaves. These microwaves are called the **cosmic microwave background radiation** or **CMBR**.
- S The **Hubble constant H_0** is defined as the ratio of the speed at which the galaxy is moving away from the Earth to its distance from the Earth.

$$\boldsymbol{H_0 = \frac{v}{d}}$$

where H_0 = Hubble constant
v = speed of movement away from the Earth
d = distance from the Earth

- S The current estimate of H_0 is **2.2×10^{-18} per second**.

Answers

This section only includes short and numerical answers.

Chapter 1: Measurement of Physical Quantities

Quick Check

p. 4: True p. 9: False p. 12: True

Let's Practise 1.1

1 1.0×10^{-5} m **2** 2.53 cm **3 (a)** m^3 **5** 4 s

Let's Practise 1.2

2 25 N, at 36.9 (anticlockwise) from the 20 N

Let's Review

Section A: Multiple-choice Questions

1 B **2** B **3** D **4** D **5** A

Section B: Short-answer and Structured Questions

1 (a) Length; Five; Metres **(b)** Time; Two; Seconds
(c) Mass; One thousand; Kilograms
2 (a) 2.05 cm
(b) Vernier calipers: 0.01 cm; Metre rule: 0.1 cm
4 $g = 9.9$ m/s^2
5 4243 N

Chapter 2: Motion

Quick Check

p.19: False p.21: False p.22: True p. 24: True; True
p. 26: True p. 31: True

Let's Practise 2.1

1 8 m/s **2** 0.6 m/s^2

Let's Practise 2.2

1 (a) $s = 0$ m; $v = 0$ m/s **(b)** $s = 160$ m; $v = 10$ m/s
(c) $s = 280$ m; $v = 0$ m/s

Let's Practise 2.3

1 (b) 50 m/s **(c)** 125 m

Let's Review

Section A: Multiple-choice Questions

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

Section B: Short-answer and Structured Questions

1 40 km/h
2 (a) 3 m/s^2 **(b)** Acceleration is zero **(c)** 2 m/s^2
(d) Acceleration is zero **(e)** Non-uniform deceleration
3 (a) The train is decelerating from $t = 12$ s to $t = 16$ s.
(b) 20 m/s^2
(c) (i) 520 m **(ii)** 32.5 m/s

Chapter 3: Mass, Weight and Density

Quick Check

p. 39: True p. 42: False

Let's Practise 3.1

3 100 N **4** 2.75×10^3 N

Let's Practise 3.2

1 density $= \frac{\text{mass}}{\text{volume}}$; SI unit: kg/m^3
2 1 cm^3 of water has a mass of 1.0 g
4 0.92 g/cm^3

Let's Review

Section A: Multiple-choice Questions

1 C **2** D **3** C

Section B: Short-answer and Structured Questions

2 (a) No change **(b)** No change
(c) Decrease **(d)** Increase
3 (a) No **(b) (i)** 0.518 cm^3 **(ii)** The piece of gold will sink.
4 (a) 14 900 g **(b)** 3000 cm^3 **(c)** 2 cm^2
5 (a) No

Chapter 4: Forces

Quick Check

p. 52: False p. 57: False p. 61: True p. 65z; True

Let's Practise 4.1

1 (a) 4.0 cm **(c)** N/cm **(d)** 7.0 cm

Let's Practise 4.2

1 (a) False **(b)** False **(c)** False **(d)** True **(e)** True
(f) True **(g)** False **(h)** False **(i)** False **(j)** True

Let's Practise 4.3

1 Moment = force × perpendicular distance from the pivot
2 no resultant force; no resultant moment
3 (a) 30 cm **(b)** 300 N m **(c)** 87.5 cm
4 320 N

Let's Practise 4.4

1 The centre of gravity of an object is the point through which the weight of the object acts.
2 Yes

Let's Review

Section A: Multiple-choice Questions

1 B **2** D **3** C **4** A **5** D **6** C **7** C

Section B: Short-answer and Structured Questions

1 (a) 5 N **(b)** 50 N
2 (a) N m
(b) (i) No resultant force and no resultant moment.
(ii) 2.5 m
3 (a) 30 000 N m **(b)** 7500 N **(c)** 2.4 m
4 200 N

Chapter 5: Momentum

Quick Check

p. 73: True p. 77: True p. 80: False

Let's Practise 5.1

1 mass × velocity **2** kg m/s
3 Vector **4** 4.8 kg m/s

Let's Practise 5.2

1 force × time **2** N s or kg m/s **3** Vector
4 momentum; time **5** 6 N s

Let's Practise 5.3

2 3.8 m/s

Let's Review

Section A: Multiple-choice Questions

1 A **2** C **3** D **4** D **5**

Section B: Short-answer and Structured Questions

1 (a) mass × velocity **(b) (i)** 16 000 kg m/s **(ii)** 1.6 m/s
2 (a) 80 kg m/s **(b)** 80 N s **(c)** 40 m/s
3 (a) 40 kg m/s **(b)**–40 kg m/s **(c)** –0.8 m/s

Chapter 6: Energy, Work and Power

Quick Check

p. 88: True p. 92: True p. 96: True

Let's Practise 6.1
1 **(a)** Electrical energy → Thermal energy
(b) Chemical potential energy → Electrical energy → Light and heat energy
3 Kinetic energy → Gravitational potential energy → Kinetic energy
4 **(a)** 900 J **(b)** 30 m/s

Let's Practise 6.2
3 **(a)** 24 J **(b)** 24 J **4** **(a)** 500 J **(b)** 500 J

Let's Practise 6.3
1 Combustion of fuel **2** **(a)** Nuclear fission
3 Only 45% of the input energy is converted into useful output.
4 70%

Let's Practise 6.4
2 100 W **3** 1.8 MJ
4 The 1000 W kettle will take half the time it takes for the 500 W kettle to bring the water to a boil.

Let's Review
Section A: Multiple-choice Questions
1 B **2** B **3** C **4** A **5** B

Section B: Short-answer and Structured Questions
1 **(b)** Gravitational potential energy **(c)** Kinetic energy
2 **(b)** **(i)** Nuclear energy; Fossil fuels; Biofuels
3 **(a)** 2×10^{-3} J **(b)** 1.5×10^{-3} J
4 **(b)** **(i)** 9 J **(ii)** 12 J **(iii)** 75%
5 **(a)** **(i)** 300 kJ **(b)** **(i)** 240 kJ **(ii)** 17.9 m s^{-1}
6 **(a)** **(i)** P = 30.4%; Q = 12.5%; R = 40.4%; S = 35.7%; T = 20.5%
(b) 868.1 MJ

Chapter 7: Pressure
Quick Check
p. 105: True p. 107: False p. 109: True

Let's Practise 7.1
1 Pressure = $\frac{\text{force}}{\text{area}}$
3 **(a)** 50 N **(b)** 0.562 m^2 **(c)** 0.75 m **4** Upright

Let's Practise 7.2
1 Density of the liquid; Depth of the liquid in which the object is being immersed in
2 **(a)** greater **(b)** smaller **3** $\Delta p = \rho g \Delta h$
4 51 250 Pa

Let's Review
Section A: Multiple-choice Questions
1 C **2** D **3** C

Section B: Short-answer and Structured Questions
2 **(a)** The pressure on the ball bearing increases.
(b) The change in pressure is greater.
3 **(a)** 2500 Pa or N/m^2 **(b)** 968 Pa or N/m^2

Chapter 8: Kinetic Particle Model of Matter
Quick Check
p. 113: True p. 118: False p. 121: True

Let's Practise 8.1
1 **(a)** A gold ring has a fixed shape.
(b) Milk has no fixed shape.
(c) Air can be compressed.

Let's Practise 8.3
2 **(b)** $pV = k$ or pV = constant

Let's Review
Section A: Multiple-choice Questions
1 A **2** D **3** B **4** D **5** B

Section B: Short-answer and Structured Questions
1 **(a)** Smoke particles
3 **(a)** The pressure will be doubled to 2×10^5 Pa
(b) 1.2×10^5 Pa **(c)** 170 cm^3

Chapter 9: Thermal Properties and Temperature
Quick Check
p.128: False p.131: False p.139: True

Let's Practise 9.1
1 Expansion can cause metal railway lines to buckle.
2 Thermal energy causes them to expand and become longer.

Let's Practise 9.2
1 **(a)** Increase **(b)** Increase **(c)** Decrease **(d)** Increase
3 1111 J/(kg K)

Let's Practise 9.3
4 Any two of the following: Windy day; Sunny day; Hot day
5 Difference: Boiling occurs throughout the liquid, evaporation takes place at the surface; Similarity: Both evaporation and boiling involve a liquid changing into a gas. (Accept other possible answers.)

Let's Review
Section A: Multiple-choice Questions
1 A **2** D **3** C **4** C **5** A

Section B: Short-answer and Structured Questions
1 **(b)** Liquid-in-glass thermometer
2 **(a)** **(ii)** Solidifying/Freezing **(b)** 60°C
3 **(a)** 50 J **(b)** 12.5°C **4** 400 J/(kg K)

Chapter 10: Transfer of Thermal Energy
Quick Check
p. 146: True p. 147: False p. 148: True p. 151: True

Let's Practise 10.1 and 10.2
1 Through conduction, convection and/or radiation

Let's Practise 10.3
1 **(a)** The density of the material decreases.

Let's Practise 10.4
1 Infrared radiation
2 Dark colours are good absorbers of infrared radiation.
4 Any three of the following: Colour of the surface; Texture of the surface; Surface area; Surface temperature

Let's Practise 10.5
1 **(a)** **(i)** Conduction **(ii)** Convection

Let's Review
Section A: Multiple-choice Questions
1 D **2** C **3** B

Section B: Short-answer and Structured Questions
1 **(c)** The hot tea will emit infrared radiation to its surroundings.
3 **(d)** Cork is a bad thermal conductor. It is used to reduce thermal energy transfer by conduction.

Chapter 11: General Properties of Waves
Quick Check
p.164: False p.167: False p.170: False; True p.174: False

Let's Practise 11.1
1 **(a)** Incorrect **(b)** Correct **(c)** Correct

2 **(b)** Transverse waves: sea waves; Longitudinal waves: sound waves

Let's Practise 11.2
1 **(a)** 0.1 s **(b)** 10 Hz **(c)** 0.1 cm
2 $v = f\lambda$ **3** $T = 2.0$ s

Let's Practise 11.3
1 **(a)** The water waves have diffracted through the gaps.

Let's Review
Section A: Multiple-choice Questions
1 B **2** D **3** D **4** C **5** C **6** C **7** D

Section B: Short-answer and Structured Questions
1 **(a)** It means two complete waves per second.
(b) **(ii)** $f = 10$ Hz
2 **(a)** 2 Hz **(b)** $\lambda = 1.5$ m
5 **(a)** 0.6 m **(b)** 5 m **(c)** **(i)** 1.25 s **(ii)** 0.8 Hz **(iii)** 4 m/s

Chapter 12: Light

Quick Check
p. 188: True p. 195: False p. 205: True

Let's Practise 12.1
2 Upright; Laterally inverted; Same size as the object; Virtual; Same distance from the mirror as the object
3 **(b)** The image is upright, laterally inverted, virtual, the same size as the object, and the same distance from the mirror as the object.
4 6.5 m

Let's Practise 12.2
2 Refractive index $n = \frac{\sin i}{\sin r} = \frac{c}{v}$

Let's Practise 12.3
3 $c = 31.8°$ **4** Glass prisms and optical fibres

Let's Practise 12.6
1 Violet, indigo, blue, green, yellow, orange, and red.
2 Red

Let's Review
Section A: Multiple-choice Questions
1 B **2** B **3** D **4** C **5** D **6** D **7** D **8** B **9** C
10 D **11** B **12** B **13** B **14** B **15** C

Section B: Short-answer and Structured Questions
1 **(a)** **(ii)** Upright; Laterally inverted; Same size as the object; Virtual; Same distance from the mirror as the object
(b) 30 m **2** **(b)** **(i)** $n = 1.46$ **(ii)** $x = 20°$; $y = 30°$
3 **(a)** **(i)** Diamond **(ii)** Air **(b)** $v = 1.76 \times 10^8$ m/s **(c)** 1.5
4 **(a)** Angle of refraction in air = 62.9° **(b)** $c = 48.8°$
5 **(a)** $r = 28.1°$ **7** **(a)** **(i)** 75 cm **(ii)** 70 cm **(b)** 2 m/s
8 **(b)** 220 cm **9** **(b)** Angle of refraction at Q is 28°.

Chapter 13: Electromagnetic Spectrum

Quick Check
p. 218: False; True

Let's Practise 13.1
1 **(a)** Gamma rays **(b)** Radio waves
2 **(a)** Radio waves **(b)** Gamma rays

Let's Practise 13.2
1 **(b)** Visible light; Radio waves
2 Microwaves
3 **(a)** Direct satellite television and satellite phones
(b) Satellite phones

Let's Practise 13.3
1 **(a)** 3×10^8 m/s **(b)** 3×10^8 m/s **(c)** 3×10^8 m/s
(d) 3×10^8 m/s
2 Can pass through some walls, only a short aerial is needed
3 Visible light; Infrared

Let's Review
Section A: Multiple-choice Questions
1 C **2** C **3** B **4** D **5** A **6** D

Section B: Short-answer and Structured Questions
1 **(a)** A: Infrared; B: Ultraviolet; C: Gamma rays; D: Frequency
2 **(a)** 3.75×10^8 m **(b)** 30 m
3 **(a)** A

Chapter 14: Sound

Quick Check
p. 225: False p. 227: False p. 232: True

Let's Practise 14.1
2 Yes

Let's Practise 14.2
1 No **2** 333 m/s

Let's Practise 14.3
1 750 m
2 Ultrasound is less hazardous than X-rays due to its lower energy.

Let's Practise 14.4
1 **(a)** Amplitude **(b)** Frequency

Let's Review
Section A: Multiple-choice Questions
1 C **2** C **3** B **4** D

Section B: Short-answer and Structured Questions
3 **(a)** 329 m/s
4 **(a)** Dogs can detect sound of frequencies above 20 000 Hz.
5 **(b)** Depth of seabed = 225 m
6 **(b)** He will not succeed.

Chapter 15: Simple Phenomena of Magnetism

Quick Check
p. 240: True p. 241: False p. 246: False

Let's Practise 15.1
1 **(a)** Any three of the following: Iron; Steel; Cobalt; Nickel
(b) Any three of the following: Copper; Wood; Plastic; Brass
3 **(a)** Wood does not completely block the magnetic field.

Let's Practise 15.2
1 Metal 1: Iron Metal 2: Steel Metal 3: Brass

Let's Review
Section A: Multiple-choice Questions
1 C **2** D **3** C

Section B: Short-answer and Structured Questions
1 **(c)** Iron

Chapter 16: Electrical Quantities

Quick Check
p. 258: False p. 261: False p. 263: True p. 265: False
p. 267: True

Let's Practise 16.1
1 Positive charges and negative charges

2 (a) The two rods attract each other.

Let's Practise 16.2
1 The two directions are the same.

Let's Practise 16.3
1 $I = \frac{Q}{t}$ **2** Ampere **3** 6.25×10^{18} electrons

Let's Practise 16.4
2 (a) 48 C **(b)** 144 J

Let's Practise 16.5
1 As the temperature increases, the resistance increases.

Let's Practise 16.6
1 2.16 kW **2** $26.24

Let's Review
Section A: Multiple-choice Questions
1 B **2** B **3** C **4** B **5** D **6** B **7** D

Section B: Short-answer and Structured Questions
1 (b) 16.2 kWh
2 (a) Wire A = 10 W; Wire B = 4 W **(b)** Wire A is longer than wire B.
(c) Wire A = 0.5 A; Wire B = 1.25 A
3 (b) (i) 2×10^{-3} A
4 (b) (i) 32 **(ii)** 0.53 A **(iii)** 22.5 Ω
6 (a) Conductor A = 15.0 Ω; Conductor B = 3.3 Ω
(b) (i) Conductor B

Chapter 17: Electrical Circuits and Electrical Safety
Quick Check
p. 277: True p. 278: False p. 280: False p. 287: False
p. 291: False

Let's Practise 17.2 and 17.3
1 (a) 25 Ω **(b)** I_1= 0.1 A; I_2= 0.3 A **(c)** 17 Ω **(d)** 75 Ω

Let's Practise 17.4
1 1 V at 0°C; 4 V at 100°C

Let's Review
Section A: Multiple-choice Questions
1 C **2** D **3** C **4** D **5** D **6** B **7** B
8 A **9** A **10** B **11** A

Section B: Short-answer and Structured Questions
1 (a) 1.3 Ω **(b)** 2 Ω **(c)** 3.3 Ω **(d)** 1.2 A
2 (a) 0.2 A **(b)** 0.6 A **(c)** 4 Ω
4 (a) There is no resistance between B and C.
(b) (i) 200 Ω **(ii)** 80 Ω
(c) The fault lies between C and D.
(d) (i) 500 Ω **(ii)** 75 Ω **(iii)** 50 Ω
(e) 100 Ω

Chapter 18: Electromagnetic Effects
Quick Check
p. 306: True p. 312: False p. 317: False
p. 321: False p. 323: True

Let's Practise 18.1
1 (a) The galvanometer needle is deflected to the left.
(c) An S pole is induced at end A.

Let's Practise 18.2
1 Slip rings; carbon brushes

Let's Practise 18.3
2 (b) Increase the number of turns per unit length of the solenoid; increase the magnitude of the current; place a soft iron core in the solenoid to concentrate the magnetic field lines

Let's Practise 18.4
1 (a) The force is downwards.
2 (b) The current could be increased and/or the wires could be placed closer to each other.

Let's Practise 18.5
1 Reverse the direction of the magnetic field; Reverse the direction of the current
3 Electrical energy to kinetic energy

Let's Practise 18.6
1 (a) (i) Soft iron **(ii)** Smaller **(b)** 0.04 A
2 Use thick wires to reduce the resistance of the cables; Transmit electricity at high voltage

Let's Review
Section A: Multiple-choice Questions
1 B **2** A **3** D **4** C **5** C **6** A **7** B **8** B **9** D

Section B: Short-answer and Structured Questions
1 (b) The magnitude of the current passing through a conductor
(c) The direction of the current passing through a conductor
2 (b) The number of turns in the solenoid; The strength of the magnet; The speed at which the magnet moves with respect to the solenoid
3 (a) The galvanometer is deflected in one direction.
(b) The galvanometer is deflected in the opposite direction.
(c) Same as **(a)** but the deflection of the galvanometer is larger.
7 (a) (i) 6.25 V **(ii)** 80 A **8 (a)** 400 turns **(b)** 0.125 A
9 (a) step-up transformer
(b) (i) 500 A **(ii)** 800 000 A **(iii)** 1.73×10^{13} J
10 (d) The coil will rotate in the anticlockwise direction.

Chapter 19: Nuclear Model of the Atom
Quick Check
p. 333: True p. 335: True p. 339 True

Let's Practise 19.1
1 (a) positively; negatively **(b)** loses **(c)** gains electrons

Let's Practise 19.2
1 (a) +1 **(b)** 0 **(c)** –1
2 (a) The proton number is the number of protons in the nucleus. The nucleon number is the total number of protons and neutrons in the nucleus.
(b) $^{35}_{17}X$ **(c)** 18
(d) X and Y are isotopes of the same element

Let's Review
Section A: Multiple-choice Questions
1 C **2** D **3** B **4** D **5** B **6** A

Section B: Short-answer and Structured Questions
3 (a) Nuclear fission is a process in which the nucleus of an atom splits and releases huge amount of energy.

Chapter 20: Radioactivity
Quick Check
p. 345: False p. 351: True

Let's Practise 20.1
2 Any two of the following: Radon gas in the air; Rocks containing radioactive minerals; Food and drink; Cosmic rays from the Sun
3 21 counts/minute
4 4 counts/minute

Let's Practise 20.2
1 Emission of radiation from a nucleus is a random process.
The count rate will always vary.
3 **(a)** γ rays **4** Positively charged and high kinetic energy.

Let's Practise 20.3
1 **(a)** Radioactive decay; spontaneous; random (in either order for the last two blanks)
(b) element
2 Big nucleon number or massive nucleus; More neutrons compared to protons
3 **(a)** decreases by 4; decreases by 2
(b) remains the same; increases by 1; fewer
4 **(a)** $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}\alpha + \gamma$ **(b)** $^{137}_{55}Cs \rightarrow ^{137}_{56}Ba + ^{0}_{-1}\beta + \gamma$

Let's Practise 20.4
1 **(b)** 15 h **(c)** 1100 counts/min **2** 115 counts/min

Let's Practise 20.5
1 Any two of the following: Kill cells; Cause mutation; Cancer.
2 Lead box **3** Time; Distance; Shielding

Let's Review
Section A: Multiple-choice Questions
1 D **2** D **3** D **4** B **5** D
6 C **7** C **8** C **9** A **10** A

Section B: Short-answer and Structured Questions
1 **(a)** 22 counts/min **(c)** Background radiation
4 **(a)** $^{60}_{27}Co \rightarrow ^{60}_{28}Ni + ^{0}_{-1}\beta + \gamma$ **(b)** 21.2 years
5 **(c)** α-particles are absorbed by the foil.

Chapter 21: Earth and the Solar System
Quick Check
p. 365: True p. 366: True p. 367: False p. 373: False

Let's Practise 21.1
1 planet; star; natural satellite
2 365 (or 365.25). **3** B
4 **(a)** True **(b)** False **(c)** False **(d)** True **5** 7800 m/s

Let's Practise 21.2
1 **(a)** Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune
3 **(a)** A natural satellite which orbits a planet.
(b) An irregularly shaped lump of rock left over from the formation of the Solar System.
4 500 s or 8 min and 20 s
5 **(b)** Any one of the following: Venus; Saturn; Uranus
(c) Jupiter **(d)** Mercury
(e) Any number between 2 and 12 years

Let's Review
Section A: Multiple-choice Questions
1 B **2** C

Section B: Short-answer and Structured Questions
2 towards; southern; Antarctic; winter
5 **(b)** An ellipse **(c)** A **(d)** C **(e)** D
6 **(b)** 3.1×10^3 m/s

Chapter 22: Stars and the Universe
Quick Check
p. 378: False p. 380: True p. 380: True

Let's Practise 22.1
1 **(a)** True **(b)** False **(c)** False **(d)** True

Let's Practise 22.2
1 **(a)** One thousand million
(b) The galaxy that contains our Solar System
2 **(a)** A red giant **(b)** A planetary nebula
(c) A supernova
(d) A white dwarf
4 9.5×10^{15} m

Let's Practise 22.3
2 C

Let's Review
Section A: Multiple-choice Questions
1 B **2** D

Section B: Short-answer and Structured Questions
2 **(b)** The graph would have a straight line through the origin.
(c) Age of Universe = $\frac{1}{\text{gradient}}$
3 **(a)** The left hand side of the galaxy is moving towards the Earth and the right hand side of the galaxy is moving away.
(b) The galaxy could be rotating.

Index

Acknowledgements

For over 60 years Marshall Cavendish Education has been empowering educators and students in over 80 countries with high-quality, research-based, Pre-K-12 educational solutions. We nurture world-ready global citizens by equipping students with crucial 21st century skills through our resources for schools and education centres worldwide, including Cambridge schools, catering to national and international curricula.

The *Marshall Cavendish Education Cambridge IGCSE™ Physics* series is designed for students preparing for the 0625/0972 syllabus. The series translates insights from educational psychology classic "How People Learn" into highly effective learner-centred classroom practices.

SB The **Student's Book**:

- Guides learners from the introduction of a new idea through engaging chapter openers to the ability to apply and extrapolate their knowledge
- Explains difficult concepts with stepwise presentation, infographics and colourful visuals
- Supports subject literacy with concise sentences and language support
- Encourages hands-on inquiry-based learning with mini-projects or activities
- Has an international flavour, with multicultural references and photographs
- Incorporates videos, animations and interactives to engage learners and aid understanding
- Allows for self-evaluation through reflective and practice questions, while exam-style reviews build exam readiness
- Includes mind maps and links that build learners' understanding of the relationships between concepts
- Helps students develop 21st century competencies, so that they become future-ready

Series architecture

- Student's Book
- Theory Workbook
- Practical Workbook
- Teacher's Guide and Teacher's Resource
- e-book

ISBN 978-981-4927-87-1
9 789814 927871

Marshall Cavendish Education