

TOP MARK

K C S E

PHYSICS

Questions and Answers



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KCSE

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Questions and Answers

by

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Tips to Candidates

Framing of Questions

It is important that the candidate is familiar with the key words used in expressing questions and the kind of response expected in each case. Common terms include:

(i) State

This type of question requires the candidate to just list the information or items expected without any further explanation. For example;

Question:

State two factors that affect melting point of water.

Answer:

- Presence of impurities.
- Pressure.

The candidate should avoid giving more than the number of items specified. Stating more than the required number of items will not earn the candidate more points, it may only put the candidate at risk of being penalised if the additional items are contradictory to the correct ones.

(ii) Explain a given observation

The candidate should always try to identify the principle or concept being tested in a given area. Once this is done, he/she should capitalise on using the key or technical terms as necessary in expressing the concept.

Explain why:

- Demands that the candidate gives a reason(s).

Explain how:

- Demands that the candidate narrates the process.

Candidates should avoid giving lengthy narratives which only amount to waste of precious time without attracting any marks.

(iii) Calculate/find/determine

Present the working clearly in steps:

- Stating the formula.
- Substituting into the formula, giving the final figure with correct units.

(iv) Complete a diagram

The candidate is expected to illustrate a concept mostly through drawing.

The candidate should include only the minimum details necessary to bring out the required principle or concept. He/she should avoid overcrowding the diagram. This can only be seen as lack of certainty on what he/she wants to present. When presenting fields, arrows should be included to indicate direction.

(v) Ray diagram construction

This applies to reflection at plane and curved mirrors and refraction as in thin lenses. The candidate should always remember that:

- (i) Only two rays are necessary in locating a given point on object or image.
- (ii) Virtual parts of the rays should be distinguished from the real by use of broken lines. This should apply to images.
- (iii) Direction of the rays must be shown.
No arrows on virtual parts of ray.

(vi) Describing an experiment

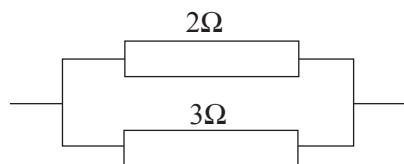
Response is given to show how a certain principle is verified, or a given constant is determined.

- (i) The description must be restricted to the use of only the apparatus listed in the question.
- (ii) The candidate should be systematic, observing the correct order of the various steps carried out in the procedure.
- (iii) Where graphical analysis is a necessary step, the candidate should come out clearly that a graph is plotted and move on to point out the expected result and how it mathematically brings out the law or concept required.

Others points to note:

The candidate should be careful about the following:

- (i) Misuse of equals sign, for example, when working out total resistance in a parallel combination.



$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = \frac{5}{6} = \frac{6}{5}$$

This is misuse of equal signs. The correct statement should be:

$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = \frac{5}{6}$$

$$\therefore R_T = \frac{6}{5}$$

- (ii) Terminating instead of rounding off figures, for example,
- in calculation, $n = 1.5957447$
 ≈ 1.59 instead of 1.60
 The correct answer is 1.60

- (iii) Misrepresenting standard formulae as they show their working, for example, $n = \frac{1}{C}$ instead of $n = \frac{1}{\sin C}$

Mathematical Skills Required

As a science, Mathematics develops logical thinking, creativity and accuracy. It contributes to intellectual development of learners and gives them ability to:

- Explore.
- Search for information.
- Make decisions.
- Analyse, synthesise and generalise information.

It is, therefore, a very important tool in the study of physics concepts. Some of the skills required include:

(i) Precision and Accuracy

Precision of a measuring instrument refers to the level of consistency that can be obtained against a measurement using the instrument repeatedly. In general, instruments that offer larger numbers of decimal places have greater precision. Thus, a vernier callipers has more precision than a metre rule when both are used to take the same measurement.

Accuracy refers to how close a measurement is to the true value. The width of a room estimated to be 6 metres, is an accurate, but not precise measurement. However, if the measured width of the room is 6.2165 metres, then this is a precise but inaccurate measurement. Only when one is very careful, can an accuracy be equal to precision when using an instrument.

Often it is easy to make accurate measurements such as when using a ruler to measure a small rectangular block. Several repeated measurements are likely to read the exact same value. Accuracy can only be improved by

repeating measurements and averaging only when the precision is finer than the accuracy. An example of repeating and averaging measurements is when using a stopwatch. The typical digital stopwatch is more precise than it is accurate. The typical stopwatch displays a precision of $\frac{1}{100}$ of a second intervals. But the human reaction time for starting and stopping the watch is about 0.2 seconds. Since the precision is 20 times finer than the accuracy, repeating and averaging can yield more accuracy.

(ii) Significant Figures and Rounding-off

Accuracy is judged based on the number of significant figures in the data. It is, therefore, imperative that you round off numbers to the last place value that is known to be accurate. Calculations and conversions can never increase the accuracy.

There are two types of numerals in ordinary numbers: significant figures and place-holding zeros. Place-holding zeros are the zeros that go away when you convert to scientific notation.

$$64\ 000 = 6.4 \times 10^4 ; \quad 0.00128 = 1.28 \times 10^{-3}$$

Not all zeros are place-holding zeros. Some are significant, for example, the zero in 508. Conversion to scientific notation yields 5.08×10^2 . All non-zero numerals are significant.

Examples of numbers with 2 significant figures:

$$35, 0.0098, 8.3, 7500$$

Examples of numbers with 5 significant figures:

$$79\ 543, 10\ 219, 4.5009, 0.0075021$$

Some numbers are considered to have an infinite number of significant figures, such as those that are part of exact formulas.

$$C = 2\pi r, \quad v = \sqrt{2gh}$$

In both expressions, 2 is an exact number. Other numbers are limited by the precision of the measuring instrument, or calculating device. Modern calculators usually display eight to ten significant figures, but the value displayed by the calculator is only as accurate as the numbers used in the calculation. An approximation cannot be multiplied by an approximation to get an exact number, no matter what the calculator displays.

Rules for keeping the correct number of significant figures:

1. For addition and subtraction, the answer should be no more precise than the least precise value being added or subtracted.

For example;

$$84.145 + 9.3 + 0.026 + 0.94 = 94.4$$

The answer is given to 1 d.p. since 9.3 has least precise number of decimal places.

2. For multiplication and division, the answer should have no more significant figures than the term with the least number of significant figures.

$$\frac{8\ 414 \times 96 \times 134}{987} = 110\ 000$$

The answer is given to 2 significant figures since 96 is the number with the least significant figures.

For numbers such as 110 000, it is impossible to be sure whether or not the zeros are significant, except by context, or by denotation with either a bar below significant zeros, or by ending with a decimal point. Non-zero numbers in parentheses to the right of a decimal may not be significant.

Examples:

- | | |
|-----|------------------------|
| 27 | 2 significant figures. |
| 402 | 3 significant figures. |

| | |
|--------|--|
| 680 | at least 2 significant figures, may be 3, judge from context. |
| 680.0 | 4 significant figures, since the decimal point shows that the zero is significant. |
| 23.20 | 4 significant figures, this zero is unnecessary if not significant. |
| 0.0005 | 1 significant figure. |

(iii) Scientific Notation

Scientific notation is a way of writing numbers that make understanding and using these numbers easier:

- (i) when the numbers are very large,
- (ii) when the numbers are very small,
- (iii) when the numbers vary greatly in size,
- (iv) when making estimates or mental calculations.

In the standard form of scientific notation, exactly one numeral is to the left of the decimal point. For example, 670 000 is expressed as $6.7 \times 100\ 000$ or 6.7×10^5 .

Other examples include:

2 630 is expressed as 2.63×10^3

6 000 000 is expressed as 6.0×10^6

0.0073 is expressed as $7.3 \times \frac{1}{1000} = 7.3 \times 10^{-3}$.

(iv) Algebraic Formulae

The most important mathematical skill is the ability to manipulate and solve algebraic formulas. This may involve deriving a general expression or determining a specific solution.

Finding a general solution to an algebraic expression

Consider Ohm's law, $V = IR$, where V is voltage, I is current and R is the resistance in an electrical circuit. Solution can be sought for V since it stands on the left side of the

equation. However, it is possible to find the values of I or R by making them the subject of the formula.

$$\text{Thus, } I = \frac{V}{R}, \text{ or } R = \frac{V}{I}$$

$$\text{In the simple pendulum equation, } T = 2\pi \sqrt{\frac{l}{g}},$$

where T is the periodic time of the pendulum, l the length of the pendulum, and g the acceleration due to gravity. To obtain the value of l , the equation has to be rearranged, thus squaring both sides yields

$$\frac{T^2}{(2\pi)^2} = \frac{l}{g}$$

$$\text{Now multiplying both sides by } g; l = \frac{gT^2}{(2\pi)^2}$$

This is the general solution that yields the length of any pendulum for any swing period. Substitution of known values into the general expression results in specific solution.

(v) Dimensional Analysis

Dimensional analysis is the process of doing a mathematical operation (such as multiplying or dividing) with units. The rules are the same as for algebraic variables.

Dimensional analysis helps us to get the correct units at the end of a problem.

Newton's second law is expressed as, $a = \frac{F}{m}$, where a is the acceleration of an object, F the applied force causing that acceleration, and m the mass of the object. The units of acceleration is m/s^2 . However, if we actually solve a problem where a force of 9.0 N is applied to a 2.0 kg object, we find that

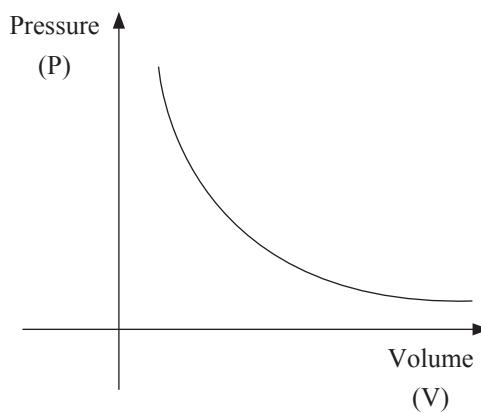
$$a = \frac{F}{m} = 9.0 \text{ N} / 2.0 \text{ kg} = 4.5 \text{ N/kg. Whereas}$$

one would expect the units for the answer to be m/s^2 it comes out as N/kg . Thus m/s^2 is same as N/kg .

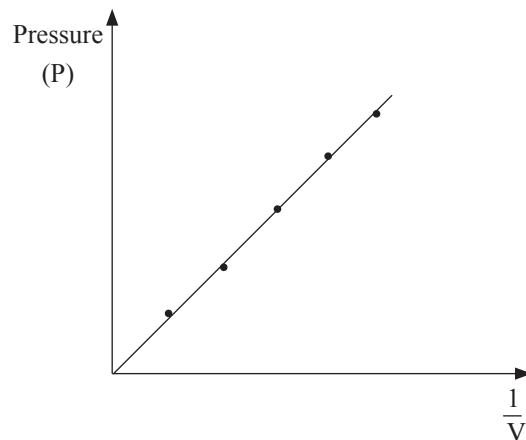
Analysis and Interpretation of Graphs

Graphs are often used to present information. They are also used for providing general overview on particular phenomena. The shape of the graph indicates mathematical relationship between some variables.

Consider the relationship between the pressure of a fixed mass of a gas and its volume. Graphically, the relationship is depicted below:



The graph illustrates that as pressure increases volume decreases, and vice versa. To establish a more clear relationship between the two variables, a graph of pressure (P) against reciprocal of volume ($\frac{1}{V}$) is drawn. This is a straight line through the origin, as below:



From the graph, it is clear that pressure and

volume of a gas are inversely proportional.

$$\text{Thus, } P \propto \frac{1}{V}, \text{ and } PV = \text{Constant}$$

Graphs in physics must have the following:

Scale: This must cover at least half of the grid provided, both horizontally and vertically. The scale must be linear, that is, there should be equal intervals for the same number of units.

Labelling: The vertical and horizontal axes should clearly show the variables represented, and their units.

Plotting: A graph may have five points or more to be plotted on the grid. A correctly plotted point has its centre of the dot or cross at the exact point given in the table.

Line or curve: Depending on the variables given, a graph may result in a straight line or curve. A straight line graph is obtained if there is a direct proportionality between the variables. Usually, the ‘lead’ words to enable a learner determine whether the expected graph is a straight line are:

- (i) ‘Determine the slope of the graph.’
- (ii) ‘What is the slope?’
- (iii) ‘Explain why the graph is a straight line.’
- (iv) ‘Use the slope of the graph to determine expected parameter.’

If the graph is a curve, the ‘lead’ words in the question are:

- (v) ‘Determine the gradient at point...’

In this case, the gradient of the tangent at the required point is determined.

Deriving Formulae from Graphs

The shape of the line or curve that best fits the data from an experiment determines the type of formula that can be made. This formula will show the relationship between the variable on the vertical axis and the one on the horizontal axis.

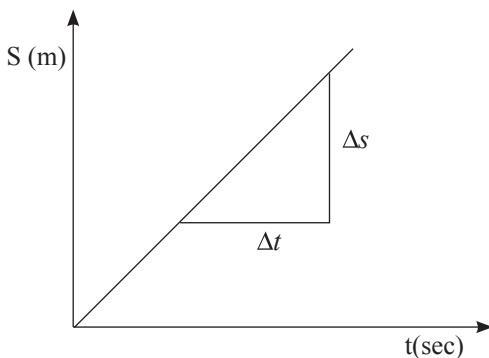
(i) Linear Graphs

When the data graphs as a straight line, the formula follows the form $y = mx + c$, where y is the dependent variable from the vertical axis of your graph, x is the independent variable from the horizontal axis of your graph, m is the slope of the line, and c is the y -value where the line crosses the y -axis (y -intercept). If $c = 0$, then the line will pass through the origin, and the relationship is called a direct proportion (if the slope is positive, going up from left to right).

The slope can be determined by seeing how much the y value changes for a corresponding change in x . If the y value increases by 6 for every increase in x of 2, the slope is found by dividing the change in y by the change in x . For this example, the slope is $\frac{6}{2} = 3$. In general,

we use the formula: $slope = m = \frac{\Delta y}{\Delta x}$, where the Greek letter delta (Δ), represents the change in the variable. Δy represents how much the y variable changes for the corresponding change in x , Δx .

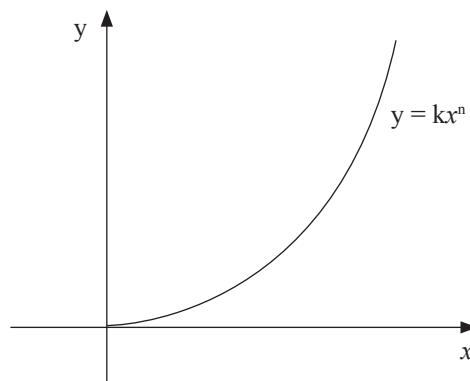
If a distance versus time graph is drawn to represent the motion of an object moving at constant speed, a linear (straight-line), direct proportion graph is produced.



The formula that matches this graph is found from $y = mx$. Here, y represents distance and can be replaced with s . Likewise, x is replaced with t . The slope, m , is, therefore, $\frac{\Delta s}{\Delta t}$, the definition of speed (v). This yields the equation, $s = vt$.

(ii) Non-linear Graphs

There are two common forms of non-linear relationships. One of these is represented by a graph where the y value grows faster with increasing x . The graph curves upward from a straight-line orientation, with ever increasing slope. This general form is probably best fit by a **polynomial equation** of the form $y = kx^n$, or by an **exponential equation** of the form $y = k^x$ (k and n are constants), as below:



Measurements I and II

Key Points

- The basic physical quantities in measurements include length, mass and time.
- Quantities like area, volume and density are known as derived quantities. They are obtained from the basic quantities.
- The quantities are expressed in an internationally agreed system of units (SI) which may be converted to other units.
- The choice of measuring instrument depends on quantity being measured and the level of accuracy required.
- The zero-error results from the zero mark of the main scale not coinciding with the zero of the vernier scale or the zero marks in the sleeve and thimble scales for the micrometer screw gauge not coinciding.
- In the oil drop experiment the spread of oil on water surface is assumed to be a perfect circle of monolayer.

Answer

(a) Length (l) is a measure of distance between one point to another. The SI unit of length is metre (m).

$$\begin{aligned} \text{(b) (i)} \quad 10 \text{ mm} &= 1 \text{ cm} \\ 45 \text{ mm} &= \frac{45}{10} \\ &= 4.5 \text{ cm} \\ \text{(ii)} \quad 1 \text{ cm} &= 10 \text{ mm} \\ 0.22 \text{ cm} &= 0.22 \times 10 \\ &= 2.2 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{(iii)} \quad 100 \text{ cm} &= 1 \text{ m} \\ 1242 \text{ cm} &= \frac{1242}{100} \\ &= 12.42 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{(iv)} \quad 1 \text{ km} &= 1000 \times 100 \times 10 \text{ mm} \\ 1.5 \text{ km} &= 1.5 \times 1000 \times 100 \times 10 \\ &= 1500000 \text{ mm} \end{aligned}$$

Revision Questions 1

- (a) Define length and state its SI units.
 (b) Convert:
 - 45 mm to cm.
 - 0.22 cm to mm.
 - 1 242 cm to m.
 - 1.5 km to mm.

- (a) Describe briefly how you would use a metre rule and a piece of thread to measure the radius of a boiling tube.
 (b) State what is meant by the term parallax error when taking measurements using a metre rule.
 (c) A student recorded the following measurements while using a metre rule: 5.32 cm, 4.9 cm and 8.013 cm. Which is the correct reading? Explain your answer.

Answer

- (a) (i) A knot is made on the thread.
(ii) The thread is wrapped tightly and closely round the tube, say 10 times.
(iii) A second knot is made at the end.
(iv) The thread is transferred to the ruler and the distance between the two knots is measured.
(v) The reading is divided by 10 to obtain the circumference (C) of the tube.
(vi) From the formula $C = 2\pi r$, the radius is obtained.
- (b) Parallax error is an error introduced in the reading when the eye is not placed such that the line of sight is perpendicular to the scale.
- (c) 4.9 cm. The accuracy is correct to 0.1 cm.

3. Express each of the following in the given unit:
- (a) 0.27 m^2 to cm^2
(b) 5 km^2 to m^2
(c) 0.00653 m^2 to mm^2
(d) 2480 m^2 to km^2

Answer

(a) $1 \text{ m}^2 = (100 \times 100) \text{ cm}^2$
 $0.27 \text{ m}^2 = 0.27 \times 100 \times 100$
 $= 2700 \text{ cm}^2$

(b) $1 \text{ km}^2 = (1000 \times 1000) \text{ m}^2$
 $5 \text{ km}^2 = 5 \times 1000 \times 1000$
 $= 5000000 \text{ m}^2$

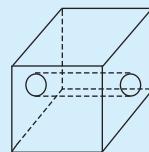
(c) $1 \text{ m}^2 = (1000 \times 1000) \text{ mm}^2$
 $0.00653 \text{ m}^2 = 0.00653 \times 1000 \times 1000$
 $= 6530 \text{ mm}^2$

(d) $(1000 \times 1000) \text{ m}^2 = 1 \text{ km}^2$

$$1 \text{ m}^2 = \left(\frac{1}{1000 \times 1000} \right) \text{ km}^2$$

$$2480 \text{ m}^2 = \frac{2480}{1000 \times 1000}$$
$$= 0.00248 \text{ km}^2$$

4. A solid cube of length 20 cm has a hole of radius 6.3 cm drilled through it as shown in the diagram.



Determine the volume of the solid making the block in:

- (a) cm^3
(b) mm^3
(b) m^3

Answer

- (a) Volume of cube $= 20 \times 20 \times 20$
 $= 8000 \text{ cm}^3$
- Volume of material drilled out $= \frac{22}{7} \times 6.3 \times 6.3 \times 20$
 $= 2494.8 \text{ cm}^3$
- Volume of material left $= 8000 - 2494.8$
 $= 5505.2 \text{ cm}^3$
- (b) $1 \text{ cm} = 10 \text{ mm}$
 $1 \text{ cm}^3 = 1000 \text{ mm}^3$
 $\therefore 5505.2 \text{ cm}^3 = (5505.2 \times 1000) \text{ mm}^3$
 $= 5505200 \text{ mm}^3$
5. (a) Define mass and state its SI unit.
(b) Describe how you would measure mass using a spring balance.

Answer

- (a) Mass (m) is the quantity of matter a body contains. The SI unit of mass is the kilogram (kg).
- (b) The scale of the spring balance is calibrated in Newtons. But since weight is proportional to mass, the scale can be converted by dividing the values on it by 'g' to read kilograms, for example, weight of 3 N is equivalent to mass of
- $$\frac{3 \text{ N}}{10 \text{ N/kg}} = 0.3 \text{ kg}$$

6. (a) Define time interval.
(b) Explain why a stopwatch may not be suitable to measure time intervals of only a few seconds.
(c) Convert 2 hrs 27 min to seconds.

Answer

- (a) Time (t) is the period of separation between two events. The SI unit of time is the second(s).
- (b) There is a difference between the time the event starts and switching on the stopwatch and off when the event ends, due to reaction time. The error for short intervals is significant.

(c)

$$1 \text{ hr} = (60 \times 60) \text{ s}$$
$$2 \text{ hrs} = 2 \times 60 \times 60$$
$$= 7200 \text{ s}$$
$$1 \text{ min} = 60 \text{ s}$$
$$27 \text{ min} = 27 \times 60$$
$$= 1620 \text{ s}$$
$$2 \text{ hrs } 27 \text{ min} = 7200 + 1620$$
$$= 8820 \text{ s}$$

7. The volume of one drop of a liquid was found to be 0.045 ml. If 30 drops were delivered by a burette from an initial

reading of the liquid being 11.4 ml, find the final reading of the liquid.

Answer

$$\begin{aligned}\text{Volume of 30 drops of liquid} &= 0.045 \times 30 \\ &= 1.35 \text{ ml}\end{aligned}$$

$$\begin{aligned}\text{Final reading} &= 1.35 + 11.4 \\ &= 12.75 \text{ ml}\end{aligned}$$

8. (a) Define density and state its SI unit.
(b) Describe experiments to determine the density of:
- (i) Irregular objects, for example, stone.
 - (ii) A floating object, for example, cork.
 - (iii) A liquid.
- (c) The density of a liquid is 0.75 g/cm³.
- (i) Express the density in kg/m³.
 - (ii) Calculate the volume of 150 gm of the liquid.

Answer

- (a) Density of an object is its mass per unit volume. The SI unit for density is kilogram per cubic metre (kg/m³)

- (b) (i) Stone:
 - Pour some water into a measuring cylinder and note the volume, V₁.
 - Find the mass, m, of the stone using a beam balance.
 - Tie the stone with a piece of thread and lower it gently into the measuring cylinder until the stone is fully immersed and note the new volume V₂.

$$\begin{aligned}\text{Density of stone} &= \frac{m}{V} \\ &= \frac{m}{V_2 - V_1}\end{aligned}$$

(ii) Cork:

- Pour water into a eureka can until it overflows.
- When no drops come from the spout, place a measuring cylinder below the spout.
- Lower a sinker tied with thread gently into the can until it is fully submerged and note the volume V_1 of the water that will be collected by the measuring cylinder.
- Find the mass m of the cork using a balance.
- Tie both the cork and sinker with thread and lower them into the eureka can and note the volume V_2 .
- Volume of sinker + cork = V_2
- Volume of sinker = V_1
- Volume of cork = $V_2 - V_1$
- Density of cork = $\frac{m}{V}$
 $= \frac{m}{V_2 - V_1}$

(iii) To find the density of a liquid:

- Determine the mass m_1 of a clean beaker.
- Pour the liquid into a measuring cylinder and note the volume V .
- Determine the mass m_2 of the beaker and water.

$$\text{Mass of liquid} = m_2 - m_1$$

$$\text{Density of liquid} = \frac{m_2 - m_1}{V}$$

(c) (i) $0.75 \text{ g/cm}^3 = \frac{0.75 \times 1\ 000\ 000}{1000}$
 $= 750 \text{ kg/m}^3$

$$(ii) \text{ Density } D = \frac{m}{V}, V = \frac{m}{D}$$

$$V = \frac{150}{0.75} \\ = 200 \text{ cm}^3$$

9. State the possible error of the reading on the scale of an instrument that give the following readings:
- (a) 28 cm.
 - (b) 37.4 kg.
 - (c) 9.45 seconds.

Answer

- (a) $28 \text{ cm} \pm 1 \text{ cm}$
- (b) $37.4 \text{ kg} \pm 0.1 \text{ kg}$
- (c) $9.45 \text{ s} \pm 0.01 \text{ s}$

10. Express:

- (a) 3748.67; and
- (b) 0.0040217 to:
 - (i) 1 s.f.
 - (ii) 2 s.f.
 - (iii) 3 s.f.
 - (iv) 4 s.f.

Answer

- (a) (i) 4 000 (ii) 3 700
(iii) 3 750 (iv) 3 749
- (b) (i) 0.004 (ii) 0.0040
(iii) 0.00402 (iv) 0.004022

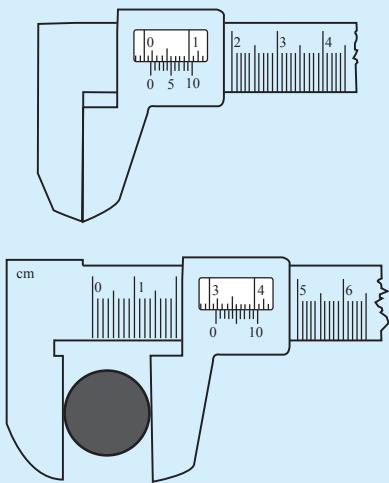
11. The mass of a density bottle filled with a liquid is recorded as 89.37 g. Given that the density of the liquid is 1.21 g/cm^3 and the capacity of the bottle is 50 mL, determine the mass of the bottle.

Answer

$$\begin{aligned}\text{Mass of liquid} &= \text{density} \times \text{volume} \\ &= 1.21 \times 50 \\ &= 60.5 \text{ g}\end{aligned}$$

$$\begin{aligned}\text{Mass of bottle} &= 89.37 - 60.5 \\ &= 28.87 \text{ g}\end{aligned}$$

12. Determine the correct value for the diameter taken from the reading shown.

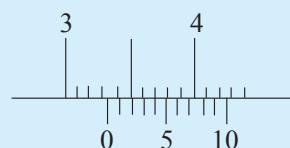


Answer

$$\text{The zero error} = +0.14$$

$$\begin{aligned}\text{Correct reading} &= 3.16 - 0.14 \\ &= 3.02\end{aligned}$$

13. (a) The figure below shows the scale of a vernier callipers when measuring a certain length.

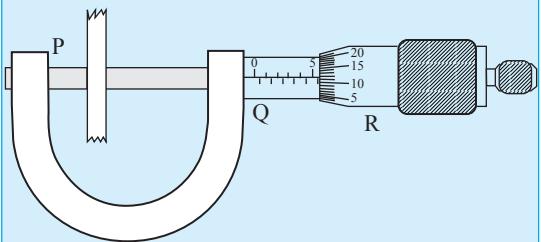


- (b) Given that the instrument has a zero-error of -0.04 cm , determine the correct measurement of the length.

Answer

$$\begin{aligned}(\text{a}) \text{ Reading} &= 3.34 \text{ cm} \\ (\text{b}) \text{ Measurement} &= 3.34 - (-0.04) \text{ cm} \\ &= 3.38 \text{ cm}\end{aligned}$$

14. The figure shows a micrometer screw gauge used to measure the diameter of a rod in millimetres.



- (a) Name the parts labelled P, Q, R.
(b) State the reading on the micrometer screw gauge.
(c) State one advantage and one limitation of the micrometer screw gauge.

Answer

(a) P – Anvil

Q – Sleeve scale

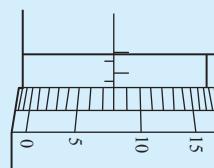
R – Thimble scale

$$(\text{b}) 5.5 + 0.12 = 5.62 \text{ mm}$$

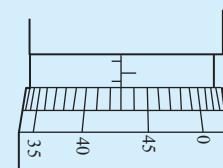
(c) *Advantage* – Can give fractions of a scale division since it works on screw principle.

(d) *Limitation* – Can measure only small distances.

15. The diagram shows two closed micrometer screw gauges.



(i)



(ii)

- (a) State the zero error of the instruments.
 (b) If the instruments are used to measure the diameter of a wire 2.3 mm, what will be the reading on each?

Answer

$$\begin{array}{ll} \text{(a) (i)} & -0.08 \quad \text{(ii)} \quad +0.07 \\ \text{(b) (i)} & 2.3 + 0.08 \quad \text{(ii)} \quad 2.3 - 0.07 \\ & = 2.28 \text{ mm} \quad = 2.23 \text{ mm} \end{array}$$

16. (a) Describe an experiment to determine the diameter of a molecule of oil.
 (b) A drop of oil of volume 0.011 cm^3 spreads on water in a bowl to form a monolayer circle of radius 10 cm. Estimate the diameter of the oil molecule.

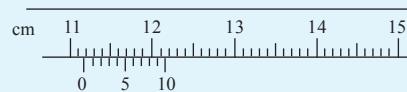
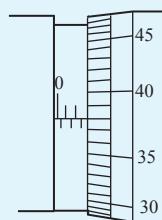
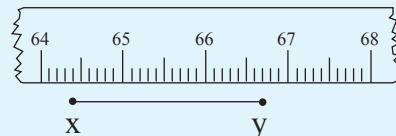
Answer

- Allow, say, 20 drops of oil to fall from a burette and note the volume.
 - Determine the volume of a single drop by dividing by 20.
 - Let one drop of oil fall on a clean water surface to spread into a uniform circular patch of monolayer. Measure diameter d of the patch.
 - $$\text{Diameter of oil molecule} = \frac{\text{thickness of monolayer patch}}{\text{Area of patch}}$$

$$= \frac{\text{Volume of one drop}}{\text{Area of patch}}$$
- (b) $0.011 = \frac{22}{7} \times 10 \times 10 \times d$
 $d = 3.5 \times 10^{-5} \text{ cm}$

Revision Exercise 1

1. What is the measurement shown by the scales?



- The density of liquid is 800 kg/m^3 . State the density in g/cm^3 .
- Explain how the thickness of a single leaf of paper from a ream may be determined.
- A piece of plastic is moulded to form a cuboid of volume 24 cm^3 . If the mould is made to form a cylindrical shape of radius 0.7 cm, determine its height.
- Describe an experiment to determine the density of air.
- Convert $5\ 257 \text{ cm}^2$ to km^2 and express your answer in standard form.
- Find the volume of cylinder with diameter 7.0 cm and height 8 cm (answer in m^3 and express your answer in standard form).

UNIT**2**

Force

Key Points

- Force is a vector quantity.
- The SI unit of a force is the Newton, which is defined as that force that will cause a body of mass 1 kg to accelerate by a value of 1 m/s^2 .
- The effect of force can be experienced when bodies are in contact or at a distance apart.

Revision Questions 2

1. (a) Define force.
(b) State three effects of force.

Answer

- (a) Force is either a push or a pull on a body.
(b) Effects of force include:
 - (i) Changing direction of motion.
 - (ii) Increasing or decreasing speed.
 - (iii) Causing deformation.
 - (iv) Starting or stopping motion.

2. Describe the following types of forces:
 - (a) Weight
 - (b) Cohesive
 - (c) Adhesive
 - (d) Surface tension

Answer

- (a) Weight – Force due to gravitational pull.
(b) Cohesive – Force of attraction between molecules of the same kind.
(c) Adhesive – Force of attraction between molecules of different kinds.

- (d) Surface tension – Force at the free surface of a liquid that tends to make the surface behave like a stretched thin elastic skin.
- 3. (a) Distinguish between a scalar and a vector quantity, giving an example of each.
(b) Differentiate between mass and weight.
(c) State the relationship between mass and weight.
(d) Calculate the weight of the following:
 - (i) A stone of mass 15 kg on the surface of the earth.
(take $g = 10 \text{ Nkg}^{-1}$)
 - (ii) A metal box of mass 0.65 tonnes on a planet where $g = 6.0 \text{ Nkg}^{-1}$

Answer

- (a) Scalar quantity has magnitude (size) only, for example, work measured in joules. Vector quantity has magnitude and direction, for example, force measured in Newtons and in a specified direction, say upwards or to the left, etc.

| Mass | Weight |
|------------------------------|-----------------------------|
| Has size (magnitude) | Has magnitude and direction |
| SI unit is kilogram (kg) | SI unit is newton (N) |
| Quantity of matter in a body | Pull of gravity on a body |

- (c) Weight (W) = mass (m) \times gravitational pull (g).

$$W = mg$$

(d) (i) $W = mg$

$$W = 15 \times 10$$

$$= 150 \text{ N}$$

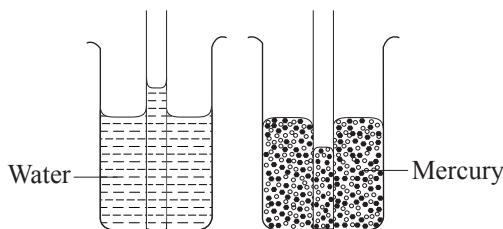
(ii) $W = mg$

$$W = 650 \times 6$$

$$= 3900 \text{ N}$$

4. Two identical capillary tubes are dipped in equal volumes of water and mercury in identical containers. Sketch and explain the levels of the liquids inside the tubes and the shapes of the meniscus.

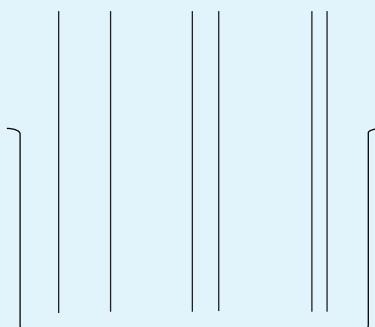
Answer



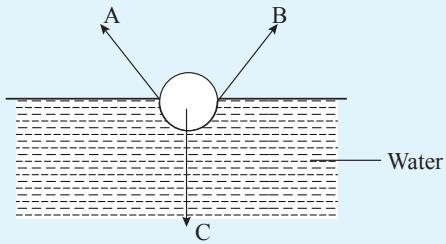
- Water in the capillary tube rises until its level is above that in the container. In the other container, mercury in the capillary tube settles at a lower level than that one in the container.
- Water forms a concave meniscus at the top. This is because adhesive forces between water and glass molecules are greater than cohesive forces between water molecules.
- Mercury forms a convex meniscus. This is due to the stronger cohesive forces between mercury molecules than adhesive forces between mercury and glass molecules.

Revision Exercise 2

1. The gravitational pull in planet Jupiter is 24.8 N/kg. Calculate the weight of an object in Jupiter given that its weight on earth is 550 N.
2. Briefly describe the following forces:
 - Tension
 - Upthrust
 - Friction
 - Magnetic
 - Electrostatic
 - Centripetal
3. The figure below shows capillary tubes of different bore stood in a beaker.

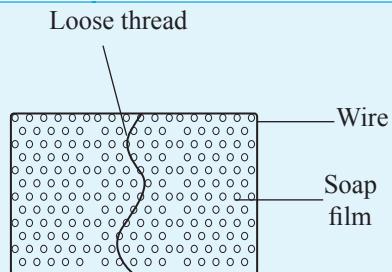


- (a) If mercury is poured into the beaker, show the expected levels it will take in the entire system.
 - (b) Sketch a similar set-up to show the behaviour of water under same conditions.
6. The figure shows a needle placed on the surface of a liquid.



Name the forces A, B and C acting on the needle.

7. The figure illustrates the formation of a soap film using a loop of wire with a thread across the middle.



State what happens when the film on one side of the thread is broken by touching it. Explain your answer.

UNIT
3

Pressure

Key Points

- Pressure is exerted when a force acts perpendicularly on a surface.
- Pressure is a scalar quantity.
- The larger the force acting on a given area or the smaller the area being acted on by a given force, the higher the pressure.
- In an enclosed, incompressible, static fluid, pressure exerted at one part is transmitted equally on all other parts of the fluid. This principle is mainly employed in hydraulic systems.
- Atmospheric pressure is pressure due to the weight of air column above earth. It is maximum at sea level and decreases with increasing altitude.

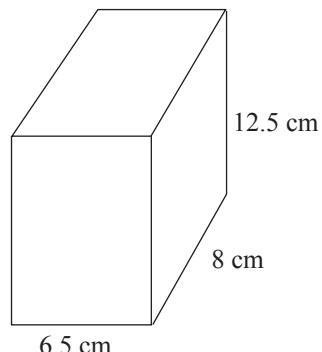
Revision Questions 3

1. (a) Define pressure, and state its SI units.
(b) A solid block measuring 6.5 cm by 8.0 cm by 12.5 cm is made of a material of density 8.93 kg/m^3 . Determine the maximum and minimum pressure it can exert when resting on a horizontal surface.

Answer

- (a) Pressure is the force acting normally per unit area. The SI unit is Nm^{-2} .

(b)



$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

$$\text{But force} = \text{weight}$$

$$= \text{mass} \times \text{acceleration due to gravity}$$

$$= mg$$

$$\text{And } m = \text{volume} \times \text{density}$$

$$= 0.065 \times 0.08 \times 0.125 \times 8.93$$

$$= 0.0058045 \text{ kg}$$

$$\text{So, force} = 0.0058045 \times 10$$

$$= 0.058045 \text{ N}$$

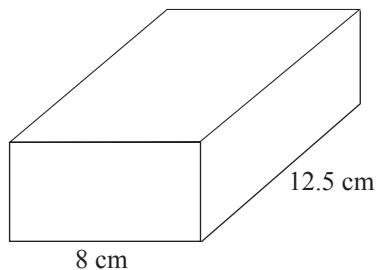
Pressure is maximum when area is minimum.

Therefore,

$$\text{maximum pressure} = \frac{\text{force}}{\text{minimum area}}$$

$$= \frac{0.058045}{0.065 \times 0.08}$$
$$= 11.1625 \text{ N/m}^2$$

For minimum pressure;



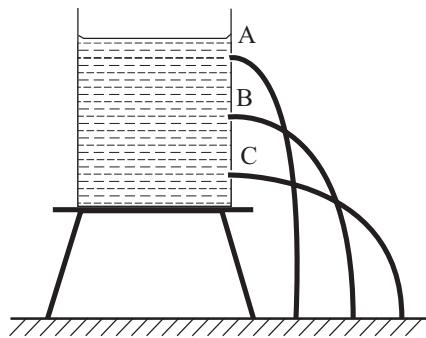
$$\begin{aligned}\text{Minimum pressure} &= \frac{\text{force}}{\text{maximum area}} \\ &= \frac{0.058045}{0.08 \times 0.125} \\ &= 5.8045 \text{ N/m}^2\end{aligned}$$

2. (a) State the factors that affect pressure at a point in a fluid.
 (b) Describe a simple experiment to demonstrate that pressure at a point in a liquid depends on its depth.

Answer

- (a) Factors that affect pressure in fluids include:
 (i) Density of the fluid – The higher the density, the higher the pressure at a given point of the fluid.
 (ii) Depth of the fluid – The greater the depth of the point, the higher the pressure.
 (iii) Acceleration due to gravity.
 (b) To demonstrate that pressure at a point in a liquid depends on depth:

The experiment is performed using a can with three identical holes A, B and C at different depths along a vertical line. When the container is filled with water, jets issue out of the holes as in the following diagram.

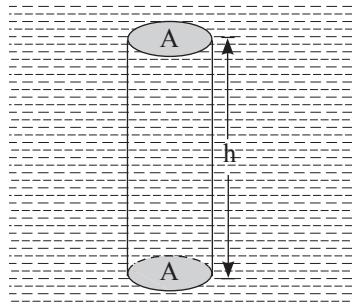


Jet C issues out with the greatest pressure, followed by B, then A. This shows that pressure in a liquid increases with depth.

3. (a) Derive the formula $P = \rho gh$ for pressure at a point in a liquid.
 (b) A rectangular container with base measuring 15 cm by 12 cm has water to a depth of 8 cm. Calculate the pressure that the liquid exerts at the base of the container.
 (c) The area of a tip of a sharp pin is 0.09 mm^2 . Find the pressure exerted at the sharp point if it is pushed into a soft board with a force of 25 N.

Answer

- (a) Consider a column of liquid of density ρ , cross sectional area A and height h as in the diagram below.



Pressure exerted by the column at the bottom is given by;

$$P = \frac{F}{A}$$

But force = weight

= mass \times acceleration
due to gravity

= density \times volume \times acceleration
due to gravity

$$= \rho \times V \times g$$

$$= \rho \times Ah \times g$$

$$= \rho Ahg$$

$$\text{So, pressure } P = \frac{\rho Ahg}{A}$$

at a point in a liquid

$$= \rho hg$$

- (b) Cross section area of the base does not affect pressure exerted.

Density of water = 1000 kg/m^3

So, pressure at the bottom of the liquid

$$P = \rho hg$$

$$= 1000 \times 0.08 \times 10$$

$$= 800 \text{ N/m}^2$$

$$(c) \text{ Pressure} = \frac{\text{force}}{\text{area}}$$

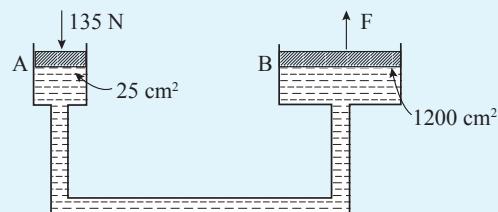
$$= \frac{25 \text{ N}}{(0.09 \times 10^{-6})\text{m}^2}$$

$$(1 \text{ mm}^2 = 1 \times 10^{-6} \text{ m}^2)$$

$$= 2.778 \times 10^8 \text{ N/m}^2$$

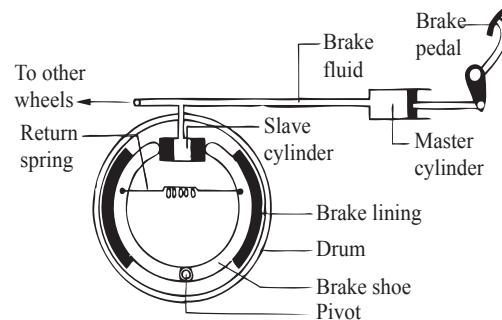
4. (a) (i) State the principle of transmission of pressure in fluids.
(ii) Use the above principle to explain the working of the hydraulic brake system of a car.
- (b) The following diagram shows a hydraulic press with two pistons A

and B of areas 25 cm^2 and 1200 cm^2 respectively. Find the force generated on piston B if a force of 135 N is applied on piston A.



Answer

- (a) (i) The principle of transmission of pressure in fluids (Pascal's principle) states that when pressure is applied to an enclosed incompressible fluid, it is transmitted equally to every part of the fluid.
- (ii) The diagram below shows a simplified hydraulic braking system.



When pressure is applied on the brake pedal, the slave cylinder expands, exerting outward pressure on the brake shoe, which rubs against the brake linings, thus slowing down the vehicle. The application of Pascal's principle is that the pressure applied at the brake pedal is uniformly distributed to all tyres.

- (b) Pressure generated at piston A

$$P = \frac{F}{A}$$

$$= \frac{135 \text{ N}}{25 \times 10^{-4} \text{ m}^2}$$

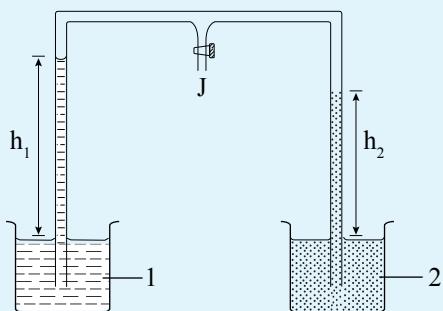
$$= 5.4 \times 10^4 \text{ N/m}^2$$

By Pascal's principle, this is the pressure transmitted to piston B.

Therefore, force on piston B

$$\begin{aligned} F &= P \times A \\ &= 5.4 \times 10^4 \times (1200 \times 10^{-4}) \\ &= 6480 \text{ N} \end{aligned}$$

5. (a) Describe an experiment to demonstrate the existence of atmospheric pressure.
 (b) The diagram below shows an arrangement for comparing densities ρ_1 and ρ_2 of liquids 1 and 2.



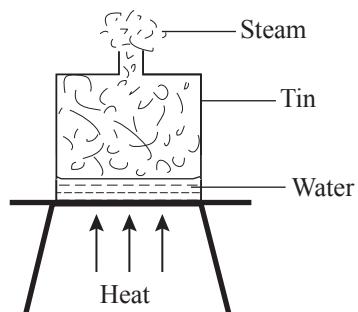
Explain how the arrangement is used to compare the densities of the liquids.

Answer

- (a) To demonstrate that air exerts pressure.

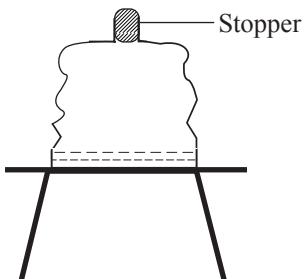
This demonstration is conducted using a metal tin with a tight-fitting stopper.

With the stopper removed, a small amount of water is poured into the tin and heated to boiling, until steam drives air out of the tin, as shown.



The cork is replaced and the source of heat removed. Cold water is then poured on the tin.

It is observed that the tin crashes inwards.



When water boils in the tin, the steam produced drives away air, lowering air pressure. Pouring cold water over the tin condenses the steam and lowers air pressure in the tin even further. The crashing of the tin is as a result of atmospheric pressure.

- (b) The two tubes are stood in beakers containing liquids 1 and 2. Air is sucked out of the tubes through the central joint J, so that a near-vacuum is created in the space. Atmospheric pressure acting on the two liquid surfaces, therefore, pushes up the liquid columns as per their relative densities – the lower the density, the longer the column created.

When the liquid columns settle, the pressure at the base of each column results from:

- (i) The pressure P above each liquid column. This is the same for both.

- (ii) The pressure due to the liquid column itself (ρhg).

Thus,

$$P + h_1 \rho_1 g = P + h_2 \rho_2 g$$

Since P is common,

$$h_1 \rho_1 g = h_2 \rho_2 g$$

$$\text{So, } \frac{\rho_1}{\rho_2} = \frac{h_2}{h_1}$$

6. (a) Explain the existence of atmospheric pressure.
 (b) Explain why mercury but not water is used as a barometric liquid.

Answer

- (a) The atmosphere contains air which is made up of many gases. The mixture has some weight which will exert pressure on any object on the earth's surface. This pressure is known as atmospheric pressure. Atmospheric pressure is therefore defined as pressure acting on the surface of an object within the atmosphere, caused by the weight of the air above that surface.
- (b) Water with density 13.6 times smaller than that of mercury will require a barometric height 13.6 times higher than that of mercury, that is, $13.6 \times 0.76 \text{ m}$ at sea level, which equals 10.3 m. This would be quite cumbersome.

7. Explain the working of the following devices:
 (a) Drinking straw.
 (b) The siphon.
 (c) Bicycle pump.

Answer

(a) Drinking straw

The drinking straw, shown in the diagram

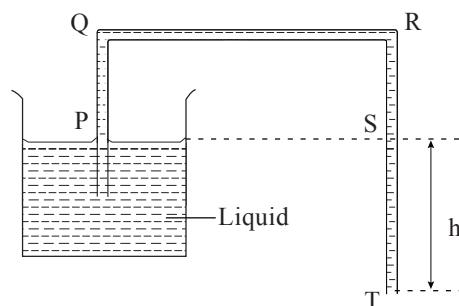
below, is a daily life application of atmospheric pressure.

Illustration of person drinking using straw

With the straw in the mouth, the user first sucks the thin column of air between his mouth and the liquid level inside the straw. This creates a region of low pressure within the space. Atmospheric pressure acting on the surface of the liquid in the container is thus able to push it up the user's mouth.

(b) The siphon

The siphon is a set-up used for emptying a liquid container, or transferring liquid from one container to another. It consists of a bent rubber or glass tube with the shorter arm dipping into the reservoir and longer one suspended outside, as below.

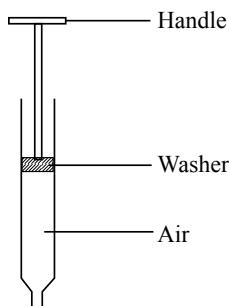


For the siphon to function, the tube must be filled with the liquid to be transferred, and the final end of the tube must be lower than the surface of the liquid in the reservoir.

The siphon works due to pressure difference between the liquid surface P and end T of the tube. The pressure at level T equals atmospheric pressure added to pressure due to column ST ($h\rho g$), where ρ is the density of the liquid. The flow of the liquid is thus due to excess pressure $h\rho g$. For the siphon to remain operational, the height PQ through which the liquid has to rise must not surpass the barometric height of the liquid.

The siphon can also work in vacuum even if the height RS is greater than the liquid's barometric height. In this case, the larger weight of the column RT pulls the shorter column PQ through cohesion between particles of the liquid.

(c) The bicycle pump



Most bicycle pumps are operated using a hand-driven piston as shown in the figure. When the handle is pulled upwards (upstroke), air is drawn into the pump through a one-way valve. At the down stroke, the air in the pump is forced into the bicycle tube.

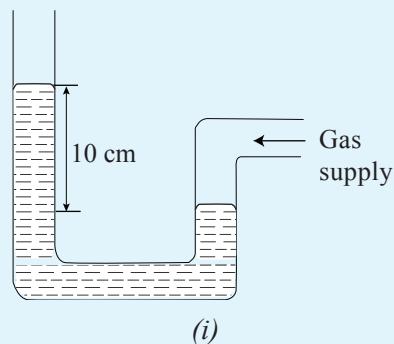
8. The figure below shows a syringe-type fountain pen being fed with ink.

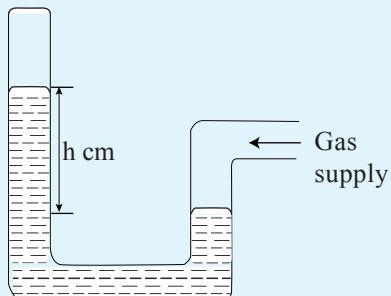
Explain how the ink gets drawn into the pen.

Answer

As the plunger is pushed down to the lowest level, it drives out most of the air from the barrel. When it is pulled outwards, it creates a partial vacuum (low pressure) on the barrel. This atmospheric pressure acting on the surface pushes ink into the barrel.

9. (a) The figure shows an open-ended manometer connected to a gas cylinder. Assuming no loss in the pressure from the gas cylinder, calculate the gas pressure if the mercury barometer reads 76 cm.





(ii)

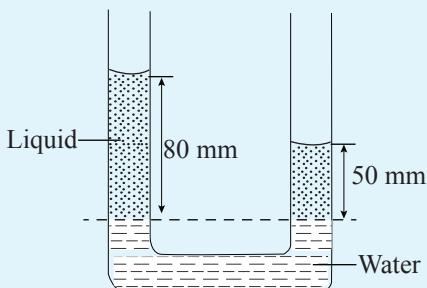
- (b) If the open end of the barometer is closed with a vacuum space created as shown in figure (ii) and same gas supply connected, determine the height h of the mercury column.

Answer

$$\begin{aligned}
 \text{(a) Gas pressure} &= \text{atmospheric pressure} + \text{pressure due to liquid column} \\
 &= 10 + 76 \text{ cm} \\
 &= 86 \text{ cm of Hg or} \\
 &0.86 \times 13600 \times 1 = 116960 \text{ Pa}
 \end{aligned}$$

- (b) The gas pressure is 86 cm of Hg. This will be the height of mercury column.

10. A U-tube filled with water is used to measure the density of a fluid which is gently poured on the left arm to attain the height shown below.



Find the density of the liquid.

Answer

$$h_1 \rho_1 g_1 = h_2 \rho_2 g_2$$

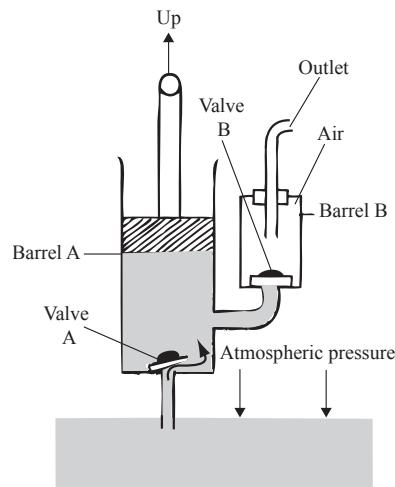
$$\begin{aligned}
 \rho_1 \times \frac{80}{1000} \times 10 &= 1000 \times \frac{50}{1000} \times 10 \\
 \rho_1 &= \frac{500}{0.8} = 625 \text{ kg/m}^3
 \end{aligned}$$

11. Briefly describe the working of:

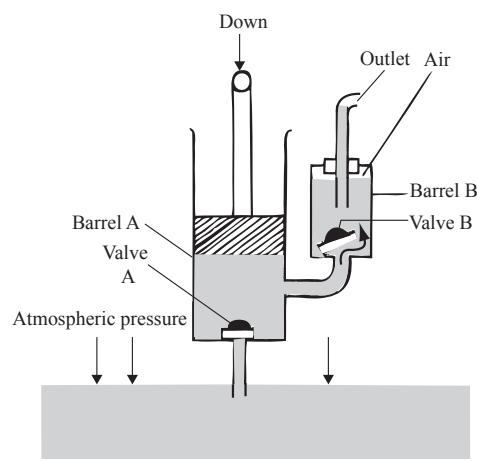
- (a) A force pump
(b) A lift pump

Answer

- (a) The force pump



(a) Upstroke



(b) Downstroke

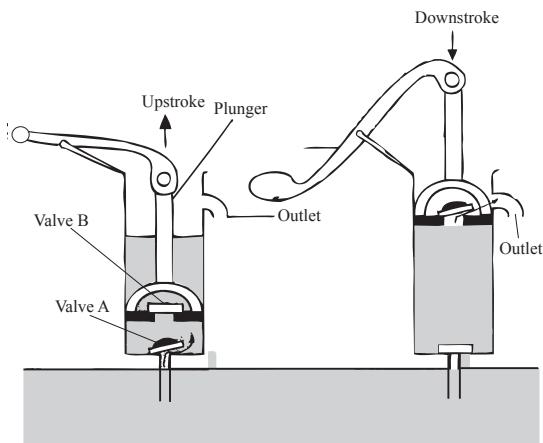
During upstroke

The pressure above the valve A decreases causing it to open, while valve B closes due to the pressure of air and water above it. The atmospheric pressure pushes water into barrel A.

During upstroke

Pressure above valve A closes due to increased pressure in barrel A. Valve B opens to allow water into barrel B, and the water eventually flows out through the outlet.

(b) Lift pump



Upstroke

Pressure between valve A and B reduces, valve A opens while valve B closes. Atmospheric pressure acting on the surfaces forces the water through valve A and out through the outlet.

Downstroke

Pressure in the barrel increases, closing valve A and opening valve B. The water flows through valve B to the upper section of the barrel.

Revision Exercise 3

Where necessary, take $g = 10 \text{ m/s}^2$ and density of water = 1000 kg/m^3

1. (a) Define pressure, giving its SI units.
(b) Describe a simple experiment to demonstrate that air exerts pressure.
2. A mercury barometer reads 730 mm at a certain location. Calculate the atmospheric pressure at the location. (Take density of mercury as $13\,600 \text{ kg/m}^3$).
3. A U-tube with water gives a difference in liquid level of 12 cm when connected to a gas outlet. Find the excess pressure of the gas above atmospheric pressure.
4. A rectangular container measuring 60 cm by 50 cm and weighing 3 kg holds water to a depth of 40 cm and rests on a large table.
 - (a) Calculate the force the container exerts on the table.
 - (b) Find the pressure exerted by the liquid at the base of the container.
 - (c) Find the pressure exerted on the table by the container.
5. The set-up below shows a simple barometer used for estimating atmospheric pressure:
 - (a) State the liquid L used in the barometer, and why it is preferred over other liquids.
 - (b) What is the height h at sea level? What happens to this height as the set-up is placed at a higher altitude?
 - (c) A student attempted to design the barometer using water. Enumerate the challenges he had to cope with.
 6. Explain why jetliner passenger cabins are pressurized.

Particulate Nature of Matter

Key Points

- Matter is made up of tiny particles called atoms. Atoms combine to form molecules.
- Kinetic theory holds that matter is made up of tiny particles which are in continuous motion. For solids the motion (vibration) of particles is to and fro. For liquids and gases the motion is random, and is known as Brownian motion.
- Matter mainly exists as solid, liquid or gas. Some rare states of matter that exist include plasma (gas with non-negligible number of ionised particles) and Bose-Einstein condensate (very low density gas cooled to extremely low temperatures close to absolute zero).
- The particle nature of matter can be demonstrated by dilution, diffusion and breaking up of particles.
- The rate of diffusion is affected by the changes in temperature and density of the particles. Diffusion is more pronounced in liquids and gases than in solids.

Revision Questions 4

- Describe a simple experiment to illustrate that matter is made up of tiny particles.

Answer

Some experimental evidence to show that matter is made up of tiny particles include:

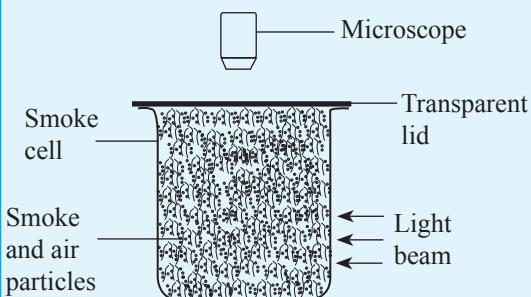
- Breaking a piece of chalk into pieces:
This can continue endlessly, giving smaller and smaller particles of chalk.

(ii) Dissolving copper sulphate solution:
From a saturated solution, dilution can be done till a colourless solution is obtained. This suggests that the particles of copper sulphate mix evenly with those of water.

(iii) Ventilating a smoky room:

When air is allowed into a room full of smoke, soon smoke particles mix with air and depending on the amount of air allowed, the room may be clear of smoke.

- The behaviour of smoke particles in air was observed using the apparatus shown below:



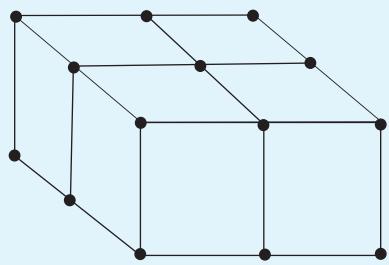
- Why is light used in this experiment?
- Why are smoke particles suitable?
- Briefly describe what would be observed when the smoke-cell is viewed using a microscope.
- What is the aim of the experiment?
- What would be the difference on smoke particles if viewed when the temperature is increased?

Answer

- The smoke particles reflect light and can therefore be seen clearly.

- (b) Smoke particles have masses small enough to be moved slightly when hit by air and are large enough to be seen (visible).
- (c) Bright specks are seen moving randomly in a zigzag manner.
- (d) The experiment shows that particles of matter are in a continuous random constant motion.
- (e) The motion of the particles would increase due to the increase in kinetic energy.

3. The model below represents the arrangement of molecules in a solid:



- (a) How can it be used to explain what happens when the solid is heated?
- (b) How does the movement of solid atoms differ from those of the liquid molecules?
- (c) Why is energy required to change a solid into a liquid at the same temperature?

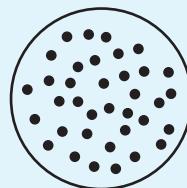
Answers(a) When a solid is heated, the particles vibrate about their mean positions with greater amplitude.

(b) In a solid, the molecules vibrate about the same mean fixed position while in a liquid, the molecules move throughout the liquid.

(c) Energy is required to separate the

molecules by breaking the attractive forces holding them together.

4. (a) The figure below represents molecules in a liquid state:



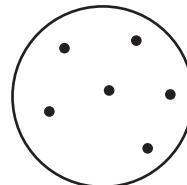
Liquid

Show the representation of the molecules in a gaseous state.

- (b) Explain why gases can be compressed easily.

Answer

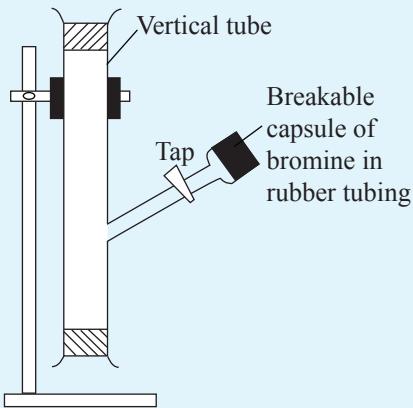
(a)



Gas

- (b) Gases are easily compressed because they have larger intermolecular distance between them.

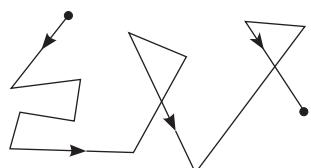
5. A capsule containing liquid bromine is placed inside a rubber tube. The tube is then broken and a tap opened to allow bromine into a tall jar as shown. Brown colour spreads up the jar.



- What is the aim of the experiment?
- Briefly describe what will be observed
 - About 10 seconds after opening the tap.
 - About 10 minutes later.
- With the aid of a diagram, explain why no bromine molecules will be observed at the top of the tube.
- Liquid bromine evaporates yet no heat is provided. Explain this process of evaporation in terms of the behaviour of bromine molecules.

Answer

- To illustrate Brownian motion.
- (i) The brown colour of bromine forms a small distance up the tube.
(ii) The brown colour fills most of the tube, but the concentration decreases upwards.
- Although the speed of the molecules is high, the net movement in one direction is very small because the molecules are continually knocked to deviate from their path, as below.



(d) At a particular temperature some bromine molecules have higher energy than the average energy of all the molecules. The more energetic molecules have enough energy to leave the liquid. As they escape, the average energy of the remaining molecules reduce, thus cooling the liquid.

- In terms of kinetic theory of matter, explain the existence of solid, liquid and gaseous states.

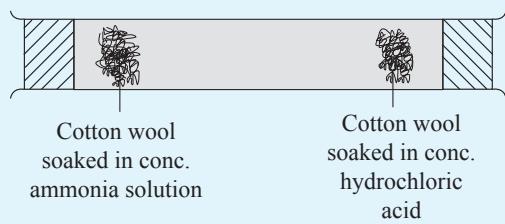
Answer

- In solids, the particles are close together. There are strong attractive and repulsive forces between neighbouring particles. The particles vibrate to and fro about the mean position. This gives solids definite shape and size.
- In liquids, the molecules are slightly apart. There is slight vibration as well as limited movement over short distances. Liquids, therefore, lack pattern, but can flow and take the shape of the container.
- In gaseous state, the molecules are farther apart and move about at very high speed, thus escaping through any available space. Occasionally, they collide with each other or the walls of the container hence exerting pressure.

Revision Exercise 4

- Give a reason why potassium permanganate crystals placed at the bottom of a beaker change the colour of water after some time.
- Explain why:
 - Solids have a definite shape, and don't flow.
 - Solids and liquids have a fixed size but gases fill the container they are in.

3. A perfume can be smelled some distance away. Explain.
4. (a) State what is meant by Brownian motion.
(b) State the effect of cooling on the movement of air molecules.
5. Some white deposits of ammonium chloride was formed when cotton wool soaked in ammonium solution and hydrochloric acid was placed at the ends of a glass tube as shown below.



- (a) What is the aim of the experiment?
- (b) Show where the deposits are formed.
- (c) Explain the observation.

UNIT
5

Thermal Expansion

Key Points

- Heat is a form of energy transferred from one body to another due to temperature difference.
- Zero kelvin (0 K), also known as absolute zero, is the temperature at which all particles in matter are suppressed to the maximum, so that they don't vibrate or move at all. This temperature is useful in scientific work because a number of physical quantities such as volume of ideal gas are directly related to it.
Note: $0\text{ K} = -273.15^\circ\text{C}$
- Expansivity is a measure of the extent of expansion a material undergoes when exposed to change in temperature. In general, expansion of materials is noticeable on free ends rather than fixed ends.
- Matter expands on heating and contracts on cooling.
- Thermal expansion is the physical change of an object due to increased heat energy.

Revision Questions 5

1. (a) Define temperature and state its SI unit.
(b) Describe an experiment to demonstrate thermal expansion in solids.

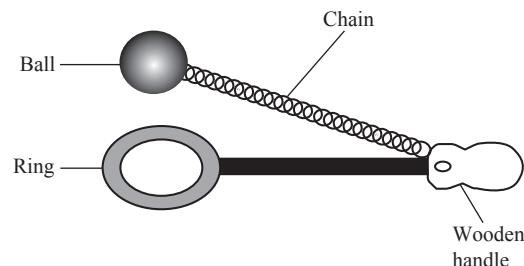
Answer

- (a) Temperature is the degree of hotness or coldness of a body on some chosen scale.

It indicates the level of the heat energy. SI unit is Kelvin.

- (b) Thermal expansion in solids.

Ball and Ring



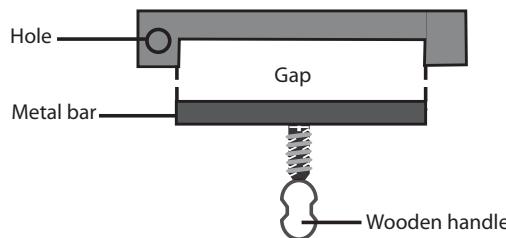
The ball is placed on top of the ring at room temperature. It is observed that it just slips through the ring.

The ball is then heated strongly in a bunsen burner flame and placed on top of the ring again. This time it does not go through initially, but after a while it slips through.

At room temperature, the diameter of the ball is just less than the internal diameter of the ring and hence goes through. When the ball is heated it expands and outsizes the internal diameter of the ring. The ring absorbs heat from the ball and expands as the ball cools and contracts. The ball thus goes through the ring again.

Or

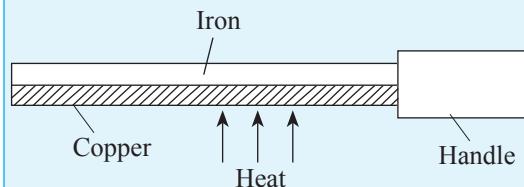
Bar and Gauge



At room temperature, the metal bar just fits into the gap and its circular cross-section just slips into the hole. When the bar is heated, it is observed that it cannot fit into the gap and also the hole.

The experiment illustrates that the metal bar expands when heated and contracts when cooled.

2. The diagram below shows a bimetallic strip of copper and iron.



Explain what happens when the strip is:

- (a) heated.
- (b) cooled.

Answer

- (a) When the strip is heated, the copper expands more than iron and the bar bends upwards.

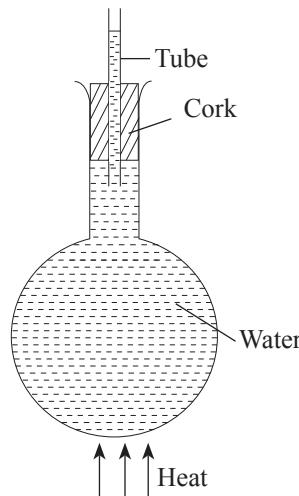
- (b) When cooled, copper contracts more than iron, and the strip bends downwards.

3. Describe an experiment to demonstrate thermal expansion in:

- (a) liquids.
- (b) gases.

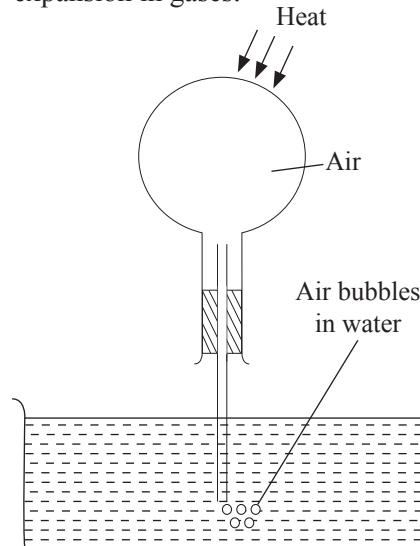
Answer

- (a) The set-up below can be used to illustrate thermal expansion in liquids.



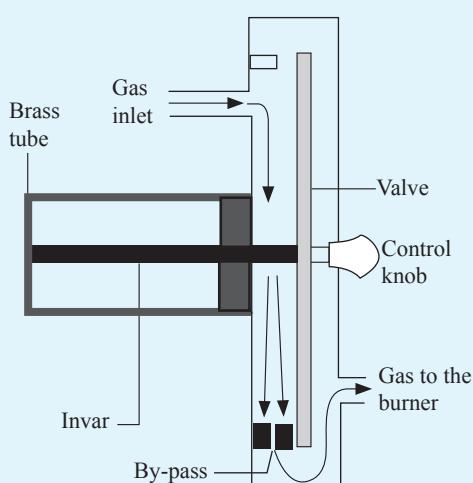
As heat is applied, the water level in the tube initially falls before it rises steadily. This is because the heat applied first reaches the glass flask, causing it to expand, resulting in decrease of the water level. As the heat eventually reaches the water, its level rises steadily since the rate of expansion of water is higher than that of glass.

- (b) The figure below illustrates thermal expansion in gases.



When the flask is heated, the air inside becomes warm. The water level in the tube thus falls and bubbles of air emerge from the mouth of the tube. On cooling, the air in the flask cools and water rises up the tube.

4. The diagram below shows a thermostat for a gas cooker oven. Describe how it works.



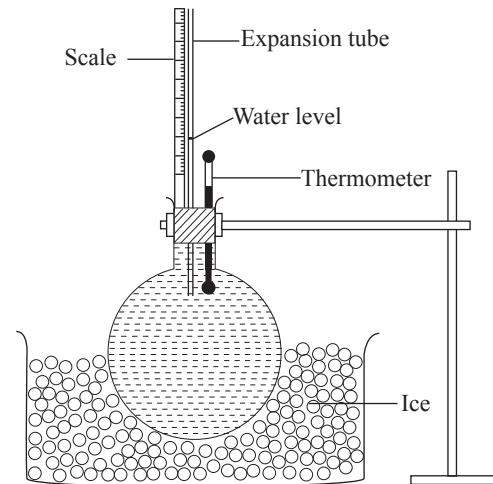
Answer

As the oven temperature rises, the brass tube expands and drifts to the left, pulling the invar along. The valve, therefore, moves towards the left and the gas supply to the burner is reduced. When the temperature goes down, the brass contracts and the reverse effect is observed.

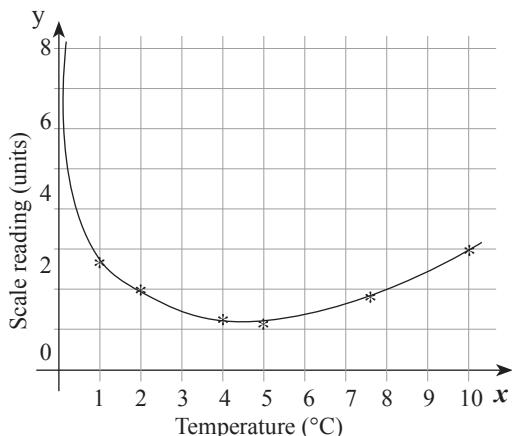
5. Describe an experiment to illustrate the anomalous expansion of water.

Answer

The figure shows the set-up that could be used to illustrate the anomalous expansion of water.



- (i) A flask filled with water (slightly coloured) at room temperature is fitted with a rubber stopper where glass tube and thermometer are inserted.
- (ii) A scale to determine the level of water is fixed along the tube.
- (iii) The flask is put in an ice trough.
- (iv) At regular intervals, temperature and the level of the water are recorded, until the temperature falls to zero.
- (v) A graph of water level (representing volume) against temperature is plotted.



- As temperature decreases, the volume of water decreases. This continues up to

4°C when the volume is minimum. Below 4°C , the volume increases, up to 0°C .

6. On a given thermometer, the temperature of the melting point of ice was marked as 20, while that of steam above boiling water as 100 at a normal pressure. Calculate:
- the temperature in $^{\circ}\text{C}$ when the reading on this thermometer is 40.
 - the thermometer reading when the temperature is 40°C .

Answer

$$\begin{aligned} \text{(a) Temperature difference} &= 100 - 20 \\ &= 80 \\ \therefore 80 &\equiv 100^{\circ}\text{C} \end{aligned}$$

When the thermometer reads 40, the change is $40 - 20 = 20$

$$\therefore \frac{20}{80} \times 100 = 25^{\circ}\text{C}$$

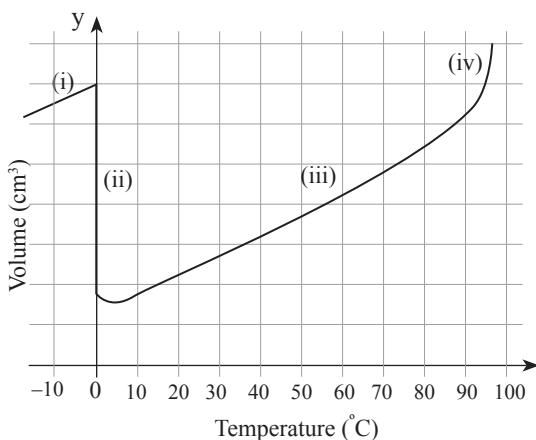
$$\text{(b) } 100^{\circ}\text{C} \equiv 80$$

$$\therefore 40^{\circ}\text{C} \equiv \frac{40 \times 80}{100} = 32$$

$$\begin{aligned} \text{Thermometer reading} &= 32 + 20 \\ &= 52^{\circ} \end{aligned}$$

7. Describe the behaviour of water from -10°C to 100°C .

Answer



- With increase in temperature, ice expands until it reaches melting point (0°C).
- At 0°C , volume of ice is greater than volume of water. Volume, therefore, drops during melting.
- Between 0°C and 4°C , volume of water decreases with rise in temperature. At 4°C , volume falls to minimum, hence attains maximum density.
- From 4°C , volume increases steadily with increase in temperature.
- At 100°C , water changes to steam with volume increasing infinitely.

8. State and explain one advantage and one disadvantage of the unusual expansion of water.

Answer

Advantage

Sustains aquatic life when temperature falls below zero.

Ice forms on the surface of the water since it is less dense than water. Ice is a poor conductor of heat, hence water below does not fall below 4°C because ice insulates it.

Disadvantage

- (i) Destruction of water pipes.

Water at 0°C expands, creating large forces inside the pipes, causing them to burst.

- (ii) Weathering of rocks.

Rocks may split off if water held in crevices freezes, causing large forces due to its expansion.

9. State and explain;
- Two effects of thermal expansion.
 - Two ways in which thermal expansion is managed in everyday life.

Answer

- (a) (i) Some glass containers may break when hot liquids are poured into them.

The parts of the utensil in contact with hot liquid expand. Glass is a poor conductor of heat, hence the parts away from the hot liquid remain cold. The non-uniform expansion creates stress and the glass breaks.

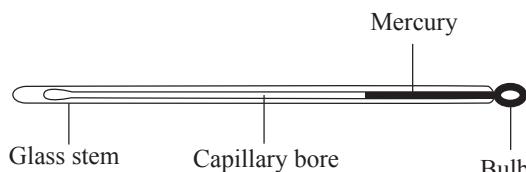
- (ii) A power line sags during hot weather but is tight when cold.

- (b) (i) Large structures like bridges and railways require expansion gaps to avoid 'sunkink'.

- (ii) Compensated pendulum (gridiron) has different arrangement of metals so that the expansion of one counters the expansion of the other, with overall length of the pendulum remaining largely unchanged when hot.

10. Draw a labelled diagram of mercury thermometer and describe its functioning.

Answer



The thermometer consists of a thin-walled glass bulb with mercury, connected to a narrow tube inside a calibrated thick glass stem.

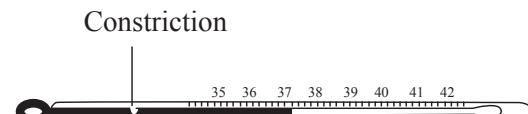
To determine the temperature of a body, the glass bulb is put in contact with the body. There is exchange of heat between the body and the mercury in the thermometer, which results in mercury either expanding or contracting within the narrow tube. The

reading is taken when equilibrium is attained and the mercury level settles.

11. (a) Draw a labelled diagram of a clinical thermometer with a range 35°C to 42°C .
- (b) State the purpose and explain the features of a clinical thermometer.

Answer

- (a)



- (b) The clinical thermometer is used for measuring temperature of the human body. Its main features are:

Glass tube: Thin for sensitivity so that it detects slight variations.

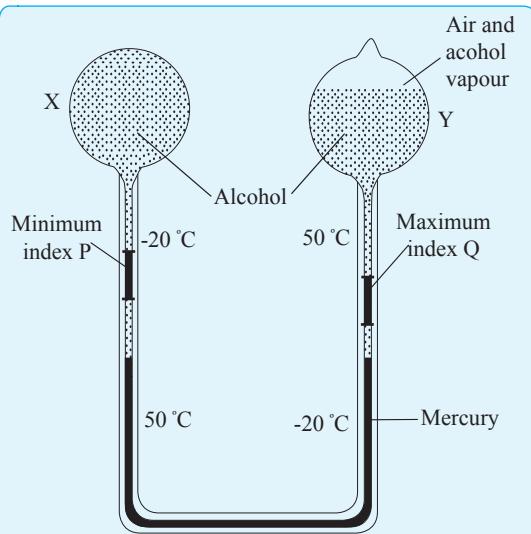
Constriction (kink): To ensure that the expanded mercury does not flow back after removal from body contact. This allows for readings to be taken even after a while.

Narrow glass bore: To ensure high degree of accuracy due to limited temperature range.

Pear-shaped glass tube: This magnifies the scale for easier reading.

Shorter scale (35°C – 42°C): Convenient thermometer size and easy reading.

12. The following figure shows Six's maximum and minimum thermometer.
- (a) Explain why alcohol and mercury are used.
- (b) Describe how the instrument functions.



Answer

- (a) Alcohol is the thermometric liquid – it is the one that actually measures the temperature by thermal expansion and constriction. Alcohol is used in the thermometer because:
- it has very low freezing point (-115°C).
 - it has high expansivity and uniform expansion.
 - it has low density and therefore flows easily past the indexes P and Q without dragging them along.

Mercury is used to separate alcohol in the two limbs of the thermometer. Because of its density and shape of meniscus, it pushes the steel indexes to indicate temperature readings on either side.

- (b) When the temperature rises, alcohol in bulb X expands, flowing past index P (minimum index) and pushing the mercury round the tube towards end Y. The mercury in turn pushes up index Q to give the maximum temperature reading. When temperature decreases, the alcohol

on side X contracts and the vapour pressure from end Y pushes both alcohol and mercury columns round the tube towards X. The alcohol flows past the maximum index Q pushing the mercury, which in turn pushes index P to give the minimum temperature reading.

Note that both temperature readings are taken from the bottom parts of the indexes. The indexes are reset using a magnet at the beginning of each day.

The scale on the minimum side increases downwards while that on the maximum side increases upwards.

13. Explain expansion of matter in terms of particle behaviour.

Answer

Rise in temperature increases kinetic energy of the particles. In the solid state, this results in the particles vibrating more vigorously and with bigger amplitude occupying more space. In the liquid and gaseous states, the increased kinetic energy causes the particles to move more vigorously, resulting to larger distances of separation and thus occupying more space.

Revision Exercise 5

- Using a sketch graph, describe how the volume of a mass of water changes over the temperature range 273 K to 283 K.
- (a) Describe how you would calibrate a thermometer by indicating the two fixed points and then use it to determine the room temperature.
(b) Explain the following features of a thermometer:
 - The bulb is made of thin glass.
 - The mercury does not immediately rise to the final

- level when the thermometer is placed in warm water.
3. (a) Draw a labelled diagram of a clinical thermometer, stating the reasons for the features in the design.
- (b) Explain why it is not advisable to sterilize a clinical thermometer in hot water.
4. Draw a labelled diagram of Six's maximum and minimum thermometer. Explain its working.
5. (a) State two advantages of mercury over

- alcohol as a thermometric liquid.
- (b) Identify a suitable thermometric liquid for a thermometer designed to measuring temperature of -70°C .
- (c) The scale of a thermometer is such that 1.5 cm thread of mercury corresponds to 0°C while 13.5 cm corresponds to 75°C . Determine the length of mercury when the temperature reads 100°C .

Key Points

- Temperature is a measure of degree of hotness or coldness of a body on some chosen scale.
- Temperature change implies the addition or removal of heat.
- Conduction and convection require a medium for transmission while radiation does not require a medium.

Revision Questions 6

- (a) Define the term heat and state its SI unit.
 (b) Differentiate between heat and temperature.
 (c) Explain why sparks from crackling fire cannot cause significant burn even though the temperatures are high.

Answer

- (a) Heat is a form of energy which is transferred from one body to another due to temperature difference. The SI unit is the joules (J).

(b) *Heat*

A form of energy (thermal) transferred from one body to another due to temperature difference.

Measured in joules (J)

Determined by calculation

Extensive property: depends on factors such as mass, temperature change and thermal capacity of the body.

Temperature

A measure of degree of hotness or coldness of a body on some chosen scale.

Or the average kinetic energy of a particle in a substance.

Measured in Kelvin

Measured using a thermometer

Intensive property: independent of the amount of material present.

- (c) Sparks have no significant mass therefore, they do not carry significant heat energy.

- (a) Define the term thermal conduction.
 (b) In terms of heat transfer, distinguish between good and bad conductors of heat, giving an example of each.
 (c) Describe an experiment to show that water is a poor conductor of heat.

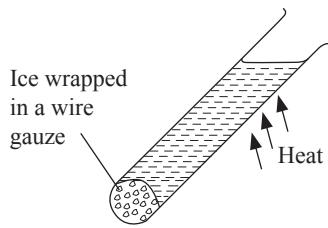
Answer

- (a) Thermal conduction is the transfer of heat through a body as a result of vibration of its particles. Vibration causes particles to knock against each other, hence passing energy to cooler parts of the material.

- (b) Poor conductors of heat are those materials that rely solely on collision of atoms as the mode of transfer, for example, cotton, cork, wood, etc. Good conductors have free electrons in addition to vibration of atoms making them much better conductors of heat. Examples are copper, iron, brass and silver.

- (c) To show that water is a poor conductor of heat.

- Ice is wrapped in a wire gauze and gently placed in a boiling tube. The boiling tube is filled with water and heated at the tip for some time.



Water will be observed to boil at the top while ice remains at the bottom (without melting). This shows that water is a poor conductor of heat.

3. (a) State any three factors affecting conduction.
(b) Explain briefly how the factors named above affect conduction.

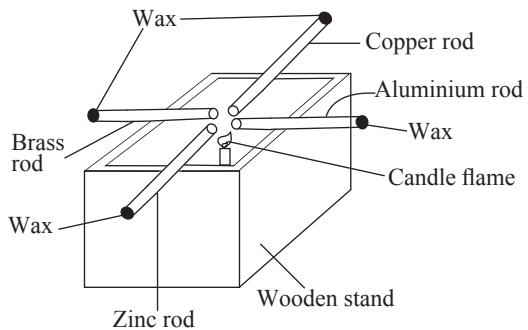
Answer

- (a) (i) Length of the conductor.
(ii) Area of cross-section of the conductor.
(iii) The temperature differences between hot and cold ends of the conductor.
(iv) Nature of the material.
- (b)
- The rate of conduction decreases with increase in length, that is, the shorter the length, the faster the conduction.
 - The thicker the conductor, the faster the heat flow as more particles per unit area vibrate.
 - The greater the temperature difference, the higher the rate of heat flow.
 - Materials conduct heat differently depending on their thermal conductivities. The higher the thermal conductivity, the faster the rate of conduction.

4. Briefly describe an experiment to illustrate thermal conductivity of various metals.

Answer

Different metal rods with identical physical dimensions are waxed at one end and heated equally.



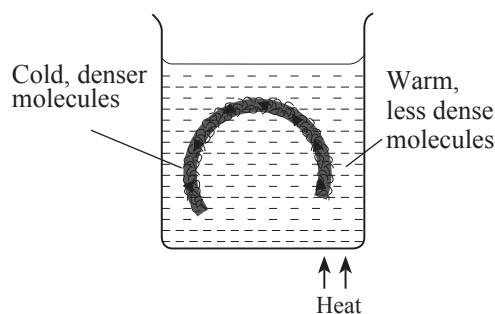
The rate at which wax falls off is observed. This occurs at different times, showing the order of thermal conductivity.

5. (a) Define the term convection and explain how it occurs.
(b) Using a diagram, describe convection:
(i) in liquids.
(ii) in gases.

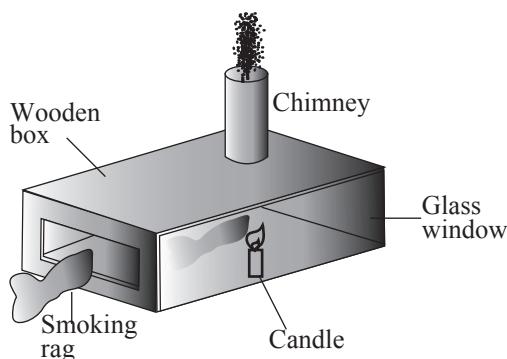
Answer

- (a) Convection is the transfer of heat through fluids as a result of movement of their particles. When a section of a fluid is heated, it expands leading to an increase in volume. Since the mass does not change, the density decreases. The less dense part of the fluid rises up and is replaced by the colder denser section of the fluid.
- (b) (i) Convection in liquids can be demonstrated using a crystal of potassium permanganate dropped in a beaker containing water. The beaker

is gently heated directly below the crystal. The coloured permanganate moves in the path of convection current.



Convection in gases can be demonstrated using a smoke box.



A burning candle is placed under one of the chimneys as smoldering rug is introduced over the other as shown above. When warm air (less dense) rises, it is replaced by cold denser air. The movement of gas (air) is shown by smoke.

6. Briefly describe two applications of convection in daily life.

Answer

Practical cases of convection include:

(i) Ventilation

Most domestic houses have ventilation where warm (less dense) air escapes through as fresher, cooler air from doors and windows replaces it. The ventilators are positioned near the ceiling.

(ii) Chimneys

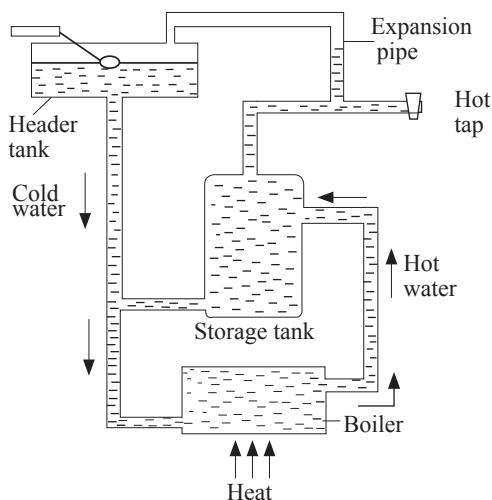
Hot gases and smoke normally move up through a tall chimney in factories and homes. The variation in density resulting in pressure difference between the cold dense air outside and warmer gases in the chimney gives rise to this movement.

(iii) Domestic hot water system

Hot water from the boiler rises up by convection to the top of storage tank, see the figure below. Meanwhile, cold water at the bottom of the tank descends to the bottom of the boiler where heating occurs.

This sets up circulation. Consequently, the storage tank is filled with hot water downwards.

A tap is used to remove hot water for domestic use. The header tank is used to provide constant supply of water and the pressure necessary to push hot water to the taps. An expansion pipe is included to serve as an overflow in case of build up steam (which might cause an explosion) or air bubbles in the system which might cause air-lock in the pipes. Thus it serves as a safety precaution.



7. Explain radiation as a mode of heat transfer.

Answer

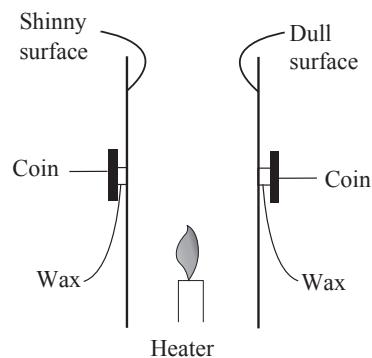
Radiation is the transfer of heat by means of electromagnetic waves.

Radiation does not require material medium, i.e., it can be transmitted through vacuum. It is the means by which energy from the sun, travelling across an empty space, through electromagnetic waves in the infra-red region of the spectrum reach the earth.

8. Describe an experiment to show that:
- Dull surfaces are better absorbers than shiny surfaces.
 - Dull surfaces are better emitters of radiation than shiny surfaces.

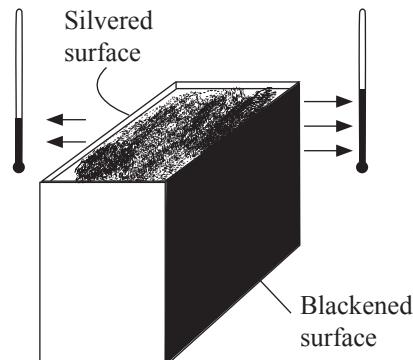
Answer

(a) Bodies with dull surfaces are better absorbers of radiant heat than those with shiny surfaces. A set-up to demonstrate this concept is shown below.



A heater is placed midway between two metal sheets, one with shiny surface and the other dull. A coin is secured on each sheet using wax. After some time, the coin on the dull surface falls as the wax melts, while that on the shiny surface remains much longer. This shows that dull surfaces are better absorbers of radiant heat.

- (b) Emission of radiation can be illustrated by rectangular tin containing water with one side blackened and other silvered. The water is heated to some temperature.



A precise observation can be made using two thermometers with blackened bulbs placed equidistant from the tin on either side. The thermometer on the blackened side will show higher temperature than that on the silvered side.

9. Outline three applications of radiation in daily life.

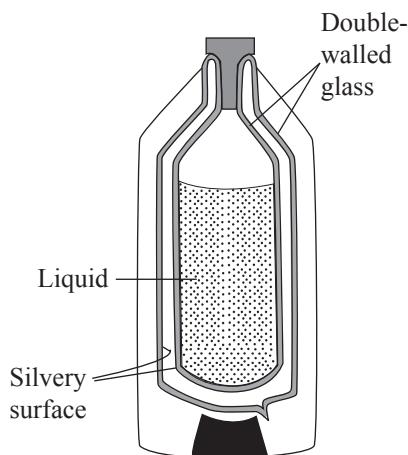
Answer

- (i) In hot places, buildings are white-washed or painted in light colours to keep them cooler.
- (ii) People prefer light-coloured clothes in hot places or during hot seasons.
- (iii) Petrol tankers are painted silvery and highly polished to minimise absorptions of heat. This prevents expansion.

10. Explain briefly how each of the following works:
- (a) Vacuum flask.
 - (b) Solar concentrators.

Answer

- (a) Vacuum Flask



This flask is specially designed to minimise heat flow in or out of it.

The vacuum reduces heat loss by conduction and convection.

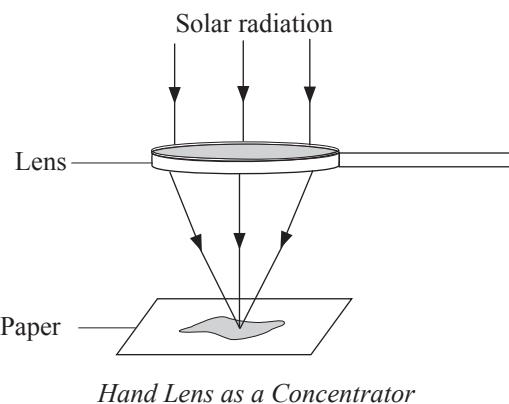
The silvered wall reduces heat loss by radiation. The lid (plastic or cork) which is an insulator prevents heat loss by conduction and convection.

Although certain amount of heat may be gained or lost by the flask, the value is so minimal that the flask is effective in maintaining the required temperature of the liquid.

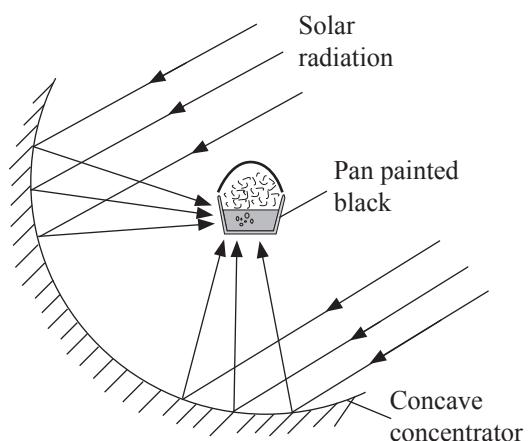
(b) Solar concentrators

The sun being at a distance sends parallel rays which are converged by either parabolic or concave reflector.

At the focal point, the temperature is usually high enough to ignite materials like piece of paper, or even boil water, see the illustration below.



Hand Lens as a Concentrator



Concave Reflector as a Concentrator

11. Explain the working of the greenhouse.

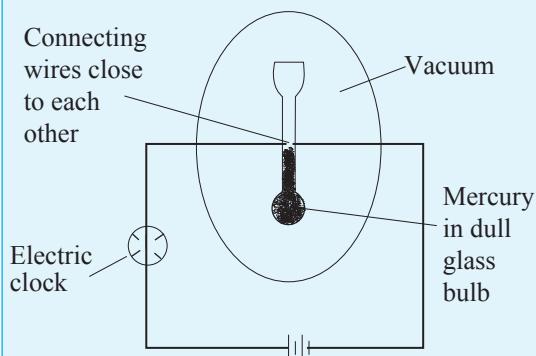
Answer

In a greenhouse, radiation from the sun goes through glass and is absorbed by the plants, air and other components inside the structure. The warm objects in turn re-radiate longer

wavelength infrared rays, which cannot penetrate the glass. Thus, the energy is trapped inside the greenhouse and it gradually gets warmer.

Revision Exercise 6

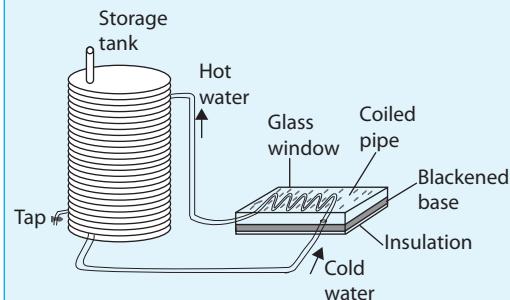
1. (a) Explain why:
 - (i) Woollen or fur coats feel warm.
 - (ii) A flame burn upwards.
 - (iii) Contents in a shiny teapot remain hot longer than when contained in a dull dark teapot.
 - (iv) It feels colder holding the metal part of a slasher than the wooden handle.
- (b) Describe the differences in the manner in which heat is transmitted by conduction, convection and radiation.
2. (a) The action of the greenhouse is based on the behaviour of infrared radiation. Explain.
- (b) Metals are better conductors than wood. Explain.
3. The figure shows an instrument used to measure the time that the sun shines during a day. It consists of mercury placed in a dull glass bulb supported by an evacuated glass case.



- (a) Briefly explain how the energy from the sun reaches mercury.

- (b) The clock ticks when the sun shines. Explain.
- (c) Why is the cross-sectional area of tube X small?
- (d) Blackening of the bulb ensures that the mercury level falls rapidly when the sun ceases to shine, why?

4. The figure shows a solar panel used to provide hot water.



- (a) State the purpose of the following:
 - (i) The glass window on top of the panel.
 - (ii) The blackened base.
 - (iii) The insulator behind the absorbing panel.
- (b) (i) State and explain the choice of materials suitable for making the absorbing panel and water ways.
 - (ii) Why are the pipes connecting the water outlet from the panel to the hot water storage pipe kept short?
5. In a vacuum flask, give:
 - (a) Two features which reduce heat loss by conduction.
 - (b) One feature which reduces heat loss by convection.
 - (c) One feature which reduces heat loss by radiation.

Rectilinear Propagation of Light and Reflection at Plane Surfaces

Key Points

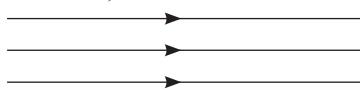
- Visible light is a form of energy that enables vision.
- A source of light is referred to as point source when light emanates from a point considered to be of negligible size compared to other surrounding objects. A typical point source is a bulb placed behind a pinhole. When the source of light is relatively larger it is referred to as an extended source.

Revision Questions 7

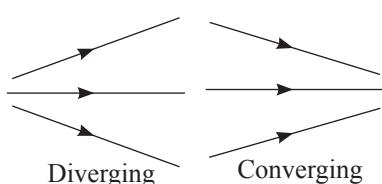
- (a) Distinguish between a ray and a beam of light.
(b) By use of a diagram, show the three types of beams.

Answer

- A ray is the representation of the path taken by light energy in a medium while a beam is a collection of rays.
- A beam may be parallel, diverging (spreading out) or converging (moving to a focus).



Parallel



Diverging

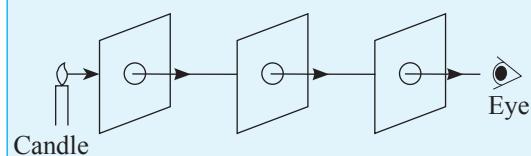
Converging

- Define the following terms as used in propagation of light, giving an example in each case:
 - Transparent object.
 - Translucent object.
 - Opaque object.

Answer

- Transparent objects allow light to pass through and we can see through them. Examples are air, ordinary glass and water.
- Translucent objects allow light to pass through, but we cannot see through them. Examples are waxed paper and frosted glass.
- Opaque objects do not allow light to pass through and we cannot see through them. Examples are concrete, stones, tree trunks and metals.

- A student placed three cards each with a small hole at the centre in a straight line as shown below.



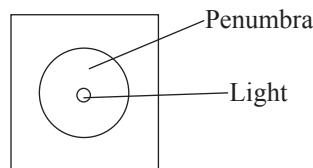
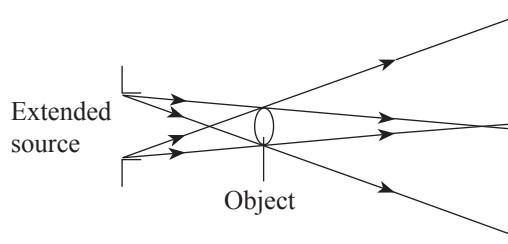
- State the aim of the experiment.
- If one of the cards was displaced slightly to the left, state what would be observed.
- Give another illustration of the concept.

Answer

- (a) To show that light travels in a straight line.
- (b) When one of the cards is slightly displaced, no light will be seen.
- (c) Another case that illustrates that light travels in a straight line is shadow formation.
4. (a) Define a shadow.
(b) One type of shadow that may be formed is umbra.
(i) State the condition necessary for its formation.
(ii) State its main characteristics.
(c) When an extended source of light is used and the distance between the object and the source varied, a partial shadow may be obtained with no umbra. Explain how this happens.

Answer

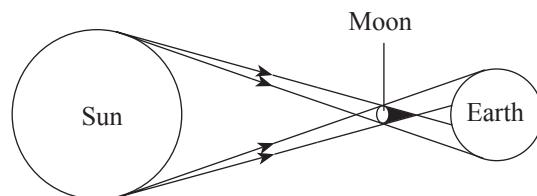
- (a) A shadow is formed when an opaque object blocks the path of light.
- (b) (i) Light must come from a very small source (point source).
(ii) The shadow formed:
– is uniformly dark.
– has sharp and clear edges.
- (c) A partial shadow without umbra is formed when the tip of umbra fails to reach the screen due to the distance between the object and the screen as shown in the following figure.



5. (a) Distinguish between solar and lunar eclipse.
(b) Describe an annular eclipse.

Answer

- (a) Solar eclipse (eclipse of the sun) occurs when the sun, moon and earth are in a straight line, with the moon at the centre. A shadow of the moon is thus cast on part of the earth's surface. Lunar eclipse (eclipse of the moon) occurs when the earth lies between the sun and the moon, with the moon falling in the earth's shadow.
- (b) Annular or ring eclipse occurs when the moon is between the sun and the earth, and the tip of the moon's umbra fails to reach the earth. Thus, only partial eclipse occurs, as shown in the figure below.



6. (a) State the effect on the image formed by a pinhole camera if:

- (i) The size of the pinhole is increased.
 - (ii) The object is moved closer to the pinhole.
 - (iii) The screen is moved farther from the pinhole.
- (b) How can a pinhole camera be modified to take photographs?
- (c) Define the term magnification.

Answer

- (a) (i) When the size of the hole is increased, a brighter but blurred image is formed.
- (ii) If the camera is moved closer to the object, a bigger image is formed.
- (iii) If the screen is moved farther, a bigger image is formed.
- (b) The pinhole camera can be modified to take photographs if:
- (i) The screen is replaced by photographic film.
 - (ii) A shutter is introduced to control light entering the pinhole.
- (c) Magnification (m) is relative change in size of the image with respect to the object.

$$\text{Magnification} = \frac{\text{image height}}{\text{object height}}$$

$$= \frac{\text{image distance from pinhole}}{\text{object distance from pinhole}}$$

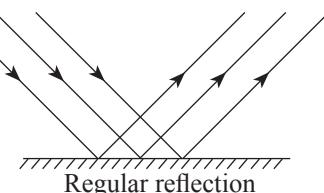
7. (a) With regard to light, state what is meant by:
- (i) Reflection of light.
 - (ii) Normal line.
- (b) Distinguish between incident ray and reflected ray.
- (c) Using a ray diagram, show the following:

- (i) Regular reflection and irregular reflection.
- (ii) Angle of incidence and angle of reflection.

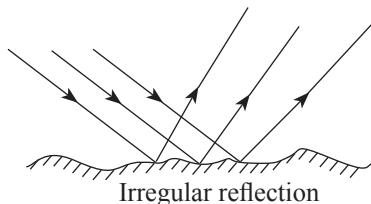
Answer

- (a) (i) Reflection is the bouncing off of light when it falls on a shiny surface.
- (ii) The normal is a line drawn perpendicular to the reflecting surface at the point of incidence.
- (b) Incident ray is the ray that strikes the reflecting surface while reflected ray is the ray which bounces off the surface.

- (c) (i)

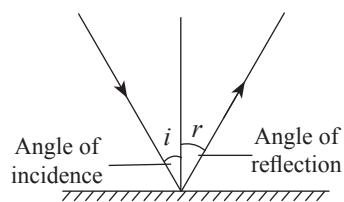


Regular reflection



Irregular reflection

- (ii)



8. (a) State the laws of reflection.
- (b) Describe an experiment to verify the laws of reflection.
- (c) An object is positioned at a point O above a mirror as shown in the following figure.

O

Eye



|||||||

- Using ray diagrams, locate the position of the image.
- State the characteristics of the image formed.

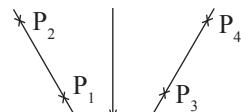
Answer

- (a) (i) The incident ray, the reflected ray and the normal all lie in the same plane at the point of incidence.
(ii) The angle of incidence equals the angle of reflection.

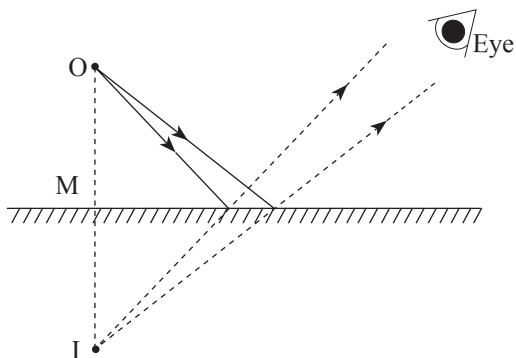
(b) To verify the laws:

- A plain paper is fixed on a soft board with the mirror line and the normal drawn on it.
- Another line is drawn at an angle of, say, $30^\circ C$ to the normal to represent the incident ray.
- Two pins, P_1 and P_2 are fixed along the line drawn as shown in the following figure.
- Observing the images of pins P_1 and P_2 from the opposite side of the normal, two search pins P_3 and P_4 are positioned so that they are in line with the images.
- Pins P_3 and P_4 are removed and the line joining them produced to the reflecting surface.
- The angle of reflection is then measured and recorded.

By varying the angles of incidence, the corresponding angles of reflection are obtained and the two angles compared.



(c) (i)



(ii) The image formed is:

- Virtual
- Laterally inverted
- Same size as the object
- Same distance behind the mirror as the object is in front of it, i.e., $OM = IM$

9. The length of a pinhole camera is 8 cm. It forms an image of linear magnification 0.25. Find the distance between the object and the camera.

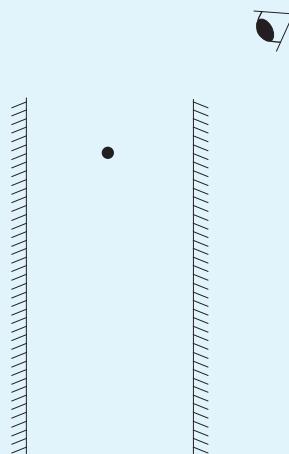
Answer

$$\text{Magnification, } m = \frac{\text{image distance}}{\text{object distance}}$$
$$0.25 = \frac{8}{\text{produced object distance}}$$

$$\therefore \text{Object distance} = 32 \text{ cm}$$

10. (a) When two mirrors are placed at an angle to each other, five images are formed between the mirrors. Calculate the angle between the mirrors.

- (b) An object placed between two parallel plane mirrors as shown in the diagram below forms infinite number of images.



Explain why the images formed far much inside the mirror appear faint.

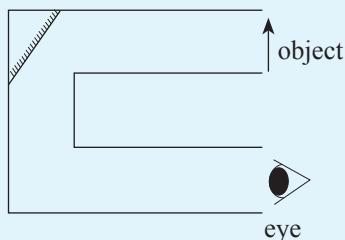
Answer

- (a) $N = \frac{360}{\theta} - 1$, where N is the number of images and θ the angle between the mirrors.

$$\begin{aligned} 5 &= \frac{360}{\theta} - 1 \\ 6 &= \frac{360}{\theta} \\ &= 60^\circ \end{aligned}$$

- (b) There is partial absorption of light energy at each successive reflection.

11. The figure shows an incomplete periscope.

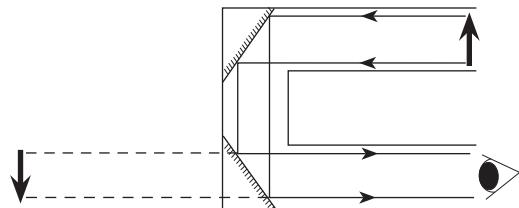


- (a) Draw the second mirror.

- (b) Complete the diagram to show how the eye views the object.
 (c) State and explain the disadvantage of this periscope.
 (d) State and explain an advantage of using glass prisms rather than plane mirrors in a periscope.

Answer

- (a) and (b)



- (c) The image is inverted.
 (d) The image generated is brighter and clearer. This is because due to thickness of the mirror glass, multiple internal reflections cause blurring images. This does not occur in a prism.

12. A ray of light is incident on a plane mirror in such a way that the angle between the reflected ray and the mirror is 15° . Calculate:
 (a) The angle of incidence.
 (b) The angle of reflection.
 (c) The angle between the incident and the reflected ray.

Answer

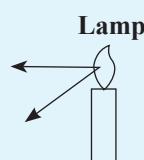
- (i) The angle of incidence $= (90^\circ - 15^\circ)$
 $= 75^\circ$
 (ii) Angle of reflection $=$ angle of incidence
 $= 75^\circ$
 (iii) The angle the ray turns through
 $= 75^\circ + 75^\circ$
 $= 150^\circ$

Revision Exercise 7

1. (a) Briefly describe a simple experiment to demonstrate that light travels in a straight line.
(b) State an occurrence which illustrates that light travels in a straight line.
2. Umbra and penumbra are two types of shadows.
 - (a) (i) Describe these shadows.
(ii) Using illustrations, state the condition that leads to the formation of penumbra.
 - (b) State conditions that do not allow for formation of penumbra.
3. (a) State the characteristics of image formed by a pinhole camera.
(b) A pinhole camera is used to take a photograph. What happens to the image formed if the hole is:
 - (i) Small
 - (ii) Large
(c) What is the effect of moving the camera away from the object? Explain.
(d) (i) Why is pinhole camera not suitable for photographs?
(ii) What is the advantage of using pinhole camera?

5. (a) Distinguish between regular and irregular reflection.
(b) The figure shows rays of light coming from a point on the filament of a light bulb.

Mirror


 - (i) Complete these rays to give the image position on the diagram.
 - (ii) Mark on the figure a normal to the mirror for any one of the reflected rays. Label the angle of reflection for the chosen ray.
 - (c) State the characteristics of the image formed by plane mirrors.
6. With the aid of a diagram, show how a periscope forms an erect image.

Electrostatics (I)

Key Points

- Electrostatics refers to the study of electric charges at rest.
- Opposite charges attract while like charges repel.

Revision Questions 8

1. A polythene rod rubbed with wool acquires a negative charge. Explain:
 - (a) How the rod acquires the negative charge.
 - (b) Why the wool is found to be neutral when tested after sometime.

Answer

- (a) Through rubbing, electrons are removed from wool and remain on the surface of the rod since it is a good insulator. The wool acquires a positive charge since it loses electrons.
- (b) The wool is gradually neutralised by charged particles present in the atmosphere.

2. A metal rod rubbed with a piece of cloth does not acquire charge.
 - (a) Explain this phenomenon.
 - (b) What precaution needs to be taken so that the rod acquires charge?

Answer

- (a) Metals are good conductors hence electrons flow easily either to or from the earth through the hand.

- (b) • Hold the metal rod with an insulating handle like glass or plastic.
 - The hand should not touch the rod while rubbing.
3. (a) State the SI unit of charge.
 - (b) State two types of charges.
 - (c) With reference to the structure of an atom, explain the source of electrostatic charges.

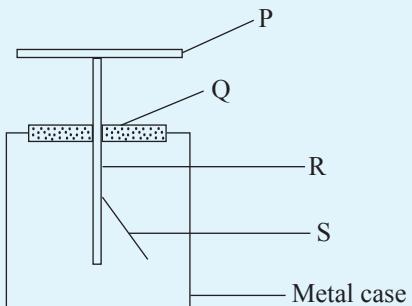
Answer

- (a) The SI unit of charge is the coulomb (C).
 - (b) Positive and negative charges.
 - (c) An atom has protons (positively charged), neutrons (neutral) and electrons (negatively charged). The protons and neutrons are in the nucleus of the atom. Electrons orbit around the nucleus. Through rubbing, the electrons at the outer shells may be shifted from one material to the other. The material that loses electrons becomes positively charged. The material that receives an electron on its surface acquires negative charge.
4. Explain why repulsion is the surest test for electrostatic charging.

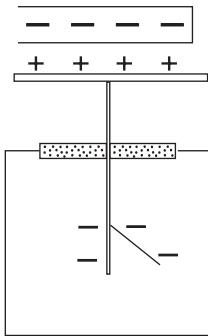
Answer

Like charges repel, indicating both objects are charged. Attraction shows either objects have unlike charges or one is uncharged (neutral).

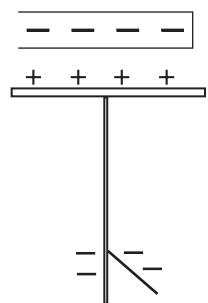
5. The following figure shows the features of a gold-leaf electroscope.



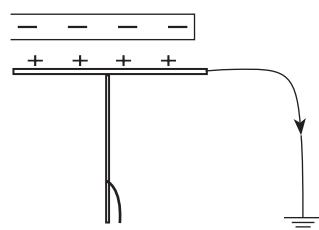
- (a) (i) Name the parts P, Q, R and S.
(ii) Explain the purpose of the metal case.
(iii) A charged polythene rod rubbed with wool is held above P. State and explain what happens.
- (b) Explain how you can use a polythene rod to charge a gold-leaf electroscope by:
(i) Induction.
(ii) Contact.
- (c) Explain how the charge on electroscope is tested.



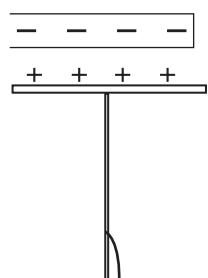
- (b) (i) Charging by induction (positively): Bring the rod near the cap. Positive charge is induced on the cap while negative charges are repelled to the rod and leaf.



Touch cap to earth. Electrons flow to earth and the leaf falls.



Remove the finger



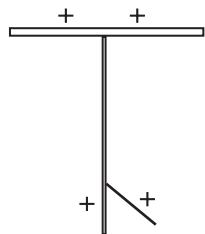
Answer

- (a) (i) P—metal cap ; Q—insulator ; R—metal rod ; S – gold-leaf
(ii) The metal case shields the gold leaf from external influence other than the charge brought near the metal cap.
(iii) The polythene rod is negatively charged.

Electrons in the cap are repelled down the metal rod and leaf, both acquiring negative charge in the process. The leaf and rod repel, as shown below.

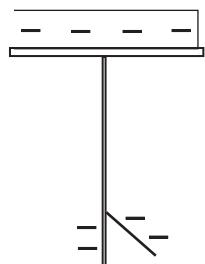
Remove charged strip

The electroscope becomes positively charged.



(ii) Charging by contact:

A negatively charged rod is brought into contact with the cap of uncharged electroscope. Some negative charges are transferred to the cap and leaf. The leaf diverges since like charges repel. Removing the rod from the cap leaves the electroscope negatively charged.



(c) To test charge on an electroscope:

- To test for a negative charge, bring a negatively charged rod close to a negatively charged electroscope. Leaf divergence occurs showing negative charge.
- To test for a positive charge, bring a positively charged rod close to a positively charged electroscope. There is leaf divergence, indicating positive charge.
- In testing for charge, leaf divergence is the only sure proof of polarity.

6. State and explain the uses of a gold-leaf electroscope.

Answer

- (i) To distinguish between conductors and insulators:

- Charge an electroscope either positively or negatively.
- Hold a metal rod (conductor) on the cap of the electroscope.
- The electroscope discharges as charges move through the conductor to the hand and to the earth.
- Hold a glass or plastic rod (insulator) on the cap of the electroscope. There is no change in leaf divergence.

Hence, conductors allow charges to pass through them. Insulators do not allow the charges to pass through them.

- (ii) To identify charge:

- A negatively charged body is brought near a negatively charged electroscope. Increase in leaf divergence indicates that body has negative charge.
- A positively charged body brought near a positively charged electroscope increases leaf divergence, indicating positive charge.

- (iii) Estimate the amount of charge in a body:

- The extent of divergence of the leaf measures the amount of charge in the body.

- (iv) To determine if material is charged or not:

- A charged body brought near an uncharged electroscope causes leaf divergence. A body without charge has no effect.

Revision Exercise 8

1. Explain why experiments to demonstrate effects of forces due to electrostatic charges may not be successful in humid conditions.
2. When rod X is rubbed with material Y, it is observed that the material acquires negative charge.
 - (a) State the charge on rod X.
 - (b) Explain how rod X acquires the charge.
3. A student attempted to charge a gold-leaf electroscope by induction using the following steps:

- (i) Charged material was brought close to but not in contact with the electroscope.
- (ii) The cap was touched using a finger.
- (iii) The charged material was then removed.
- (iv) The finger was removed.

Explain why the electroscope did not get charged.

Cells and Simple Circuits

Key Points

- For current to flow, there must be a source of electrical energy and a complete circuit for it to pass through. The cell provides electrical energy for the circuit.
- Flow of electrons is responsible for electric current. Conventional current flows from positive to negative terminal, but electrons flow from negative to positive terminal.

Revision Questions 9

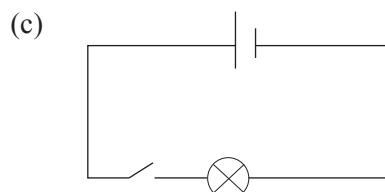
- (a) State three major components of a simple circuit.
 (b) The table below shows some devices used in simple circuits alongside their symbols. Complete the table as necessary.

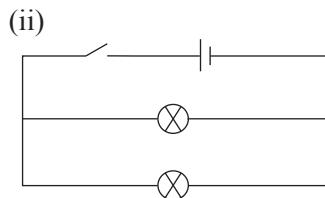
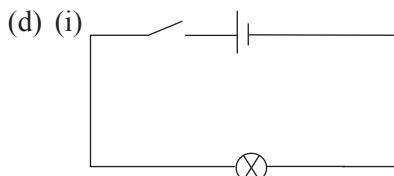
| Device | Symbol |
|--------------------------------|-----------|
| A | — |
| B | — ... — |
| Bulb (lamp) | C |
| D | —/— |
| Fixed resistor | E |
| Ammeter | F |
| G | —(V)— |
| Galvanometer | H |
| Wires crossing (in contact) | I |
| J | — — —\— — |

- (c) Using relevant symbols, draw a circuit that consists of a cell, switch and a lamp.
- (d) Given a cell, two bulbs , a switch and connecting wires, show how you can arrange the bulbs:
- In series.
 - In parallel.

Answer

- (a) A simple circuit consists of:
 - Source of energy – This may be a cell or number of cells (battery).
 - Conductor – These are materials that provide the path for current flow.
 - Load – These are devices in the circuit that convert electrical energy to other forms, for example, electric lamps.
- (b) A – Cell B – Battery
 C – —○— D – Switch
 E – —□— F – —A—
 G – Voltmeter H – —G— or —↑—
 I – —+— J – Variable resistor





2. (a) Define electric current and state its SI unit.
- (b) A device allows current of 10A to pass through a point in a circuit for 25 seconds.
 - (i) Calculate the total charge passing through the point within the period.
 - (ii) If the value of the current changes to 10 mA, how long would the same amount of charge take to pass?

Answer

(a) Electric current is the rate flow of charge.
The SI unit of current is amperes (A).

(b) Charge = current × time

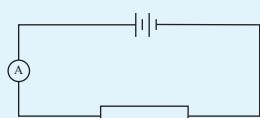
$$= 10 \times 25$$

$$= 250 \text{ C}$$

(c) Time = charge/current

$$\begin{aligned} &= \frac{250}{10 \times 10^{-3}} \\ &= 2.5 \times 10^4 \end{aligned}$$

3. The ammeter reading in the circuit shown below is 3.2 A.



How many electrons drift past a point in the resistor each second?

Answer

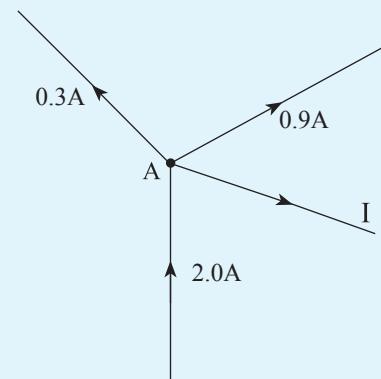
Charge = current × time

$$\begin{aligned} Q &= It \\ &= 3.2 \times 1 \\ &= 3.2 \text{ C} \end{aligned}$$

$$\begin{aligned} \text{Number of electrons} &= \frac{\text{total charge}}{\text{charge on an electron}} \\ &= \frac{3.2}{1.6 \times 10^{-19}} \\ &= 2.0 \times 10^{19} \end{aligned}$$

Thus in each second, 2.0×10^{19} electrons drift past a point in the resistor.

4. Four wires carrying current meet at a junction A, as shown in the diagram below.



Determine the value of current I.

Answer

Total current flowing into junction = total current leaving junction

Total current flowing into junction is 2.0 A

Thus, $0.9 + 0.3 + I = 2.0$

$$1.2 + I = 2.0$$

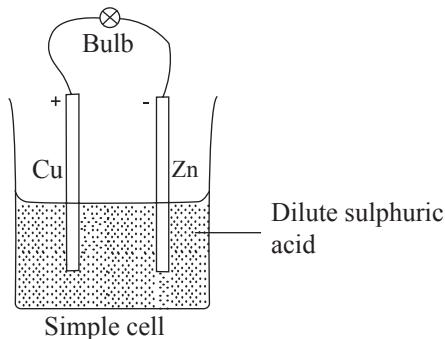
$$I = 0.8 \text{ A}$$

5. (a) What is a cell?
 (b) Using a diagram, briefly describe the working of a simple cell.
 (c) State two defects of a simple cell and explain how each can be reduced.

Answer

- (a) A cell is a device that converts chemical energy stored in it to electrical energy.
 (b) Simple cell:

A simple cell consists of two electrodes (zinc and copper) dipped in dilute sulphuric acid, as shown in the figure below.



The dilute acid has hydrogen and sulphate ions. Zinc reacts with the sulphate ions liberating electrons (source of current). Hydrogen ions move to copper plate, where they gain electrons to form hydrogen atoms. The zinc plate is negative while copper plate is positive. The electrons liberated from the zinc/sulphate reaction flow to the copper plate hence constituting electric current.

- (c) The two defects of a simple cell are:
 (i) Polarisation – This is the formation of hydrogen gas bubbles round the copper plate. The bubbles insulate the copper, resisting the flow of charge. Polarisation can be reduced by using potassium or dichromate which oxidises hydrogen to form water.

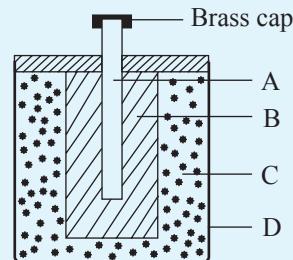
- (ii) Local action – The gradual corrosion of the zinc plate as a result of the presence of impurities in it. Local action is reduced by coating zinc with mercury (amalgamation).

6. Differentiate between primary and secondary cells, giving examples of each.

Answer

Primary cells are cells that cannot be recharged since the chemical reactions in them are not reversible. Examples include the dry (Leclanche) cell. Secondary cells are cells that can be recharged. Examples are lead-acid and nickel-alkaline cells. Other rechargeable cells include the lithium polymer batteries used in phones and laptops.

7. The figure shows a dry cell. Name the parts labelled A, B, C and D and briefly explain their functions.

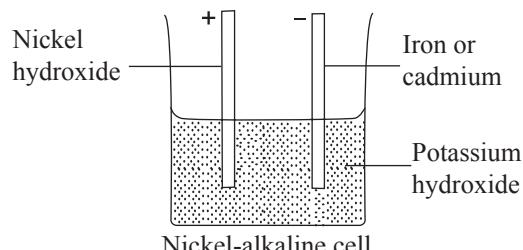


Answer

- A – Carbon rod, acts as positive terminal.
 B – Manganese (IV) oxide, a depolariser, oxidises hydrogen to form water.
 C – Ammonium chloride jelly, the electrolyte, dissociates into ions.
 D – Zinc can, is the negative terminal and also the container.

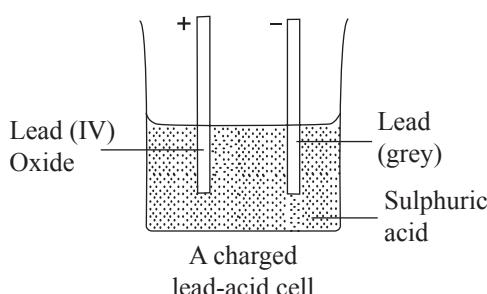
8. Using diagrams, outline the features of the following cells:

- Lead-acid cell.
- Nickel-alkaline cell.



Answer

(a) Lead-acid cell:



The lead-acid cell consists of two lead plates dipped in dilute sulphuric acid (density 1.25 g/cm^3). During charging, the positive electrode becomes lead (IV) oxide (chocolate brown) while the negative electrode remains lead (grey), as shown above. During discharge, both plates are slowly converted to lead (II) sulphate (white). The acid in the process becomes dilute and its relative density falls to about 1.18. The lead-acid cell has a typical voltage of 2.2 V, and it has the advantage of low internal resistance.

(b) Nickel-alkaline cell:

The nickel-alkaline cell consists of nickel hydroxide as positive terminal, potassium hydroxide as electrolyte and either iron or cadmium as negative terminal, see the following figure.

Nickel alkaline cells offer a longer life cycle with a relatively steady supply of power over a wide range of temperature. This makes them suitable for use in hospitals, ships and public premises.

9. (a) State two advantages and two disadvantages of lead-acid cell over the dry cell.
(b) State two advantages of nickel-alkaline cell over lead-acid cell.

Answer

(a) Advantages:

- Can be re-charged.
- Has much lower internal resistance.
- Has higher e.m.f (2.0V).
- Larger current can be drawn for long.

Disadvantages:

- Heavy (not easily portable).
- The acid is corrosive.
- Can explode during gassing if a flame is present.

- (b)
- Can remain in discharged condition for a much longer time without getting damaged.
 - Larger amounts of current can be drawn.
 - Has a much longer life.

10. State four maintenance precautions for lead-acid cells.

Answer

- (i) The acid level must be maintained at the manufacturer's recommended level. Top-up is done with distilled (or de-ionised) water only.
- (ii) Charging should be done regularly.
- (iii) The terminals should be kept clean and little grease applied.
- (iv) Avoid short-circuiting (connecting the positive and negative terminals directly).

Revision Exercise 9

- 1. (a) Define the term circuit as used in electricity.
(b) Distinguish between closed circuit and open circuit.
(c) Using appropriate symbols, draw a circuit consisting of two cells in series, a switch, an ammeter and two lamps in parallel with a voltmeter across them.
- 2. (a) Why is an ammeter connected in series when measuring electric current?
(b) How long does a charge of 1600 C circulate round a circuit maintaining a current of 0.48 A?
(c) A current of 3 A flows through a conductor for 4 minutes. Determine the total charge that flows past the conductor.
- 3. (a) Explain what is meant by lead-acid sulphation in lead-acid cells.
(b) State two measurements that can be made on a lead-acid accumulator to show that it is fully charged.
- 4. A lead-acid battery of e.m.f 12 V is used to start a car – this is not achievable with eight dry cells each of value 1.5 V connected in series. Explain.
- 5. Explain why hydrogen bubbles may be formed on the zinc plate in simple cell.

UNIT**10**

Magnetism

Key Points

- The earth exhibits natural magnetism having magnetic north and magnetic south poles on opposite ends.
- Magnetic force is exhibited without bodies necessarily coming into contact with each other.

Revision Questions 10

- Describe properties of magnets.

Answer

Magnets have the following properties:

- Attractive property – Magnets attract magnetic materials, namely, iron, nickel and cobalt.
 - Repulsive property – Like poles of magnets repel each other, unlike poles attract.
 - Directive property – When freely suspended a magnet points in the North-South direction.
 - Magnetic force is strongest at the poles.
- Distinguish between magnetic and non-magnetic materials, giving an example of each.

Answer

Magnetic materials are strongly attracted by magnets, for example, iron and cobalt.

Non-magnetic are not affected by magnetic force, for example, wood and plastic.

- (a) State the basic law of magnetism.

- (b) Why is attraction not a sure test when establishing the polarity of a magnet?

Answer

- (a) Like poles repel and unlike poles attract.
(b) A magnet can attract another magnet and also a magnetic material, while only like poles of a magnet repel.

4. Show the magnetic field patterns in the following:

(a)



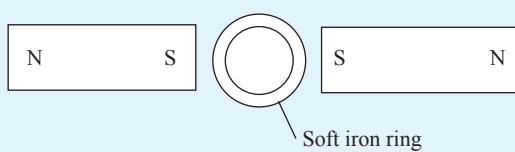
(b)



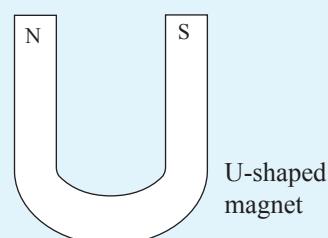
(c)



(d)

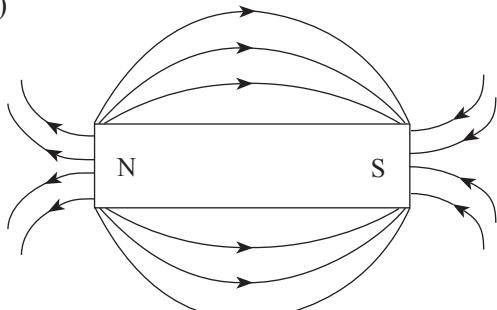


(e)

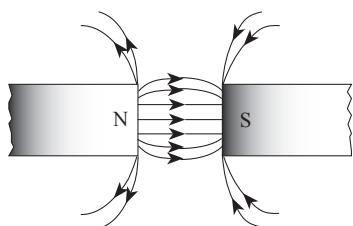


Answer

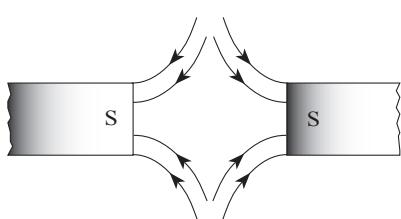
(a)



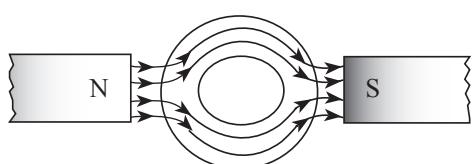
(b)



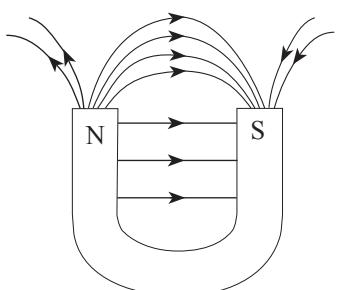
(c)



(d)



(e)



5. (a) Explain magnetisation in terms of the domain theory.
 (b) State and explain two methods of magnetisation.

(c) Describe how a magnet can be destroyed.

Answer

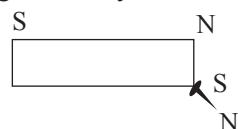
(a) The domain theory considers an atom or molecule of a magnetic material as a small magnet with north and south poles called dipole. Magnetisation makes the dipoles point in one direction.

(b) Methods of magnetisation are:

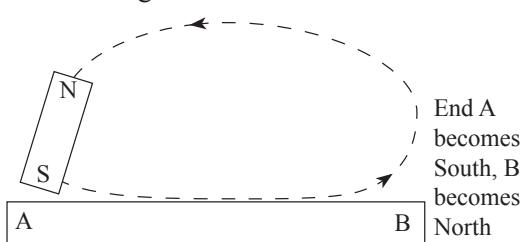
(i) Hammering a steel rod in a North-South direction.

(ii) Heating a steel rod strongly and giving time to cool as it lies in a North-South direction.

(iii) Bringing a steel needle into contact with a strong magnet. The needle is magnetised by induction, as shown.

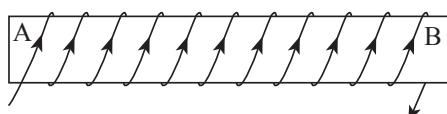


(iv) Stroking a steel rod with a permanent magnet.



Two magnets can be used to stroke in double touch stroking.

(v) Using the electrical method by placing a steel rod inside direct current carrying solenoid.



- (c) A magnet can be destroyed by:
 (i) Hammering and heating a magnetised

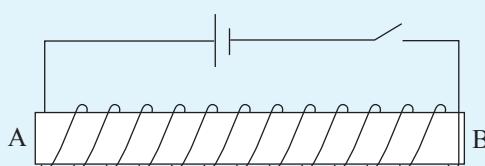
- steel rod in East-West direction destroys the magnetism.
- (ii) Placing the magnet in a solenoid carrying alternating current and aligned in East-West direction.
6. Explain the following:
- Magnetic induction.
 - Magnetic screening.
 - (i) Distinguish between soft and hard magnetic materials.
 - (ii) Which of the two types of materials is suitable for use as:
 - Compass needle?
 - Core of an electromagnet?

Answer

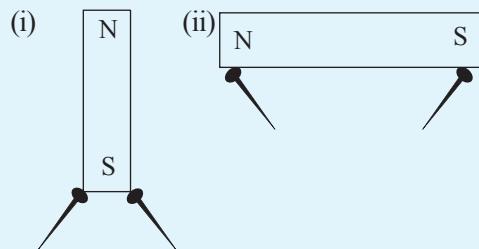
- Magnetic induction is the process of magnetising a magnetic material by placing a magnet near it.
- Magnetic screening is placing a soft-iron ring in the path of the magnetic field. The area inside the ring is then shielded (no magnetic force).
- (i) Soft magnetic materials make weak magnets while hard magnetic materials make strong and permanent magnets.
 (ii) • hard • Soft

Revision Exercise 10

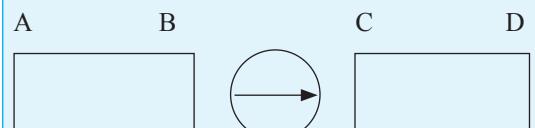
- State three uses of magnets in everyday life.
- In the figure below, a steel rod is placed inside a solenoid to make a magnet:



- Indicate the direction of the current on the solenoid.
 - Identify the polarities of ends A and B.
 - Why is steel used as rod AB?
 - What would happen if soft-iron core was used as rod AB?
 - What happens if alternating current was used instead of direct current?
3. Using the domain theory, explain how hammering can be used to:
- magnetise
 - demagnetise
4. (a) In the diagram below, explain the behaviour of the pins and indicate the polarities on the pins at the ends.



5. The figure shows a plotting compass placed between two magnets.



Indicate the polarity of each end of the magnets. Explain your answer.

- Using the domain theory, explain:
 - the meaning of magnetic saturation.
 - why soft-iron keepers are used to store magnets.

UNIT**11**

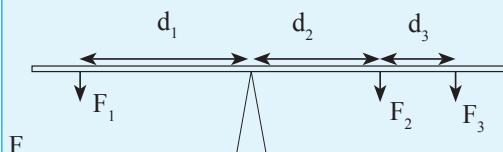
Turning Effect of a Force

Key Points

- One of the effects of a force is to cause a body to turn about a fixed point.
- In determining the moment of a force, the distance between the turning point and the force must be perpendicular to the line of action of the force.

Revision Questions 11

- (a) Define the term moment of a force about a point, and state its SI unit.
(b) The diagram below shows a uniform plank balanced about the pivot placed at its centre by the forces indicated.

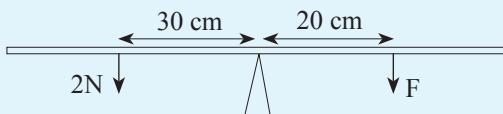


Find the moment of each of the forces shown about the pivot.

Answer

- The moment of a force about a point is the product of the force and the perpendicular distance to its line of action from the point. The SI unit of moment of force is the newtonmetre (Nm).
 $F_1 = F_1 \times d_1$
 $F_2 = F_2 \times d_2$
 $F_3 = F_3 \times (d_2 + d_3)$
- (a) State the principle of moments.

- (b) The figure below illustrates a uniform metre rule pivoted at the 50 cm mark and balanced by the forces at the positions shown.



- Obtain expressions for the clockwise and anticlockwise moments.
- Find the value of F.

- A uniform metre rule is pivoted freely at the 40 cm mark and balances horizontally when a 0.2 N force is hung from the 8 cm mark. Use a diagram to illustrate the forces acting on the rule, and find its weight.

Answer

- The principle of moments states that at equilibrium the sum of anticlockwise moments about a point equals the sum of clockwise moments about the same point.

- Clockwise moments = $F \times 0.20$
= 0.2 F Nm
Anti-clockwise moments = $2 \times 0.30 \text{ Nm}$
= 0.6 Nm

- $0.2F = 0.6$
 $F = \frac{0.6}{0.2}$
= 3 N

(c)



Let the weight of the rule be W. Since the metre rule is uniform, the line of action of the weight acts through the 50 cm mark.

Sum of clockwise = sum of anticlockwise moments moments

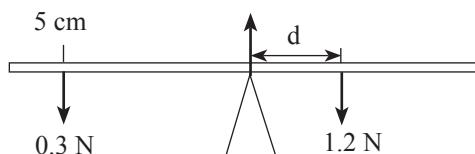
$$W \times 0.1 = 0.2 \times 0.32$$

$$W = \frac{0.2 \times 0.32}{0.1}$$
$$= 0.64 \text{ N}$$

The weight of the metre rule is 0.64 N.

3. A uniform rod of length 50 cm weighs 120 g. It is balanced on a knife-edge when a 30 g mass is suspended 5 cm from one end.
- Using a clear diagram, show the forces on rod.
 - Find the position of the knife-edge.

Answer



- (b) Let the distance from the 120 g to the pivot be d. At equilibrium, the sum of clockwise moments equals the sum of anti-clockwise moments.

$$1.2 \times d = 0.3 \times (0.2 - d)$$

$$1.2d = 0.06 - 0.3d$$

$$1.5d = 0.06$$

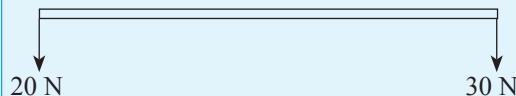
$$d = \frac{0.06}{1.5}$$

$$= 0.04 \text{ m}$$

$$= 4 \text{ cm}$$

The knife-edge is at a position 4 cm from the centre of gravity, i.e., at the 21 cm mark.

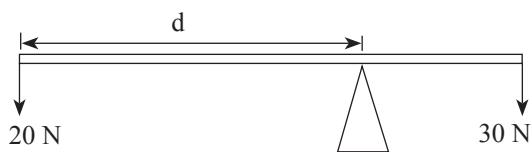
4. Two weights of 20 N and 30 N are suspended from the ends of a light beam of length one metre as shown in the diagram below. A pivot is placed under the beam so that the weights are balanced.



Find the position of the pivot from the 20 N force for the system to be an equilibrium.

Answer

Since the beam is light, its weight can be ignored. Let the pivot be at a position d from the 20 N force, as below.



Clockwise moments = anticlockwise moments

$$30 \times (1 - d) = 20 \times d$$

$$30 - 30d = 20d$$

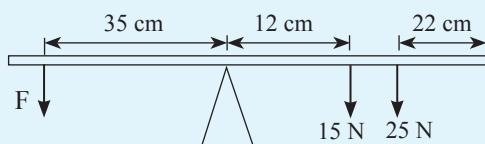
$$30 = 50d$$

$$d = \frac{30}{50}$$
$$= 0.6 \text{ m}$$

The pivot is positioned at 60 cm from the 20 N force.

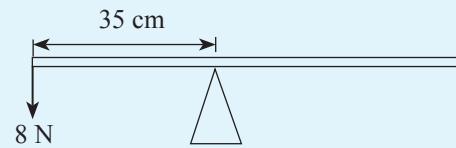
Revision Exercise 11

1. A uniform rod 1.2 m long balances on a pivot placed at 64 cm mark when a 0.6 N weight is suspended from one end. At which end should the weight be suspended? What is the weight of the rod?
2. The figure below shows a uniform metre rule in a state of equilibrium with three forces acting on it.



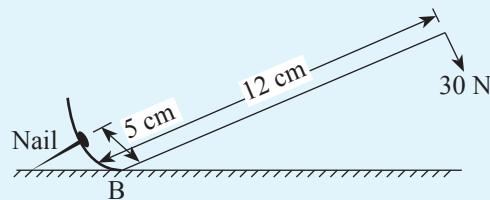
Determine the value of force F.

3. The diagram shows a uniform rod of length 96 cm well balanced with a weight of 8 N suspended on one end.



Calculate the weight of the rod.

4. The diagram shows a crow bar used to pull out a nail from a block of wood. Given that the length of the crow from the point of contact with the nail and the pivot is 5 cm, determine the force required to remove the nail from the wood.



**UNIT
12**

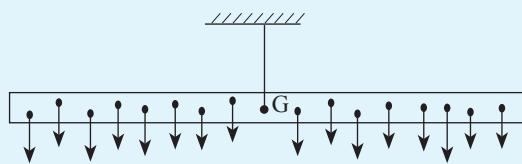
Equilibrium and Centre of Gravity

Key Points

- The centre of gravity of a body depends on its shape and distribution of matter in it.
- The position of centre of gravity of a body plays a key role in its stability.

Revision Questions 12

1. The figure below shows a uniform plank of wood suspended on a string such that it balances when the point of suspension is G. The forces of gravity acting on its evenly distributed particles are illustrated by the vertical arrows.



- What causes the plank to balance?
- Why does the plank balance about point G?
- What name is given to point G and how is it defined?

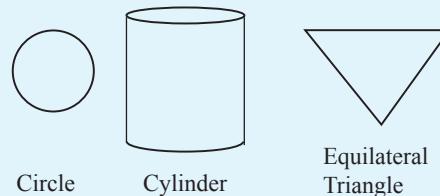
Answer

- The plank balances because the sum of clockwise moments and that of anticlockwise moments of the forces of gravity of the particles about the point G are equal.
- Point G is the position through which the resultant of all gravitational forces on the plank acts. Since these forces are acting downwards, an equivalent force acting

upwards (tension in the string) through the same point causes equilibrium.

- (c) G is called centre of gravity. It is the point where the weight of the plank acts through.

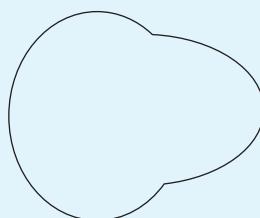
2. (a) A student was given the following regular figures:



Circle Cylinder Equilateral Triangle

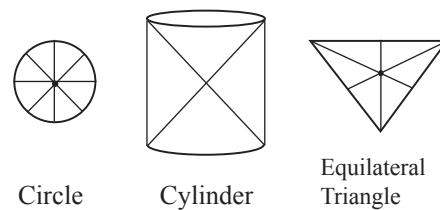
Use geometrical construction to locate centre of gravity.

- (b) Suppose the student was given a flat irregularly-shaped object shown, how would the centre of gravity be determined?



Answer

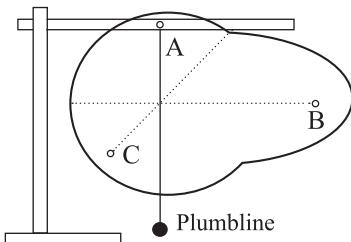
- (a)



Circle Cylinder Equilateral Triangle

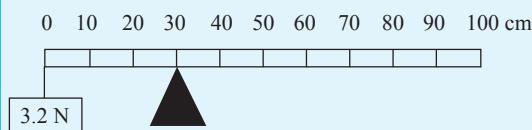
For regular figures, centre of gravity (COG) is the geometric centre of the shapes.

- (b) Make three holes A, B, and C on the irregular object and suspend it from each of the holes as shown below.



With the help of a plumbline, draw the vertical line through the hole. Repeat with the other two holes. The intersection of the lines is the centre of gravity.

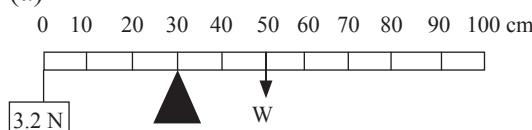
3. A uniform bar one metre long is balanced at the 30 cm mark when a load of 3.2 N is hung at the zero mark as shown in the figure.



- (a) Show the position through which the weight of the bar acts.
 (b) Calculate the weight of the bar.
 (c) If the pivot is shifted to the 60 cm mark, what weight would you suspend at the 90 cm mark for it to balance?

Answer

(a)



- (b) Taking moments about the pivot, sum of anticlockwise = sum of clockwise moments

$$3.2 \times 0.3 = W \times 0.2$$

$$W = \frac{3.2 \times 0.3}{0.2}$$

$$= 4.8 \text{ N}$$

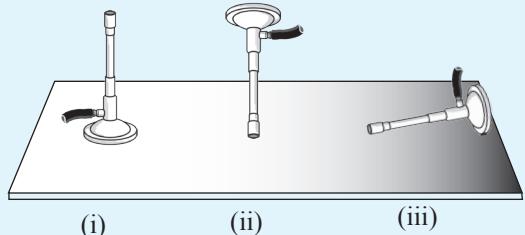
- (c) Taking moments about the pivot,

$$(3.2 \times 0.6) + (4.8 \times 0.1) = W \times 0.3$$

$$W = \frac{2.4}{0.3}$$

$$= 8 \text{ N}$$

4. (a) Name three states of equilibrium.
 (b) The figure below shows a bunsen burner in three different positions.



Identify the states of equilibrium in (i), (ii) and (iii). Explain your answer.

Answer

- (a) Stable, unstable and neutral equilibrium.

- (b) (i) Stable equilibrium: Slightly tilting the body raises its centre of gravity and the body falls back to its original position when the tilting force is removed. This is because the line of action of its weight remains within the base of support.

- (ii) Unstable equilibrium: Slightly tilting the body lowers the centre of gravity and the body topples over. This is because the line of action of its weight falls out of original base of support.

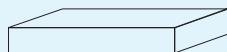
- (iii) Neutral equilibrium: Slightly tilting the body neither raises nor lowers its

centre of gravity. The body therefore rolls, maintaining its position of centre of gravity.

5. A narrow box is placed in two different positions as shown.



(i)

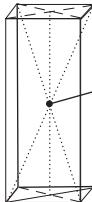


(ii)

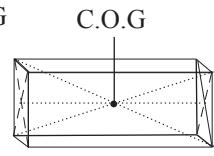
- (a) (i) Show the position of centre of gravity in each case.
(ii) How does the position shown above affect the stability of the box?
(b) Other than position of centre of gravity what other factor affects the stability of an object?

Answer

(a)



(i)



(ii)

- (ii) In (i), the COG is raised, making the box less stable, while in (ii), COG is low, hence the box is more stable.

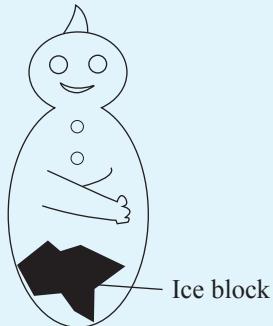
- (b) Area of support (base area).

6. (a) Explain how stability is achieved in the following cases:

- (i) Racing cars.
(ii) Laboratory tripod stands.

- (b) What modifications are introduced to the buses to ensure stability?

- (c) A balancing toy made of a plastic container has an ice block inside it as shown below.

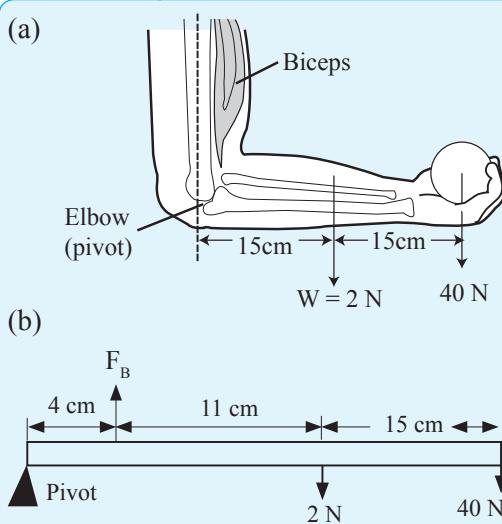


- (i) Explain its state of equilibrium.
(ii) What changes in stability will be experienced when ice in the plastic container melts?

Answer

- (a) (i) Racing cars are designed with low centre of gravity and wide wheelbase.
(ii) Tripod stands have the three legs slightly inclined outwards on a triangular plane to increase the base area.
(b) The upper parts of the buses are made of lighter materials, while the engine, heavy chassis and luggage compartments on the lower part are heavy to ensure low centre of gravity.
(c) (i) Unstable, because ice has bigger volume, hence this raises its COG.
(ii) Stability increases because water settles at a lower level.

7. The diagram (a) below shows the forces acting on a fore arm when holding a shotput. If the elbow acts as a pivot and the system can be configured as shown in figure (b), calculate the force exerted by the biceps, F_B .



Answer

Taking moments about the elbow (pivot).

Sum of anticlockwise = Sum of clockwise moments

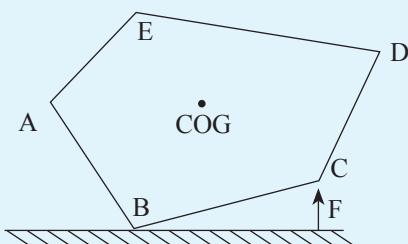
$$0.04 \times F_B = (2 \times 0.15) + (40 \times 0.3)$$

$$F_B = \frac{12.3}{0.04}$$

$$= 307.5 \text{ N}$$

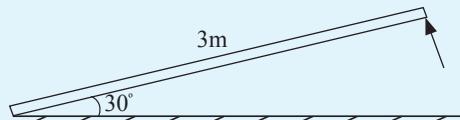
Revision Exercise 12

1. What type of equilibrium has:
 - (a) A basketball lying on a smooth surface.
 - (b) A marble placed on a hemispherical trough.
2. An object is tilted about one edge by a force F as shown below.



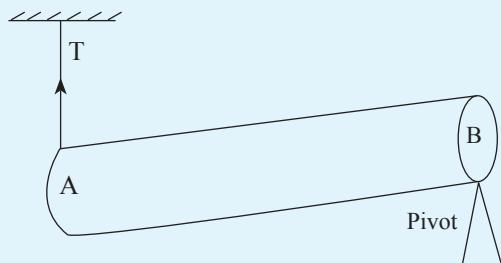
State and explain the side on which it will fall when force F is released.

3. A student supports a uniform ladder of mass 40 kg at one end while the other end is on a horizontal ground, as shown below.



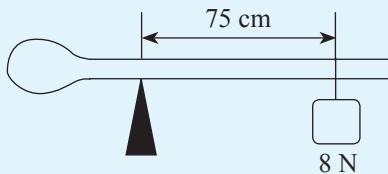
Determine the minimum force exerted by the student to lift the ladder of length 3 m.

4. A log of length 120 cm and mass 5 kg is balanced on a pivot by the tension T at the position shown below.



Given that the tension on the string is 30 N, determine the position of the centre of gravity from the pivot.

5. A club of mass 1 500 g is balanced on a sharp blade as shown in the diagram.



Find the distance of the centre of gravity of the club from the pivot.

UNIT**13**

Reflection at Curved Surfaces

Key Points

- A spherical reflecting surface that curves inwards is said to be concave while the one that curves outwards is described as convex.
- Virtual rays and images are represented by broken lines.
- A spherical reflector does not have a single point focus for a parallel beam, it forms a caustic curve.
- Magnification is the ratio of image height to object height.
- Images formed in a convex mirror are always virtual, diminished and erect.
- A concave mirror gives a virtual image only when the object is between the pole and the principal focus.

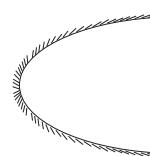
surface is curved outwards as in the diagram below.



Convex

Concave and convex reflectors are part of a sphere.

A parabolic reflector is one whose reflecting surface curves inwards but is not part of a sphere, as in the diagram below.



Parabolic

Revision Questions 13

1. With aid of appropriate diagrams, describe convex, concave and parabolic reflectors.

Answer

A concave reflector is one whose reflecting surface is curved inwards as in the diagram below.



Concave

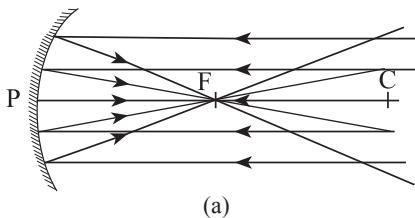
A convex reflector is one whose reflecting

2. With aid of a diagram, define the term principal focus for:

- (a) concave mirror
- (b) convex mirror

Answer

- (a) The principal focus of a concave mirror is the point where incident rays parallel and close to the principal axis converge after reflection on the surface of the mirror.



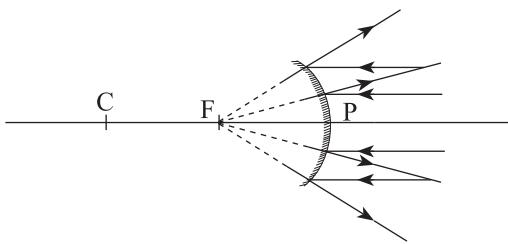
(a)

- (a) Object between P and F
 (b) Object between F and C
 (c) Object at C

Answer

(a)

- (b) The principal focus of a convex mirror is the point where incident rays parallel and close to the principal axis appear to diverge from after reflection on the surface of the mirror.



3. Define the following terms as applied to curved mirrors:

- (a) Pole
- (b) Centre of curvature
- (c) Principal axis
- (d) Focal plane

Answer

- (a) Pole of the mirror – Geometrical centre of a reflecting surface.
- (b) Centre of curvature C – The centre of the sphere of which the mirror is part.
- (c) Principal axis – A line drawn connecting the pole P of the mirror to the centre of curvature.
- (d) Focal plane – A plane perpendicular to the principal axis and passing through the principal focus F.

4. By ray diagram construction, locate and describe the image fully when the object is at the given positions from a concave mirror.

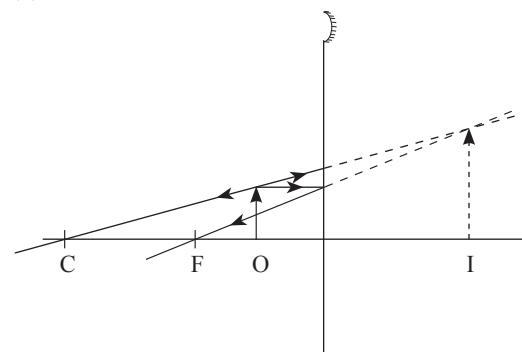


Image is virtual, upright and magnified

(b)

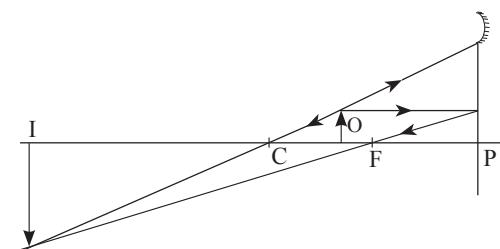


Image is real, inverted and magnified

(c)

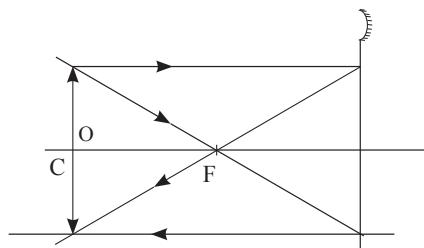


Image is real, inverted and same size as object.

5. Illustrate by ray diagram construction the formation of the image for an object placed before a convex mirror.

Answer

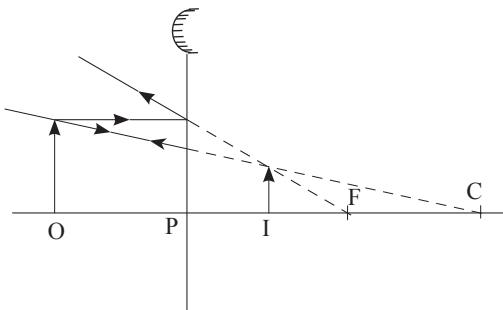
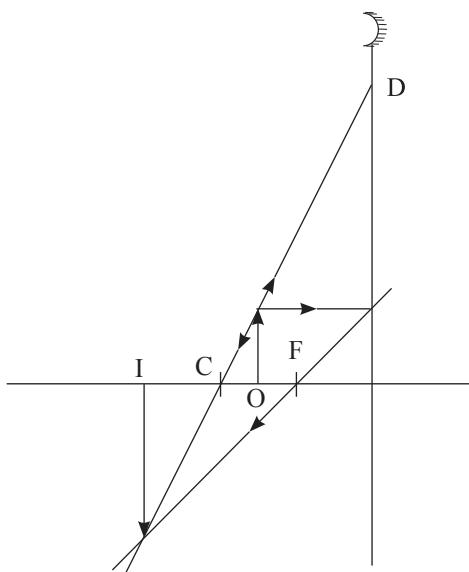


Image is virtual, erect and diminished.

6. An object of height 10 cm is placed 15 cm before a concave mirror of focal length 10 cm.
- Using a scale of 1 cm rep 10 cm. Determine:
 - the image position.
 - the magnification.
 - Repeat (a) above for a convex mirror of the same focal length.

Answer

(a)



$$(ii) \text{ Magnification} = \frac{\text{image height}}{\text{object height}}$$

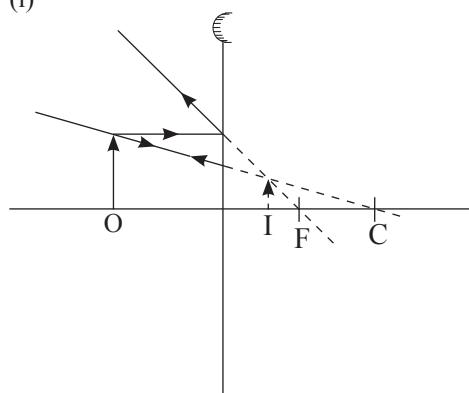
$$= \frac{20 \text{ cm}}{10 \text{ cm}} \\ = 2$$

Alternatively;

$$\text{Magnification} = \frac{\text{image distance}}{\text{object distance}}$$

$$= \frac{30 \text{ cm}}{15 \text{ cm}} \\ = 2$$

(b) (i)



$$(ii) \text{ Magnification} = \frac{\text{image height}}{\text{object height}} \\ = \frac{4 \text{ cm}}{10 \text{ cm}} \\ = 0.4$$

Alternatively;

$$\text{Magnification} = \frac{\text{image distance}}{\text{object distance}} \\ = \frac{1.2 \text{ cm}}{3 \text{ cm}} \\ = 0.4$$

7. State two factors that account for:

- the convex mirror being suitable as a driving mirror.
- the concave mirror being suitable for use by dentists when inspecting teeth of a patient.

Answer

- (a) • Has a wide field of view.
• Gives an erect image.
- (b) • Gives a magnified image hence clarity of features.
• Image is virtual, hence seen by just looking into the mirror.
8. Explain why the spherical concave mirror is not suitable as a reflector in the making of search-light.

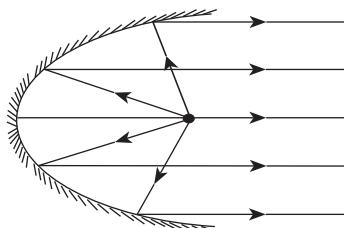
Answer

It does not have a single point focus hence does not give a perfect parallel beam.

10. By ray diagram construction, illustrate how a parabolic reflector produces a parallel beam.

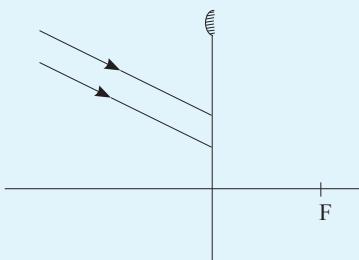
Answer

With the source at principle focus F the ray is reflected as a parallel beam.



Revision Exercise 13

1. Illustrate by ray diagram construction the formation of the image for an object placed before a convex mirror. Describe the image fully.
2. The following figure shows rays coming from a distant object which has its foot on the principal axis.



Complete the diagram to locate the position of the image.

3. An object of height 4 cm is placed 15 cm before a concave mirror, focal length 10 cm.
 - (a) By use of suitable scale diagram, determine:
 - (i) the image position.
 - (ii) the magnification.
 - (b) Repeat (a) above for a convex mirror of the same focal length.
4. A mirror forms an image 2 times the size of an object and on the same side as the object.
 - (a) What type of mirror is it?
 - (b) If the distance between the object and the image is 30 cm, determine the object and image distances.
 - (c) What is the focal length of the mirror?
5. An object at an unknown distance has its image forming at a distance of 2.5 cm from a convex mirror of focal length 10 cm. By calculation, determine:
 - (a) the object distance.
 - (b) the magnification.
6. An object and its image are on opposite sides of a mirror of focal length 15 cm. If the image height is 3 times that of the object:
 - (a) State what type of mirror it is.
 - (b) Determine the object and image distance.
7. Distinguish between the terms real and virtual, as applied to images in mirrors.

**UNIT
14**

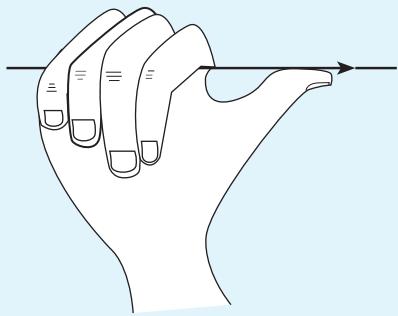
Magnetic Effect of an Electric Current

Key Points

- When current flows through a conductor, it creates a magnetic field around it.
- The magnetic field pattern is determined by the direction of the current flow and the shape of the conductor.
- The right hand grip rule may be used to establish the direction of the magnetic field.

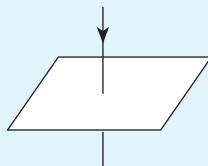
Revision Questions 14

1. (a) The figure shows a current-carrying conductor, gripped by the right hand. State what the direction of the thumb and the other fingers indicate.

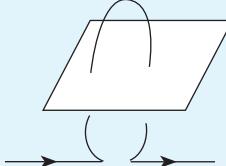


- (b) Draw the magnetic field pattern around the conductors carrying current, shown in the figures below.

(i)



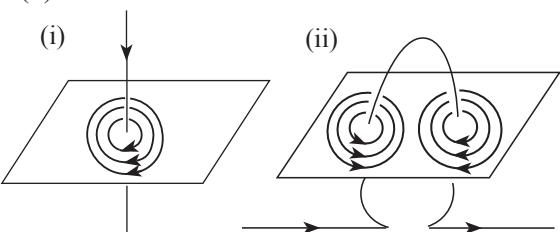
(ii)



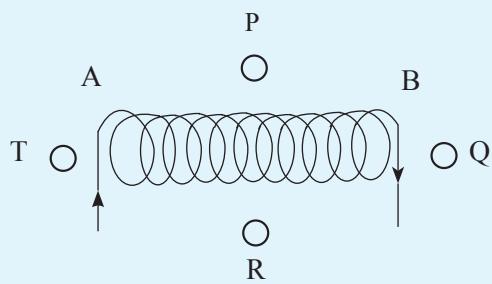
Answer

- (a) With the thumb pointing in the direction of flow of current, the curled fingers point in the direction of the magnetic field.

(b)



2. Current flows in a solenoid AB with magnetic compass needles P, Q, R and S placed around it as shown in the figure below.



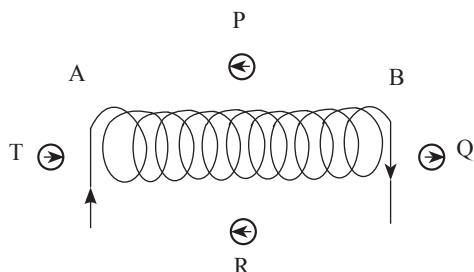
- (a) (i) Show on diagram the directions in which the compass needles point.

(ii) State the polarity of A.

- (b) With the aid of a diagram, illustrate the magnetic field around a solenoid.

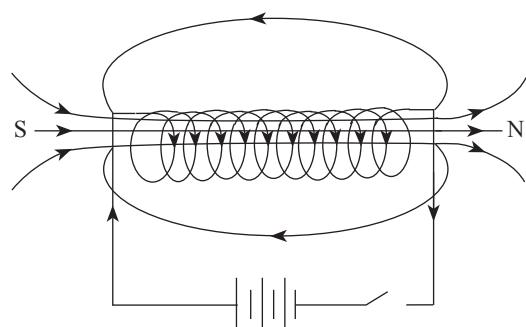
Answer

(a)



(ii) Polarity of A is south.

(b)



3. You are provided with the following apparatus: connecting wires, a soft iron rod, a battery of 3 cells, a switch, a long insulated copper wire and a rheostat.

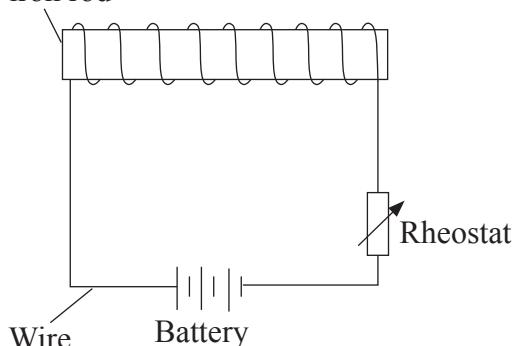
- Using a suitable diagram, show how an electromagnet can be made with the given apparatus.
- State two ways by which the strength of an electromagnet can be increased.

Answer

- The copper wire is wound on the soft iron rod and the ends connected to the circuit as shown.

Soft

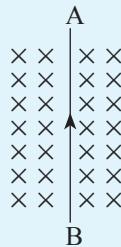
iron rod



- By increasing the amount of current.
- By increasing the number of turns on the solenoid.

4. (a) State Fleming's left hand rule.

(b) The figure below shows a straight conductor AB carrying current in a magnetic field.



- Indicate the direction of the force on the conductor.

- State any two ways in which the force can be:

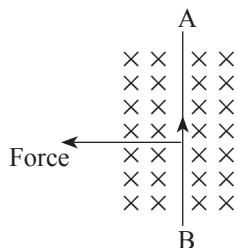
- increased
- made to change direction

Answer

- If the left hand is held with the thumb, the first finger and the second fingers mutually at right angles so that the first finger points in the direction of the

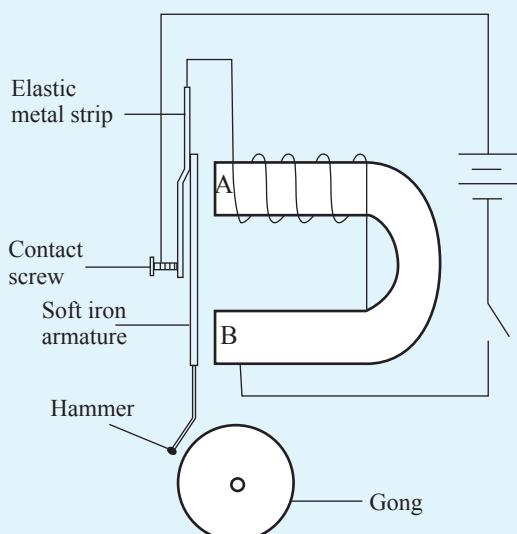
magnetic field and the second figure in the direction of current then the thumb points in the direction of motion.

(b) (i)



- (ii) • By increasing the amount of current and by using a stronger magnetic field.
- By changing the direction of flow of current and by changing the direction of the magnetic field.

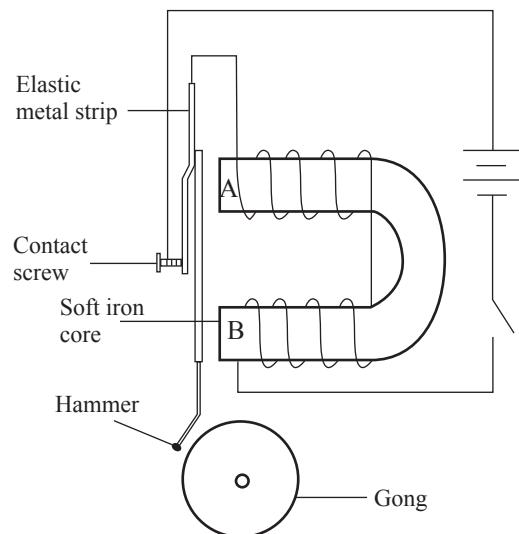
5. The figure illustrates an incomplete circuit diagram of an electric bell.



- (a) Show the windings of the coil on limb B of the soft iron core and complete the circuit.
- (b) Explain how the bell works.

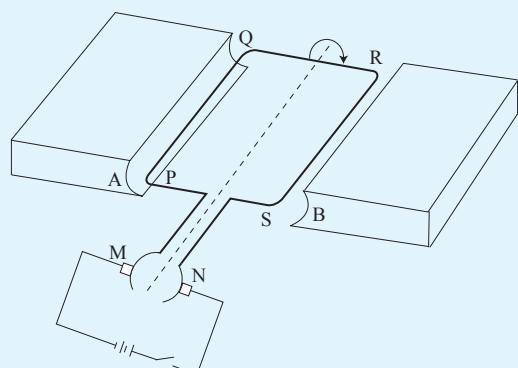
Answer

(a)



(b) When switched on, current flows and the electromagnet attracts the soft iron armature moving the hammer to hit the gong. When this happens, contact is broken and current stops flowing switching off the electromagnet. The springy metal strip pulls back the armature to make up the contact again and the process repeats itself.

6. The figure below shows a coil PQRS lying between two unlike magnetic pole pieces A and B of an electric motor.



- (a) Identify the parts:

M _____

N _____

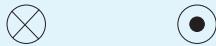
- (b) Given that PQRS rotates in a clockwise direction, state the polarity of A.
(c) State how you would increase the speed of rotation of the coil.

Answer

- (a) M is carbon brush.
N is half ring or split ring commutator.
(b) A is North pole.
(c) (i) By increasing the current.
(ii) By increasing the number of turns on the coil.
(iii) Using a stronger magnet.

Revision Exercise 14

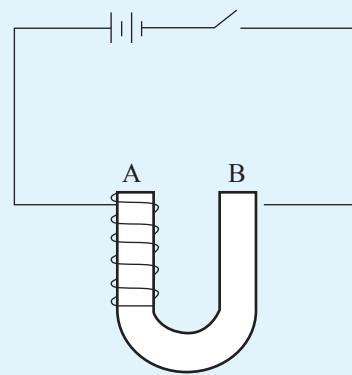
1. Current in two parallel conductors flows in opposite directions as shown below:



- (a) Show on the diagram the magnetic field lines and state the resulting direction of force between them.

- (b) State two ways in which the force between the conductors can be increased.

2. Describe with the aid of a diagram how Maxwell's corkscrew rule can be used for determining the direction of magnetic field around a conductor.
3. The figure below is an incomplete circuit diagram for a U-shaped electromagnet.
(a) Complete the winding to make end B an unlike pole to A.
(b) State the polarity of end A.
(c) State any two ways in which the strength of this electromagnet can be increased.



**UNIT
15**

Hooke's Law

Key Points

- A spring undergoes permanent or temporary deformation when subjected to stretching or compressing force.
- The strength of the spring depends on the nature and physical dimensions of the material of which it is made.

- (i) Draw a graph of Force (y-axis) against extension.
- (ii) Use the graph to determine the spring constant.

Answer

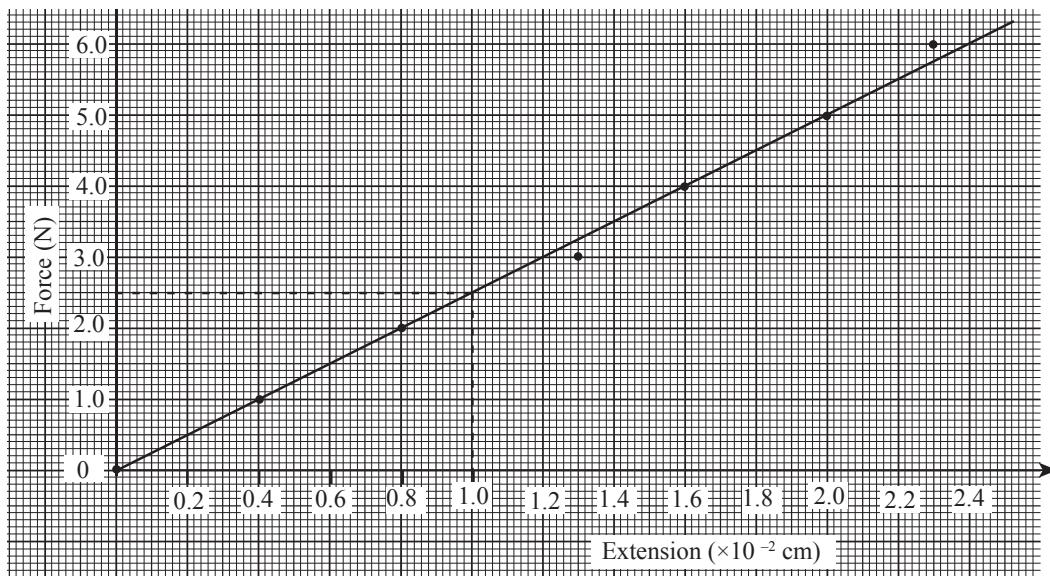
1. (a) The extension of a spring is directly proportional to the stretching force provided the elastic limit is not exceeded.

Revision Questions 15

1. (a) State Hooke's Law.
(b) In an experiment to verify Hooke's Law, the following results were obtained:

| | | | | | | | |
|----------------|---|-----|-----|-----|-----|-----|-----|
| Force (N) | 0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 |
| Extension (cm) | 0 | 0.4 | 0.8 | 1.3 | 1.6 | 2.0 | 2.3 |

(b) (i)



- (ii) Taking the point (1.0, 2.5), spring constant k is the gradient of graph since line passes through the origin.

$$k = \frac{3 - 0}{(1.2 - 0) \times 10^{-2}} \\ = 250 \text{ N/m}$$

2. (a) State three factors that affect spring constant.
 (b) A force of 3.5 N causes an extension of 5.0 cm on a given spring. Given that the elastic limit is not exceeded, determine the spring constant.

Answer

- (a) • Diameter of turns.
 • Length of spring.
 • Nature of material of which it is made.
 • Number of turns per unit length.
 (b) Spring constant = $\frac{\text{force}}{\text{extension}}$
 $= \frac{3.5}{5 \times 10^{-2}}$
 $= 70 \text{ N/m}$

3. A spring when supporting a weight of 4 N stretches to a total length of 7 cm. Given that it has a spring constant of 500 N/m, determine the length of the unloaded spring.

Answer

Load 500 N gives extension 1m

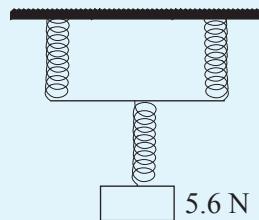
$$4 \text{ N extension gives } = \frac{1}{500} \times 4 \\ = 0.008 \text{ m} \\ = 0.8 \text{ cm}$$

Loaded length – extension = unloaded length

$$\text{Unloaded length} = 7 - 0.8$$

$$= 6.2 \text{ cm}$$

4. The figure shows an arrangement of three identical springs supporting a load of 5.6 N.



Given that the springs have a spring constant of 2.8 N/cm each, determine the total extension of the arrangement.

Answer

$$\text{Extension} = \frac{\text{load}}{\text{spring constant}}$$

1 spring supporting 5.6 N

$$\text{Extension} = \frac{5.6}{2.8} \times 1 \\ = 2 \text{ cm}$$

2 springs sharing load 5.6 N;

$$\text{Load per spring} = \frac{5.6}{2} \\ = 2.8 \text{ N}$$

$$\text{Extension} = \frac{2.8}{2.8} \times 1 \\ = 1 \text{ cm}$$

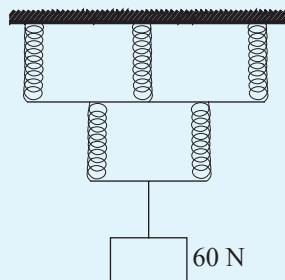
Total extension of the system = 2 + 1

$$= 3 \text{ cm}$$

Revision Exercise 15

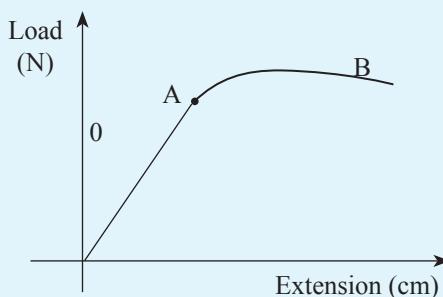
1. The unstretched length of a spring is 9.0 cm. When 300 g mass is suspended on it, the length becomes 10.2 cm. When another unknown mass m is added, the length increases by 0.4 cm. Determine:
 (a) the spring constant.
 (b) the mass m .

2. The figure illustrates a network of identical springs supporting a load of 60 N.



Given that each spring has a spring constant of 200 N/m, determine the total extension.

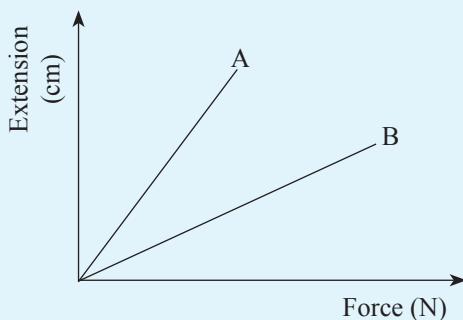
3. The graph below shows the variation of load with extension for a certain given spring.



Describe the behaviour of the spring over sections:

- (a) OA
(b) AB

4. The sketches below show the variation of extension with force for spring A and B.



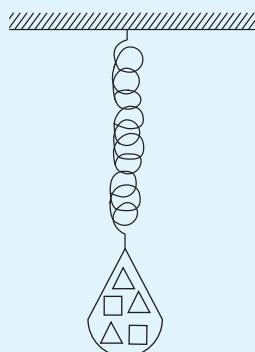
Given that the spring A and B are of equal length, state any two factors that can be used to explain the difference in the graphs.

5. The table below shows the values of length of a spring as it is subjected to different forces of compression.

| Length (mm) | Compression Force (N) |
|-------------|-----------------------|
| 140.0 | 0 |
| 138.0 | 2.0 |
| 136.2 | 4.0 |
| 134.0 | 6.0 |
| 132.0 | 8.0 |
| 130.2 | 10.0 |
| 130.1 | 12 |
| 130.0 | 14 |
| 130.0 | 16 |
| 130.0 | 18 |

- (a) State the unloaded length of the spring.
(b) Introduce a third column and fill in the compression values.
(c) Plot a graph of length (y-axis) against compression force.
(d) Explain the shape of the graph.
(e) Using the appropriate section of the graph, determine the spring constant.

6. A spring is loaded with masses supported on a scale pan, as below:



When a mass of 250 g is placed on the pan, the spring stretches by 2.0 cm and when an additional 150 g is placed on the pan, the extension is 3.0 cm. Determine the mass of the pan.

7. The table below shows the scale readings of the pointer level on a spring as it is loaded with different masses:

| Mass (g) | 0 | 50 | 100 | 150 | 200 |
|--------------------|------|------|------|------|------|
| Scale Reading (cm) | 39.2 | 40.0 | 40.7 | 41.6 | 42.4 |
| Load (N) | | | | | |
| Extension (cm) | | | | | |

(a) Fill in the table the corresponding values of load and extension.

(b) Plot a graph of load (y-axis) against extension.

(c) From your graph, determine the value of the spring constant.

8. An unknown mass m attached to a spring causes an extension of 2.1 cm. When a mass of 250 g is suspended on the same spring, it causes an extension of 1.25 cm. Determine:

(a) the spring constant.

(b) the mass m .

UNIT**16****Waves I****Key Points**

- A wave is a means of transfer of energy. As the wave progresses, the medium does not move, but particles oscillate about a mean position.
- Waves may be categorised as either mechanical or electromagnetic. Mechanical waves require a material medium for propagation, for example, sound, water waves and those in a slinky spring. Electromagnetic waves, for example, light, radiowaves and microwaves, do not require a material medium for propagation.
- Mechanical waves are either transverse or longitudinal.
- Progressive waves transfer energy from the source to the surrounding. They can be transverse or longitudinal.

Revision Questions 16

- (a) Distinguish between transverse and longitudinal waves.
(b) Briefly describe the formation of transverse and longitudinal waves using a slinky spring.

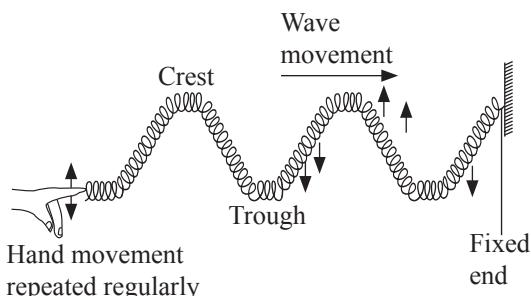
Answer

- (a) For a transverse wave, particles of matter vibrate perpendicularly to the direction of the wave motion.

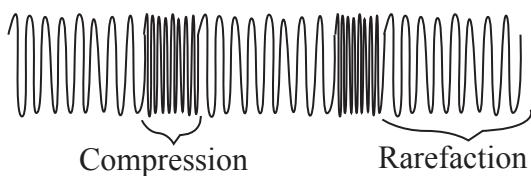
For a longitudinal wave, the particles of matter vibrate along the direction of the wave motion.

Transverse Wave

A slinky spring is fixed at one end and the other end jerked up and down continuously. The wave is characterised by crests and troughs.

**Longitudinal Wave**

The slinky spring is fixed at one end and jerked to and fro continually. A longitudinal wave characterised by compressions and rarefactions is generated.



- (a) Derive the relation $v = f\lambda$
(b) The frequency of a waterwave is 6.4 Hz. If the wave travels a distance of 8 m in 4 seconds, find:
 - the speed of the wave
 - its wavelength.

Answer

$$\text{Velocity} = \frac{\text{displacement}}{\text{time taken}}$$

$$= \frac{\text{wavelength}}{\text{period}}$$

$$v = \frac{\lambda}{T}$$

$$\text{But } T = \frac{1}{f}$$

$$v = \frac{\lambda}{1/f}$$

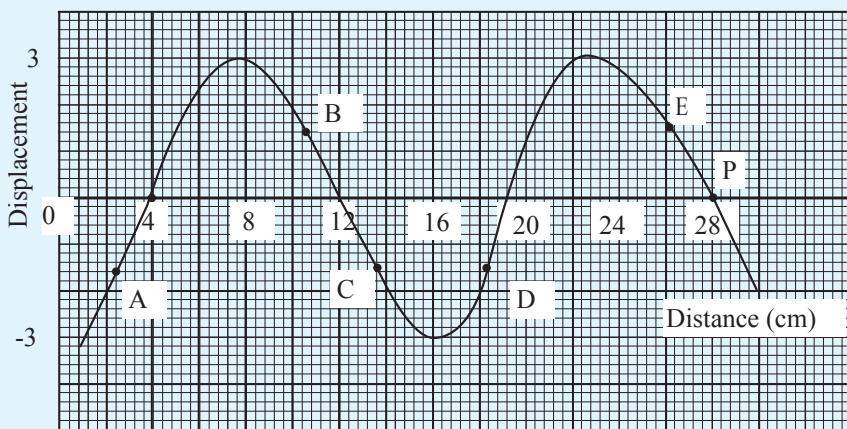
$$v = f\lambda$$

(b) (i) Speed = $\frac{\text{distance}}{\text{time}}$
 $= \frac{8}{4}$
 $= 2 \text{ m/s}$

(ii) $\lambda = \frac{v}{f}$
 $= \frac{2}{6.4}$

$$= 31.25 \text{ m}$$

3. The figure shows a displacement distance graph of a transverse wave:



- (a) Find the amplitude.
- (b) Determine wavelength.
- (c) If time taken by the wave to move from O to P is 0.14 seconds, find:
 - (i) the frequency of the wave.
 - (ii) speed of the wave.
- (d) State points on the graph which are in phase.

Answer

(a) Amplitude = 3

(b) Wavelength = 16 cm

(c) (i) $1\frac{3}{4} T = 0.14$

$$T = 0.08 \text{ s}$$

$$\text{But } f = \frac{1}{T}$$

$$\text{So, } f = \frac{1}{0.08}$$

$$= 12.5 \text{ Hz}$$

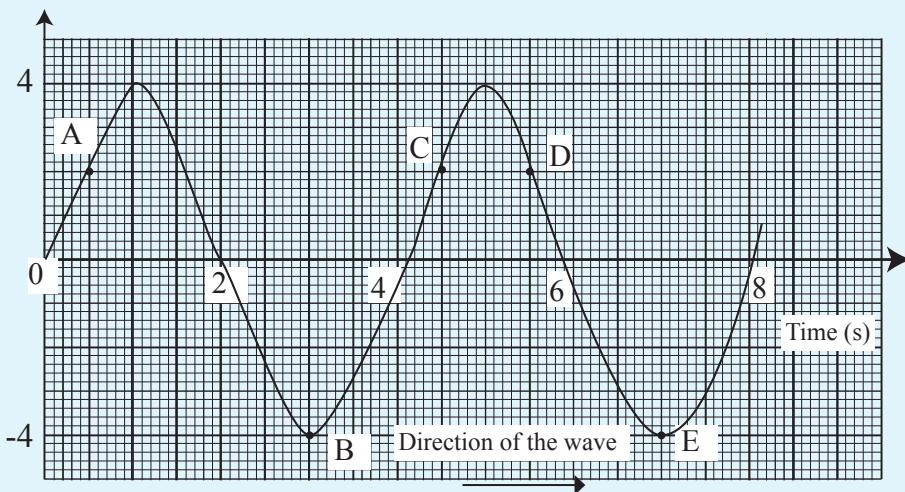
(ii) Speed = $f\lambda$

$$= 12.5 \times 0.16$$

$$= 2 \text{ m/s}$$

(d) A and D, B and E

4. The figure shows a displacement time-graph of a transverse wave:



Determine the:

- (a) period.
- (b) frequency.

Answer

- (a) Period = 4 s
- (b) Frequency = 0.25 Hz

5. (a) Distinguish between a wave and a wave pulse.
 (b) Describe a simple experiment to illustrate pulse on a string.

Answer

- (a) A wave is a continuous disturbance transmitted through some medium while a pulse refers to a one-time disturbance in a material medium.
- (b) Tie one end of a rope or slinky spring to a fixed point. Jerk the free end of the rope up and down once.

Revision Exercise 16

1. (a) What is a wavefront?
 (b) With the aid of a diagram, explain the term amplitude and periodic time (T).
2. The wavelength of a transverse wave is 5 m and its frequency is 512 Hz. Determine the velocity of the wave.
3. The speed of a wave is 3×10^8 m/s.
 (a) Calculate the wavelength if the frequency is 250 kHz.
 (b) Find the frequency of a similar wave if the wavelength is 1800 m.
4. The distance between 16 successive crests of a wave is 3.0 m. If the speed of the wave is 40 m/s, calculate the frequency of the wave.

5. An example of a longitudinal wave is sound wave. Longitudinal waves consist of compressions and rarefactions as in the medium. Explain with the aid of diagrams the meaning of the following:
- (a) longitudinal wave.
 - (b) compressions.
 - (c) rarefactions.
6. A source produces sound of frequency

550 Hz. The speed of sound in air is 330 m/s.

- (a) Calculate the wavelength of the waves produced.
- (b) Deduce the distance from a compression to the nearest rarefaction.

UNIT**17****Sound****Key Points**

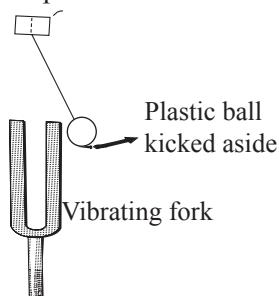
- Sound is produced by mechanical vibrations and requires material medium for transmission (solid, liquid, gas and plasma).
- The characteristics of sound wave produced depends on the source of sound and the nature of the transmission medium.
- Sound, like other waves, exhibits properties of reflection, refraction, interference and diffraction.

Revision Questions 17

1. Describe a simple experiment to illustrate the following:
 - (a) Sound is produced by a vibrating body.
 - (b) Sound cannot travel through vacuum.

Answer

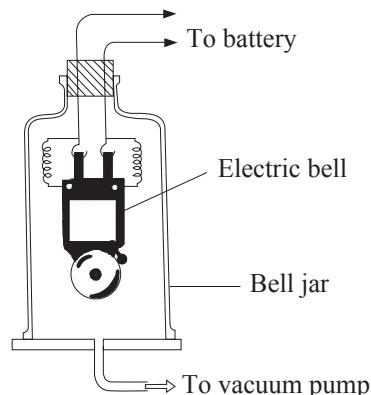
1. (a) A tuning fork is struck against hard rubber. Sound is produced by the tuning fork as it is held in isolation. A plastic ball is then held in contact with the prongs of the fork. It is observed that the ball is continuously kicked aside showing that a vibrating fork produces sound.



This shows that sound is produced by vibration.

- (b) To demonstrate that sound cannot travel in vacuum.

An electric bell is suspended inside a bell jar connected to a vacuum pump, as in the diagram below. The bell is set ringing.



As air is gradually pumped out of the jar, it is noted that the sound from the bell slowly fades away to the extent of almost getting inaudible, even though the hammer can still be seen striking the gong. The experiment shows that sound cannot travel in vacuum as it requires a material medium for transmission.

- (a) Explain why sound is considered a longitudinal wave.
- (b) State some three common sources of high frequency sound.

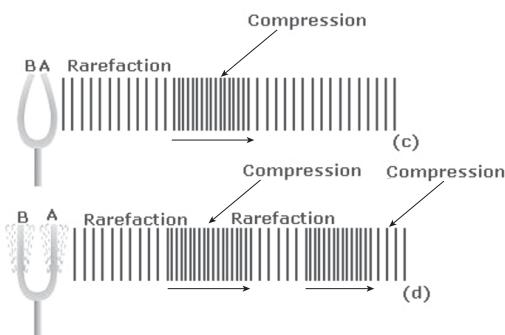
Answer

- (a) A longitudinal wave is one that causes particles of the medium it is traversing to vibrate along the direction of its motion.

Longitudinal waves are also known as compression waves.

Sound waves are considered longitudinal because when an object vibrates to produce sound, the vibration causes an oscillatory to and fro movement of particles of the transmitting medium along the direction of propagation of the wave. The sound waves consist of alternating pressure variations that are regions of compression and rarefactions.

For example, when a tuning fork vibrates, it causes compressions whenever there is an outward movement of the prongs and rarefactions when the prongs move inwards as below.



(b) Sound of high frequency implies high pitched or sharp sound. Common sources of high frequency sound are:

- (i) Football referee's whistle.
- (ii) Police or ambulance siren.
- (iii) Chirping of birds.

3. (a) What is an echo?

(b) Describe an experiment to determine the speed of sound using the echo method. Show clearly how the speed is established using the approach.

(c) A person standing 110 m from the foot of a cliff claps his hands and hears a sound 0.75 seconds later. Find the speed of sound in air.

Answer

- (a) An echo is a reflected sound.
- (b) Determination of speed of sound using the echo method.

This demonstration involves two students A and B in an open space and with a high wall about 100 m away from them. One student makes some sound while the other does the timing.

Student A claps two wooden blocks and awaits the echo from the wall. This is repeated until the student has some fairly accurate perception of how long it takes for the echo to be heard. With this, the student is then able to clap the blocks in such a way that the sound from the blocks coincides with the echo of the previous clap. Once this is achieved, the time interval between the claps equals the time taken to travel twice the distance between the students and the wall.

Student B should then time and record the time taken for at least 30 clap intervals and the speed of sound is then established as follows:

Distance from the wall = d metres

Number of clap intervals = N

Time taken = t seconds.

So, sound travels $2d$ metres in t/N seconds

$$\begin{aligned} \text{Thus, speed of sound} &= \frac{2d}{t/N} \\ &= \frac{2dN}{t} \text{ m/s} \end{aligned}$$

(c) In 0.75 seconds, the sound has travelled 220 m.

$$\begin{aligned} \text{Speed} &= \frac{220}{0.75} \\ &= 293.3 \text{ m/s} \end{aligned}$$

4. State and explain the effects of medium, temperature, pressure and pitch and loudness on the speed of sound.

Answer

Effect of medium, temperature, pressure and pitch on the speed of sound:

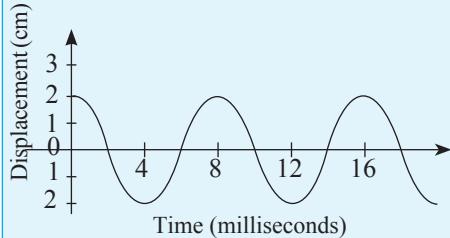
- Medium : Generally, sound travels faster in solids than liquids and gases, in that order. Sound travels 2 to 4 times faster in solids than liquids, and about 10 to 15 times faster than in gases.
- Temperature: The speed of sound in dry air at 0°C is about 330 m/s, and this increases as the temperature gets higher provided the pressure of the air does not change.
- Pressure: Changes in pressure will not affect the speed of sound.
- Pitch and loudness: The pitch and loudness of sound has no effect on its speed.

Revision Exercise 17

1. (a) Using appropriate diagram, explain how sound wave is propagated in air.
(b) Describe a simple experiment to determine the speed of sound in air.
2. A boy stands 190 m from a high wall and claps his hands. If he hears an echo 1.3 seconds later, calculate the speed of sound in air.

3. A girl uses an instrument that produces clicking sounds at half second intervals. She observes that echoes of the sound produced from a wall 45 m away come midway between the clicks. Use this information to calculate the speed of sound in air.

4. The graph below shows how the displacement d of the skin of a vibrating drum varies with time t :



- (a) Describe the nature of the waves produced by the drum skin.
- (b) Calculate the frequency of vibration of the drum skin.
- (c) Given that the speed of sound waves in air is 335 m/s, find the wavelength of the sound produced.

**UNIT
18**

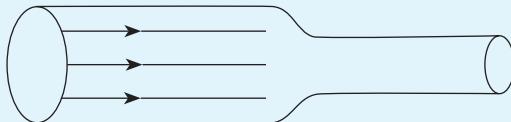
Fluid Flow

Key Points

- The study of fluid flow deals with liquids and gases in motion.
- Flow of a fluid may be termed as either streamline or turbulent.
- Viscosity of a fluid is its internal resistance to flow. It is considered as fluid friction and is caused by the forces between the molecules resisting their relative movement.

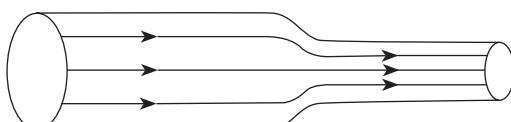
Revision Questions 18

- (a) Define the term streamline.
(b) The figure shows a tube of varying cross-section with streamlines drawn in the wider section. Complete the streamline in the narrower section and comment of the speed of the fluid in the two sections.



Answer

- (a) Streamline (line of flow) is the path traced (followed) by fluid particles.
- (b) The streamlines in the narrower section are closer, indicating higher speed of particles.



- (a) Distinguish between streamline flow and laminar flow.
(b) State the conditions necessary for a streamline flow.

Answer

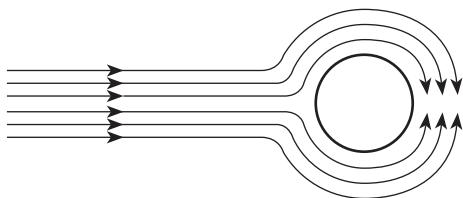
- (a) Streamline flow occurs when the particles of the fluid passing through a given point follow the same path with the same speed (same velocity). The flow is laminar when the fluid particles follow the same path with different speeds, that is, the speed of particles in one layer is different from the speed of particles in adjacent layers.
- (b) The fluid should:
 - be non-viscous.
 - have low speed (below the critical speed).
 - be incompressible.
- (a) What is meant by turbulent flow?
(b) State the conditions that may result in a flow being turbulent.
(c) How can turbulence be reduced? Illustrate using a diagram.

Answer

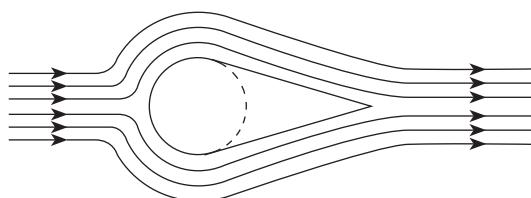
- (a) The flow is turbulent when fluid particles passing a given point follow different paths. It is also referred to as irregular flow.
- (b) Turbulence may occur if:
 - the velocity of the particles exceeds a certain value known as critical speed.
 - there is an obstacle in the path of the fluid, or the path is rough.

(iii) there is an abrupt change in the shape of the tube, either in diameter or direction.

(c) Turbulence can be reduced by streamlining, that is, modifying the shape of the obstacle, thus raising the critical velocity.

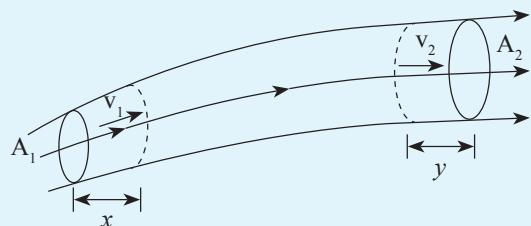


Turbulence



Streamlining

4. The figure shows a tube of flow with sections of varying cross-section areas A_1 and A_2 :



- (a) Derive the equation of continuity, stating any assumptions made.
 (b) A horizontal pipe of cross-section area 60 cm^2 has a constriction at one of its ends. A liquid is made to flow through the pipe and the constriction. The speed of the liquid in the pipe is 8 ms^{-1} and 15 ms^{-1} in the constriction. Determine the area of the constriction.

Answer

(a) In a given time t , the liquid in the narrower section covers a distance x , while that of the wider section covers a distance y . The volume per second in the narrower section is $A_1 \times \frac{x}{t}$ while that of a wider section is

$$A_2 \times \frac{y}{t}$$

$$\text{But } \frac{x}{t} = v_1 \text{ and } \frac{y}{t} = v_2$$

Thus, $A_1 v_1 = A_2 v_2$ (which is the equation of continuity).

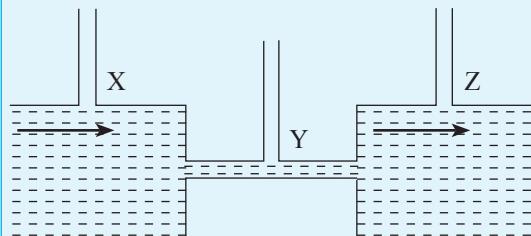
Assumptions made are that:

- (i) the liquid is incompressible.
 (ii) no fluid friction (viscosity) occurs.

- (b) From $A_1 v_1 = A_2 v_2$

$$\begin{aligned} A_1 &= \frac{A_2 v_2}{v_1} \\ &= \frac{60 \times 15}{8} \\ &= 112.5 \text{ cm}^2 \end{aligned}$$

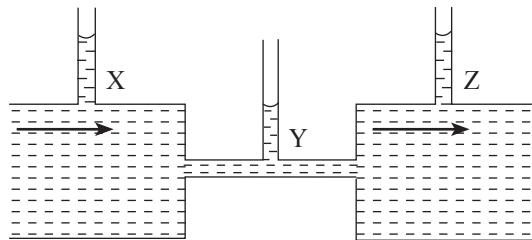
5. (a) State Bernoulli's principle.
 (b) The figure below represents an incompressible and non-viscous liquid flowing in the direction shown.



- (i) Mark on the diagram the relative levels of the liquid in sections X, Y and Z.
 (ii) Compare the pressure at the positions marked. Give reasons for your answer.

Answer

- (a) For a fluid exhibiting streamline flow, increase in velocity causes a corresponding decrease in pressure and decrease in velocity causes increase in pressure.
- (b) (i) The levels of X and Z are equal and higher than that of Y.

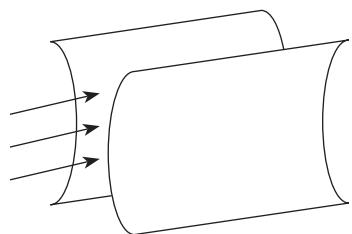


(ii) From the equation of continuity, the liquid will flow with same velocity at X and Z but much faster at Y. According to Bernoulli's principle, the liquid with higher velocity has lower pressure and vice versa. The pressure at Y is, therefore, lower than that at X and Z hence the difference in levels.

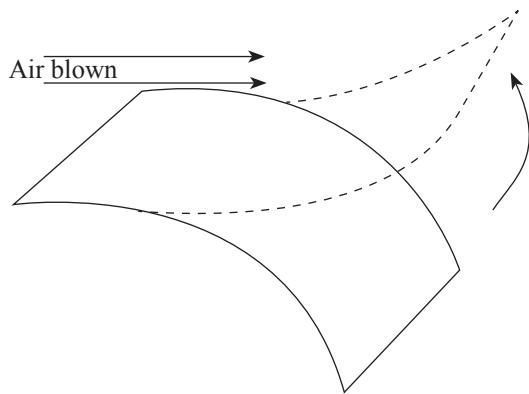
6. Describe an experiment to demonstrate Bernoulli's effect.

Answer

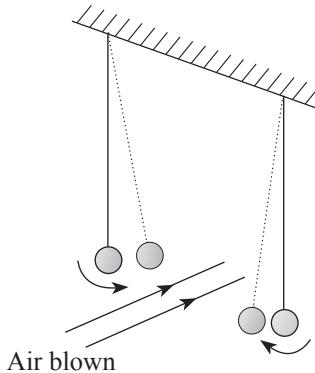
- When two pieces of paper are held apart vertically and air blown between them, the papers drift towards each other, as below.



- When a piece of paper is held in the hand and air blown above it as shown, the paper rises upwards from the folded part.

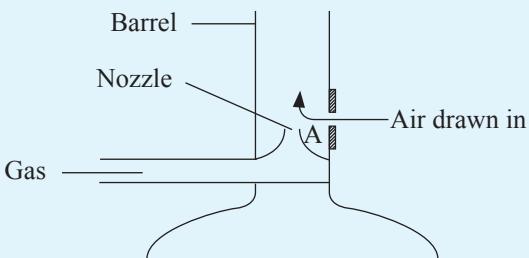


- Two light balls are suspended by strings of the same length as shown.



When air is blown in between them, the balls drift towards each other.

7. (a) The diagram below shows a bunsen burner.



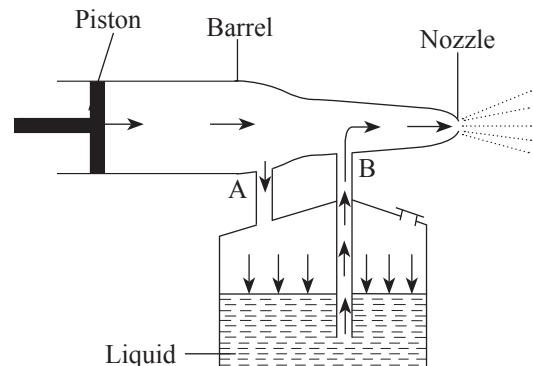
Explain the working of the burner as an application to Bernoulli's principle.

- (b) Apart from the bunsen burner, state and explain other applications of Bernoulli's principle.

Answer

- (a) The fast moving gas coming from a narrow jet (A) creates a region of low pressure inside the burner. External pressure, being greater, pushes in air, which mixes with the gas ready for combustion.
- (b) Other devices include: spray gun, aerofoil, carburettor and spinning ball.

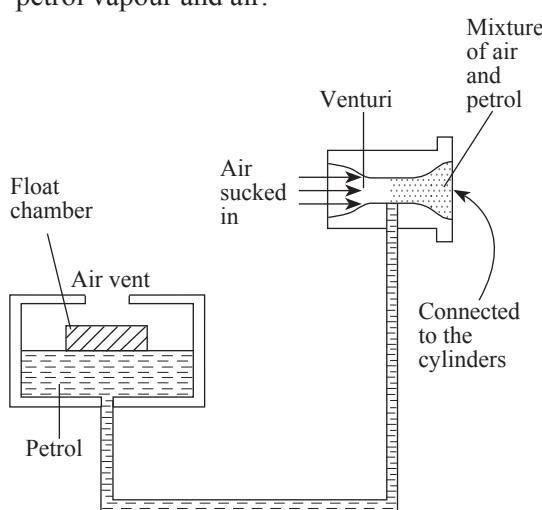
Spray gun



When air is pumped in, it enters the constriction at high speed, thus reducing the pressure inside. Atmospheric pressure pushes the liquid upwards and on impact with the fast moving air, the liquid breaks into a spray.

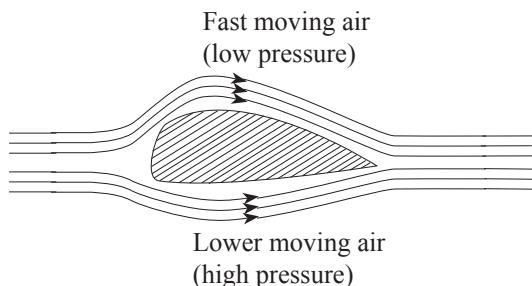
Carburettor

The carburettor is component for mixing petrol vapour and air.

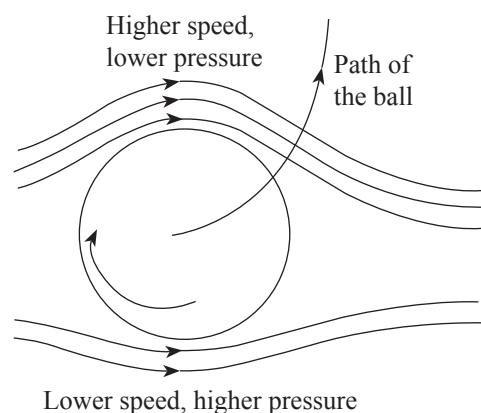


Downward movement of the engine piston results in low pressure in the venturi. Air is, thus, sucked in and mixes with petrol pushed up by atmospheric pressure.

Aerofoil



The design enables the speed at the top to be greater than that at the bottom. The pressure difference between the top and bottom produces a lifting force.



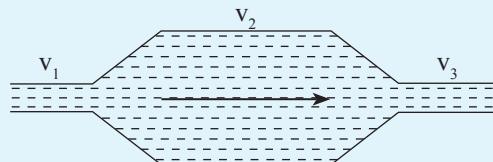
Spinning ball

When a ball spins and moves through air, the air above moves at greater speed hence reduced pressure. This creates a lifting effect.

Revision Exercise 18

1. Define the term turbulent flow.
2. Explain why it is dangerous to stand close to a railway line when a fast-moving train is passing.

3. Water flows in a pipe of varying cross-section area. The velocity of water in a wide section of the pipe is 2.0 m/s. If the diameter of the narrow part is 18 cm and that of the wider part is 54 cm, calculate the velocity at the narrow section.
4. The figure below represents the speed v_1 , v_2 and v_3 of water at various sections of a pipe:



- Arrange the speed in increasing order.
5. The path of a spinning ball normally curves. Explain why this happens.

**UNIT
19**

Linear Motion

Key Points

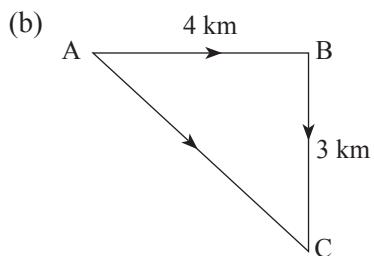
- Linear motion is a state whereby a body continuously changes its position along a straight line.
- Displacement, velocity and acceleration are vectors, hence negative sign must be introduced for quantities in opposite direction.

Revision Questions 19

1. (a) Distinguish between distance and displacement.
(b) A student moved 4 km from point A due east to point B and then 3 km due south to point C. Determine the distance and displacement of the motion.
(c) (i) Define speed, uniform speed and average speed.
(ii) A motorist drove a distance of 250 km in 5 hours. Determine the average speed in ms^{-1} .

Answer

(a) Distance is the length along actual path taken by a body while displacement is the length of a straight line connecting two points in a specified direction.



$$\text{Distance} = (4 + 3) \text{ km}$$

$$= 7 \text{ km}$$

$$\text{Displacement} = \sqrt{4^2 + 3^2}$$

$$= \sqrt{25}$$

= 5 km, in direction AC.

- (c) (i) Speed is the change of distance per unit time. Speed is said to be uniform if equal distances are covered in equal intervals of time.

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

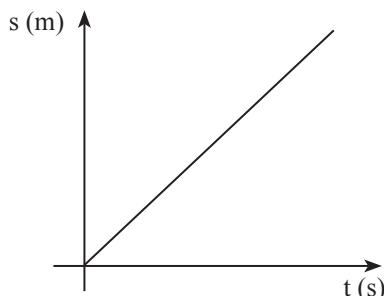
$$\text{(ii) Average speed} = \frac{250 \times 10^3 \text{ m}}{(5 \times 3600) \text{ s}}$$
$$= 13.89 \text{ ms}^{-1}$$

2. (a) (i) Define velocity and state its SI unit.
(ii) State what is meant by the term uniform velocity.
(iii) Sketch graphs of displacement against time showing uniform velocity, increasing velocity and decreasing velocity.
- (b) (i) Define acceleration and state its SI unit.
(ii) From the definition of acceleration, show that $v = u + at$, where v is the final velocity, u the initial velocity, a the acceleration and t the time taken for the change from u to v.
(iii) A car starts from rest and accelerated to speed of 72 km/h in two minutes. Calculate the acceleration.

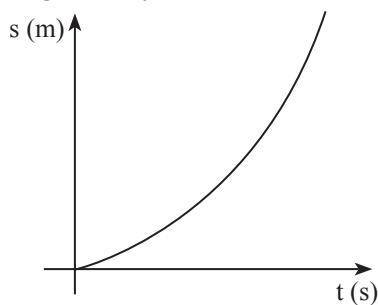
Answer

- (a) (i) Velocity of a body is the displacement per unit time. Its SI unit is ms^{-1} .
- (ii) Velocity is said to be uniform if the same displacement is covered in equal time intervals.
- (iii)

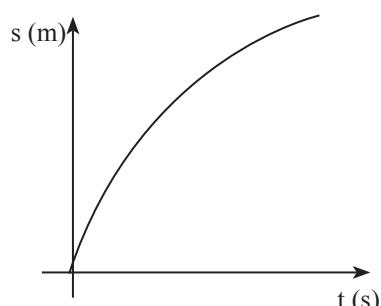
Uniform velocity



Increasing velocity



Decreasing velocity



- (b) (i) Acceleration is the change in velocity per unit time. The SI unit is metre per second (m/s^2).

$$\text{(ii) Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

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

$$at = v - u$$

$$v = u + at$$

$$\text{(iii)} a = \frac{v - u}{t} \quad u = 0,$$

$$v = 72 \text{ km/h} = 20 \text{ ms}^{-1}, t = 120 \text{ s}$$

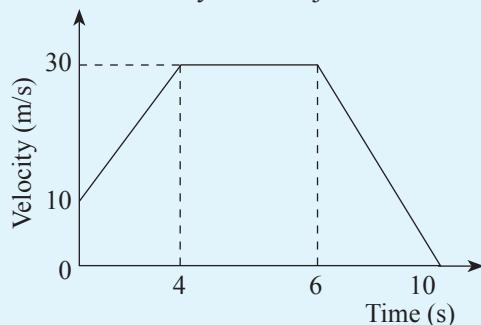
$$u = 0$$

$$\therefore a = \frac{20 - 0}{120}$$

$$= 0.1667 \text{ ms}^{-2}$$

3. (a) A body moving at 3 ms^{-1} and accelerates constantly at 4 ms^{-2} for t seconds. If the distance covered is 40 m , determine the time t .

- (b) The graph below shows the variation of velocity of an object with time:



- (i) Describe the motion.

- (ii) Determine acceleration between 4th and 6th second and between 6th and 10th second.

- (iii) Calculate the total displacement.

Answer

$$\text{(a)} \quad u = 3 \text{ ms}^{-1} \quad t = ?$$

$$a = 4 \text{ ms}^{-2} \quad s = 40$$

$$\text{From } s = ut + \frac{1}{2} at^2$$

$$40 = 3t + \left(\frac{1}{2} \times 4t^2\right)$$

$$= 3t + 2t^2$$

$$\text{So, } 2t^2 + 3t - 40 = 0$$

Using the quadratic formula;

$$t = \frac{-3 \pm \sqrt{9 + 320}}{4}$$

This gives;

$$t = 3.78 \text{ or } -5.29$$

Since t must be positive, the time taken is $t = 3.78 \text{ s}$

- (b) (i) The object starts off with an initial speed of 10 ms^{-1} and accelerates for 4 s. It then moves another 2 seconds at a constant velocity of 30 ms^{-1} before decelerating to rest in the last 4 seconds.

- (ii) Between 4th and 6th second;

$$a = 0 \text{ ms}^{-1}$$

Between 6th and 10th second;

$$a = \frac{0 - 30}{4} \\ = -7.5 \text{ ms}^{-2}$$

- (iii) Total displacement = area under the graph

$$s = \frac{1}{2}(10 + 30) \times 4 (30 \times 2) + \left(\frac{1}{2} \times 4 \times 30\right) \\ = 2(40) + 60 + 60 \\ = 200 \text{ m}$$

4. An object slides down an inclined plane 8 m long with an acceleration of 2 ms^{-2} . If the initial velocity is 2 ms^{-1} , determine final velocity.

Answer

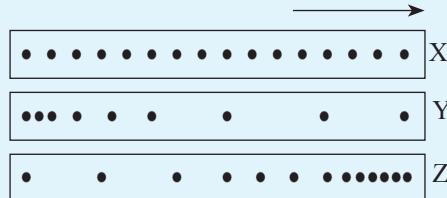
From $v^2 = u^2 + 2as$

$$v^2 = 2^2 + (2 \times 2 \times 8)$$

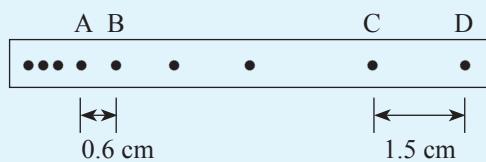
$$= 36$$

$$\therefore v = 6 \text{ ms}^{-1}$$

5. (a) The figure below shows ticker-timer tapes representing motions of various bodies. For each tape, describe the motion if the tape is moving in the direction shown.



- (b) In an attempt to measure acceleration of a body, a ticker timer tape attached to it showed the pattern shown. The ticker timer was operated at a frequency of 50 Hz.



- Calculate the time interval between one mark and the next.
- Determine the average velocity between regions AB and CD.
- What is the acceleration of the body?

Answer

(a) X – The dot interval is constant. The body is moving with a constant speed.

Y – Space between the dots is decreasing with time. This implies that the body is slowing down.

Z – The dot interval increases with time. The speed of the body is increasing.

$$(b) (i) f = \frac{1}{T} \Rightarrow T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec}$$

$$(ii) v_{AB} = \frac{s}{T} = \frac{6 \times 10^{-3}}{2 \times 10^{-2}} = 0.3 \text{ ms}^{-1}$$

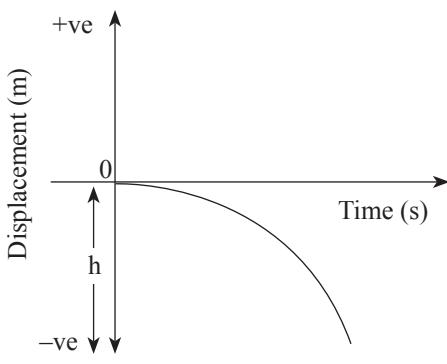
$$v_{CD} = \frac{15 \times 10^{-3}}{2 \times 10^{-2}} = 0.75 \text{ ms}^{-1}$$

$$(iii) \text{ Acceleration} = \frac{0.3 - 0.75}{4 \times 0.02} \\ = -5.625 \text{ m/s}^2$$

6. (a) For a body falling from a given height, sketch the graph of:
- (i) displacement against time.
 - (ii) velocity against time.
- Where possible, state the significance of the graphs.
- (b) (i) Explain why a feather reaches the ground after a stone even if both have the same mass and are released from same height.
- (ii) An object was dropped from a building 20 m high. Determine the time it will take to hit the ground below.

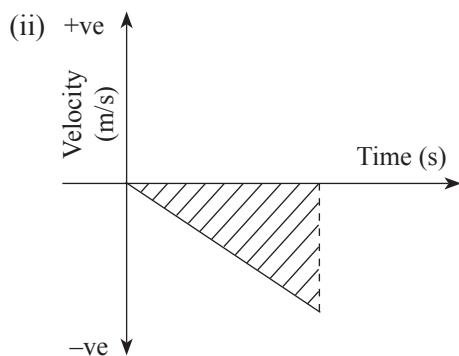
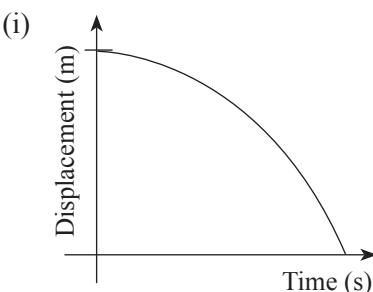
Answer

- (a) (i) If the point of release is taken as the zero displacement position and downward as negative, the graph of displacement against time is as shown below (displacement increases non-uniformly with time).



Alternatively, if the ground level is taken as reference point, then initially the body is at position of displacement so the graph appears

as follows:



A straight line graph, uniform increase in velocity with time. The area under the graph represents the distance while the gradient represents acceleration due to gravity 'g'.

- (b) (i) Air resistance due to increased surface area reduces the speed of feather.

$$(ii) s = 20 \text{ m} \quad t = ?$$

$$g = 10 \quad u = 0$$

$$s = ut + \frac{1}{2}gt^2$$

$$s = \frac{1}{2}gt^2$$

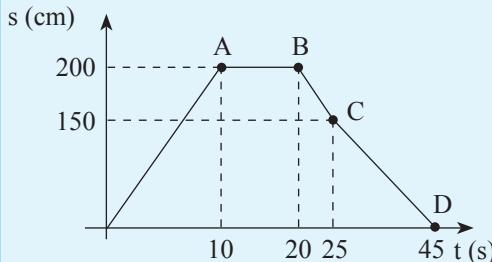
$$20 = \frac{1}{2}gt^2$$

$$t^2 = \frac{40}{10}$$

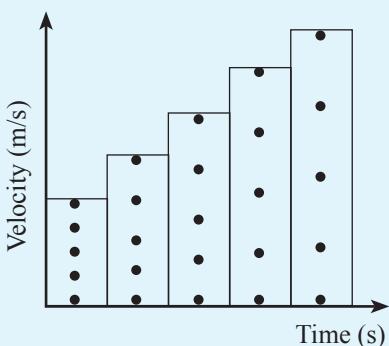
$$t = 2 \text{ s}$$

Revision Exercise 19

1. (a) The figure below shows the position of an object with respect to time:



- (i) Describe the motion of the object.
 - (ii) Obtain average velocity values for the sections OA, AB, BC and CD.
 - (iii) Draw a graph of average velocity against time and determine the acceleration for every section of the journey.
2. (a) In an experiment to determine acceleration of a body, a ticker-timer tape is cut in sections of 5 dot-spaces long. The tapes are put side to side as shown.

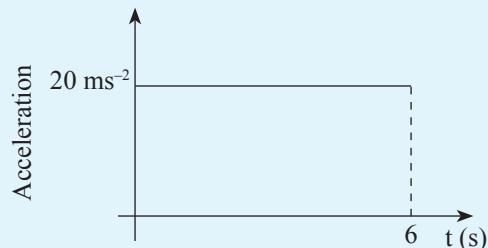


If it is taken that the size of a strip is equivalent to 0.1s, determine its acceleration.

- (b) A lorry is travelling at 20 ms^{-1} . The driver applies brakes for 4 seconds generating a retardation of 2.5 ms^{-2} .

Determine the final velocity of the lorry.

3. A cyclist starts a race with an acceleration of 10 ms^{-2} .
- (a) How long does it take to cover the first 20 m?
 - (b) What is the velocity at this point?
4. (a) The figure below is an acceleration-time graph for a body whose initial velocity is 0 ms^{-1} :



- (i) What is the significance of the area under the graph?
 - (ii) Determine the velocity after 4 s, and after 6 s.
- (b) In an experiment to determine the value of gravitational acceleration g , the following results were obtained:

| | | | | | | |
|--------------------------|-------|-------|-------|-------|-------|-------|
| $l (\text{cm})$ | 40 | 60 | 70 | 80 | 90 | 100 |
| Time for 10 oscillations | 12.57 | 15.17 | 16.47 | 17.61 | 18.70 | 19.73 |

Given that $T = 2\pi^2 \sqrt{\frac{l}{g}}$, plot a graph of T^2 against l and obtain the value of g .

**UNIT
20**

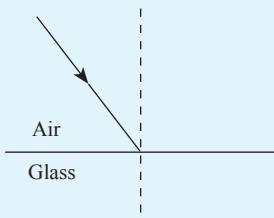
Refraction of Light

Key Points

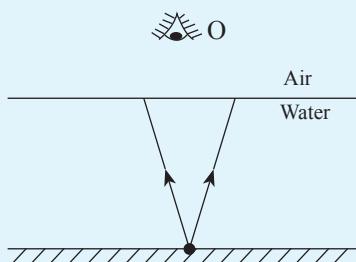
- Optical density is a measure of a material's ability to absorb (or resist the transmission of) light. In general, the higher the optical density, the higher the refractive index.
- Refraction of light occurs as a result of light changing its speed as it crosses from one medium to another of different optical density.

Revision Questions 20

- (a) A spoon partly submerged in a glass of water appears bent. Explain.
 (b) (i) Complete the path of rays of light as shown in the situation below:



- (ii) The figure below shows a point at the bottom of a pond. Complete the ray diagram to illustrate how it appears to an observer O.

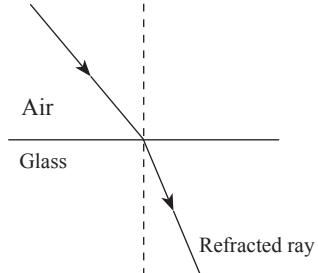


- (c) What is the effect on frequency, wavelength and speed of light during refraction process?

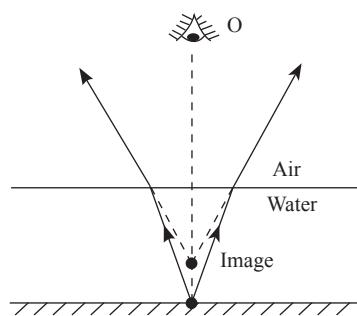
Answer

- As the rays of light from the air traverse the air-water interface, they are refracted, hence the bent appearance of the spoon.

- (i) Incident ray

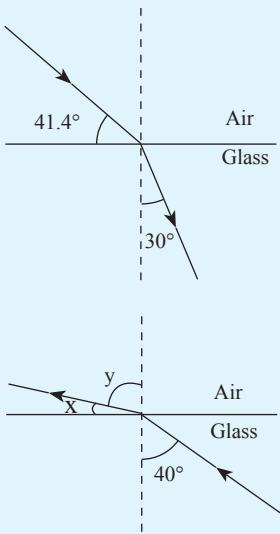


- (ii)



- (c) During refraction of light, wavelength and speed of light change, but the frequency remains unchanged.

- (a) State the laws of refraction.
 (b) (i) Use the following figures to calculate $a\eta_g$, $g\eta_a$ and the value of x.



- (ii) The speed of light in air is 3×10^8 m/s. Calculate:
- the speed of light in a glass of refractive index 1.5.
 - the wavelength of light in air and glass for light of frequency 6×10^{14} Hz.

Answer

- (a) • The incident ray, the refracted ray and the normal at the point of incidence all lie on the same plane.
• The ratio of the sine of angle of incidence to the sine of angle of refraction is a constant for a given pair of media, i.e., $\frac{\sin i}{\sin r} = \text{constant}$.

$$(b) (i) \eta_a = \frac{\sin (90^\circ - 41.4)}{\sin 30} \\ = \frac{\sin 48.6}{\sin 30} \\ = \frac{0.75016}{0.5} \\ = 1.5$$

$$\eta_g = \frac{1}{\eta_a} \\ = \frac{1}{1.5} \\ = 0.6667$$

$$\eta_a = \frac{\sin 40}{\sin y} \\ 0.6667 = \frac{0.6428}{\sin y} \\ \sin y = \frac{0.6428}{0.6667}$$

$$y = 74.6$$

$$x = 90 - 74.6 \\ = 15.4^\circ$$

$$(ii) \bullet \eta_g = \frac{\text{speed of light in air } (v_g)}{\text{speed of light in glass } (v_g)} \\ 1.5 = \frac{3 \times 10^8}{v_g}; \quad v_g = \frac{3 \times 10^8}{1.5}$$

$$v_g = 2 \times 10^8 \text{ ms}^{-1} \\ \bullet \lambda_g = \frac{c}{f} = \frac{3 \times 10^8}{6 \times 10^{14}} \\ = 5 \times 10^{-7} \text{ m}$$

$$\lambda_g = \frac{2 \times 10^8}{6 \times 10^{14}} \\ = 3.3 \times 10^{-7} \text{ m}$$

Alternatively,

$$\eta_g = \frac{\lambda_a}{\lambda_g} \\ 1.5 = \frac{5 \times 10^{-7}}{\lambda_g} \\ \lambda_g = \frac{5}{1.5} \times 10^{-7} \\ = 3.3 \times 10^{-7} \text{ m}$$

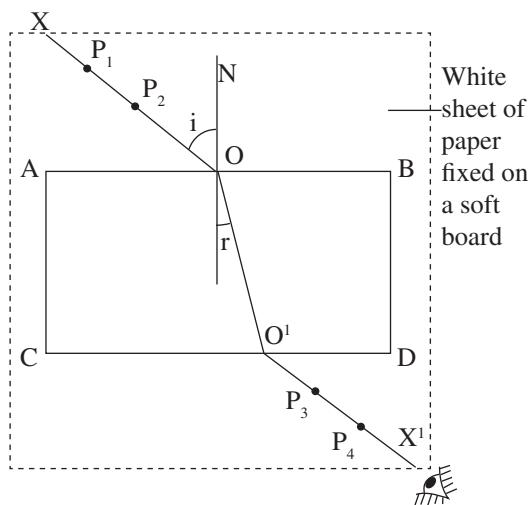
3. (a) Given four drawing pins, a rectangular glass block protractor, soft board and white sheet of paper, describe an experiment to verify Snell's Law.
 (b) The following results were obtained in the experiment in part (a):

| | | | | |
|--------------------------------|-----|-----|-----|-----|
| Angle of Incidence (i) | 30° | 40° | 50° | 70° |
| Angle of refraction (r) | 19° | 25° | 30° | 38° |

Plot a suitable graph to determine the refractive index.

Answer

(a) Verifying Snell's Law



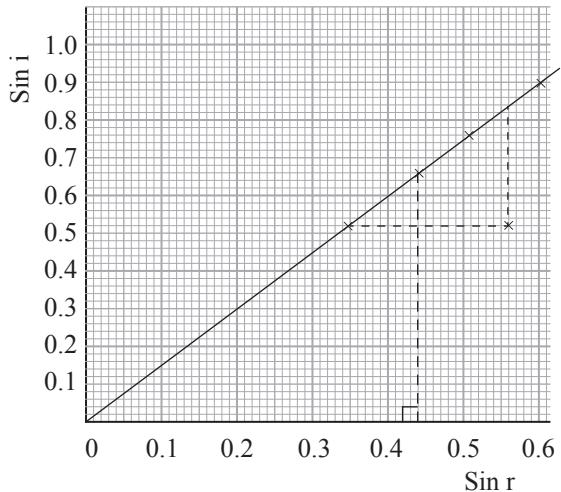
- The rectangular glass block is placed on white paper fixed on the soft board and its outline ABCD traced.
- The block is removed from the paper and a normal ON drawn to side AB to meet it at point O.
- A line is drawn to meet AB at O at an angle i , say 60° , to the normal ON. This line represents the incident ray.
- The glass block is put back to fit into its

outline and pins P_1 and P_2 fixed on the incident ray.

- With the eye placed on the side CD of the block, pins P_3 and P_4 are fixed so that they are in line with images of pins P_1 and P_2 .
- The block and pins P_3 and P_4 are removed and a line O^1X^1 drawn to pass through the positions of P_3 and P_4 .
- The line OO^1 is drawn and the angle r measured.
- The procedure above is repeated for other angles of incidence.
- A graph of values of $\sin i$ is plotted against values of $\sin r$. A straight line is obtained through showing that the ratio $\frac{\sin i}{\sin r}$ is a constant. This is Snell's Law.
- The gradient of the line gives the refractive index of the glass.

(b)

| | | | | |
|--------------|------|------|------|------|
| Sin i | 0.50 | 0.64 | 0.77 | 0.94 |
| Sin r | 0.33 | 0.42 | 0.50 | 0.62 |



$$^{a}\eta_g = \frac{0.66 - 0}{0.44 - 0} \\ = 1.50$$

4. (a) Show that:

$$(i) \quad {}_2\eta_l = \frac{1}{{}_1\eta_l}$$

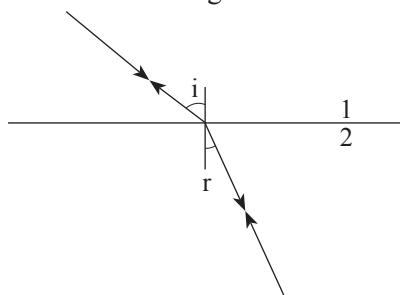
$$(ii) \quad {}_1\eta_l = {}_1\eta_l \times {}_2\eta_l$$

(b) A ray of light is incident in water on water-glass boundary. The angle of incidence is 30° . Calculate the angle of refraction in glass.

$$\left({}_a\eta_g = \frac{3}{2}, {}_a\eta_w = \frac{4}{3} \right)$$

Answer

(a) (i) Consider a ray travelling from medium 1 to 2 and incident at the interface at angle i as shown below.



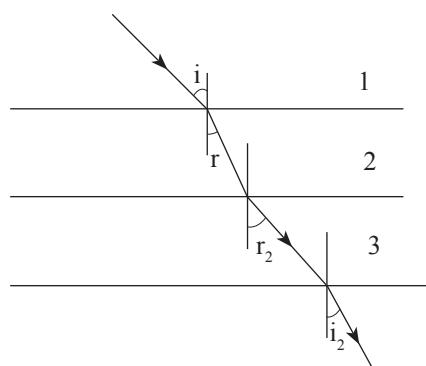
On traversing the interface, the ray is refracted at an angle r .

Thus;

$${}_1\eta_l = \frac{\sin i}{\sin r}$$

By reversibility of light

$${}_2\eta_l = \frac{\sin r}{\sin i} = \frac{1}{{}_1\eta_l}$$



$$(ii) \quad {}_1\eta_l = \frac{\sin i}{\sin r}$$

$${}_2\eta_l = \frac{\sin r}{\sin r_2}$$

$${}_3\eta_l = \frac{\sin r_2}{\sin i}$$

$$\text{But } {}_1\eta_l = \frac{\sin i}{\sin r_2}$$

$$\text{Now, } {}_1\eta_l \times {}_2\eta_l = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin r_2}$$

$$\text{Thus, } {}_1\eta_l \times {}_2\eta_l = {}_1\eta_l \times {}_2\eta_l$$

$$(b) \quad {}_w\eta_g = {}_w\eta_a \times {}_a\eta_g$$

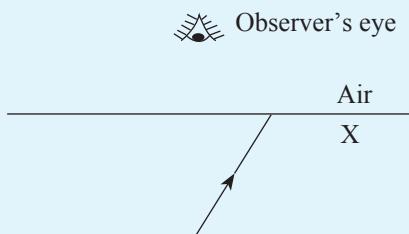
$$= \frac{3}{4} \times \frac{3}{2} = \frac{9}{8}$$

$$\frac{9}{8} = \frac{\sin 30}{\sin x};$$

$$\sin x = 0.5 \times \frac{8}{9} = 0.4444$$

$$x = 26.39^\circ.$$

5. (a) (i) The figure below shows a small object placed under a transparent medium X. Complete the ray diagram to show the apparent depth of the object as seen by the observer.



(ii) Define refractive index in terms of real and apparent depth.

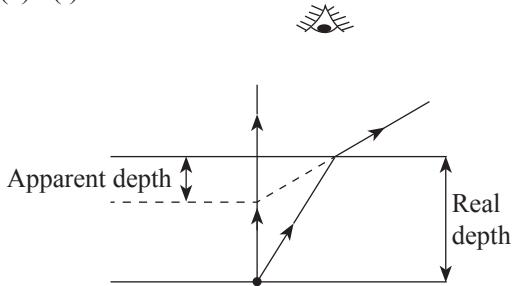
(b) In an experiment to determine the refractive index of water, the following results were obtained:

| | | | | |
|----------------------------|-----|------|------|------|
| Real depth (mm) | 7.5 | 10.5 | 14.5 | 17.5 |
| Apparent depth (mm) | 5.8 | 8.0 | 11.0 | 13.2 |

- (i) Plot a graph of real depth against apparent depth.
- (ii) From the graph, determine the value for the refractive index of water.

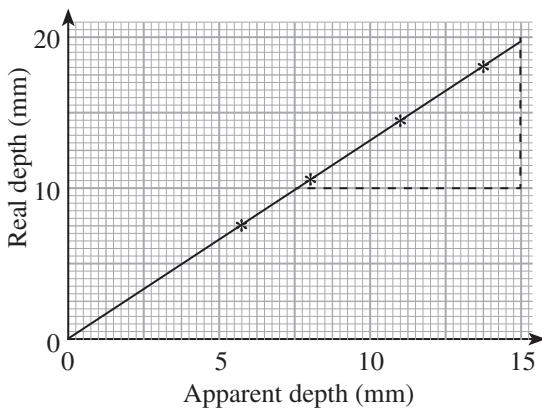
Answer

(a) (i)



- (ii) Refractive index is the ratio of real depth to apparent depth.

$$\text{that is, } a\eta_w = \frac{\text{real depth}}{\text{apparent depth}}$$



$$\begin{aligned} \text{Gradient} &= \frac{20 - 10}{15 - 7.5} \\ &= 1.33 \end{aligned}$$

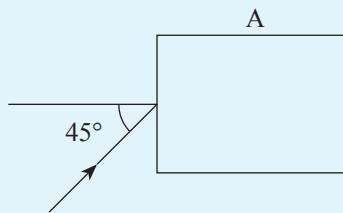
6. (a) (i) What do you understand by the terms total internal reflection and critical angle?

- (ii) What conditions are necessary for total internal reflection to occur?

- (iii) Show that refractive index $a\eta_w = \frac{1}{\sin c}$ where c is the critical angle.

- (iv) Diamond has refractive index of 2.4. Calculate critical angle.

- (b) The diagram below shows a ray of light incident on the face of a glass cube of refractive index 1.5.



Calculate:

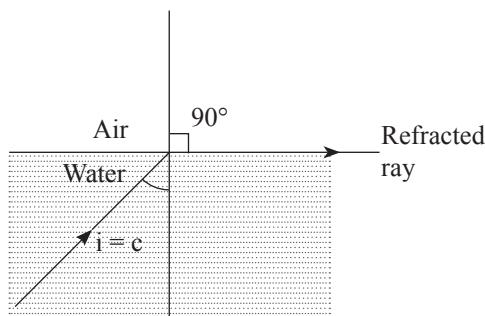
- (i) the angle of refraction.
(ii) the critical angle c for glass-air interface.

- (c) When a drop of a liquid of refractive index 1.4 is placed on the upper surface of the cube so as to cover point A, light emerges from block at A. Explain.

Answer

- (a) (i) When light moves from an optically denser medium to a less dense one, the refracted ray bends away from normal. When the refracted ray makes an angle of 90° , the incident ray becomes totally reflected within the dense medium. The incident angle at which the angle of refraction is

90° is called the critical angle. If the angle of incidence is greater than the critical angle, the ray is totally reflected, as shown below.



(ii) Conditions necessary for total internal reflection to take place.

- Ray must be from optically denser medium to a less denser one.
- The angle of incidence must be greater than the critical angle.

$$(iii) a\eta_w = \frac{\sin i}{\sin r}$$

At critical angle, $i = 90^\circ$ and $\sin 90^\circ = 1$

$$\text{Thus, } a\eta_w = \frac{1}{\sin c}$$

$$(iv) a\eta_d = \frac{1}{\sin c}$$

$$2.4 = \frac{1}{\sin c}$$

$$\sin c = 0.4167$$

$$c = 24.6^\circ$$

$$\simeq 25^\circ$$

$$(b) (i) a\eta_g = 1.5 = \frac{\sin 45}{\sin r}$$

$$\sin r = \frac{0.707}{1.5}$$

$$= 0.4714$$

$$r = 28.1^\circ$$

(ii) The critical angle c ;

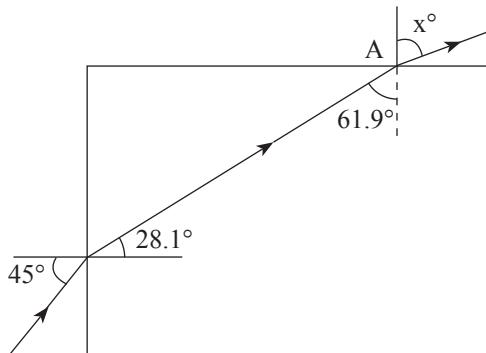
$$a\eta_g = \frac{1}{\sin c} \\ = 1.5$$

$$\sin c = 0.6667$$

$$\therefore c = 41.8^\circ$$

$$(c) 1.5 = \frac{\sin 45^\circ}{\sin r}$$

$$r = 28.1^\circ$$



Total internal reflection occurs since 61.9° is greater than the critical angle c .

$$g\eta_c = g\eta_a \times a\eta_c \\ = \frac{1}{1.5} \times 1.4 \\ = 0.9333$$

$$0.9333 = \frac{\sin 61.9}{\sin x}$$

$$\sin x = \frac{0.8821}{0.9333} \\ = 0.9453$$

$$x = 71^\circ$$

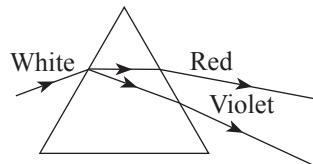
The ray emerges at A since the critical angle between glass and water is higher than the angle of incidence at the glass-water boundary.

7. (a) Describe an experiment to illustrate dispersion of white light.

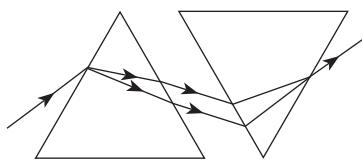
- (b) (i) Explain why dispersion occurs.
(ii) How can the dispersed light be recombined into white light?

Answer

- (a) • A narrow beam of white light is directed towards an equilateral prism with a white screen placed on the other side of prism. It is observed that a spectrum forms on the screen as below.

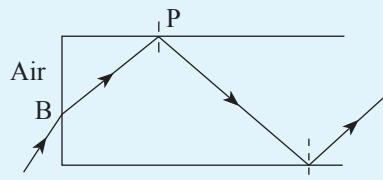


- (b) (i) White light consists of light of different colours having different wavelengths. Hence, they travel with different velocities when they enter glass and are thus refracted to different extents. The lower the velocity, the greater the refraction. Thus, red light is refracted least and violet light most.
(ii) The dispersed light can be recombined by arranging the prisms as shown.

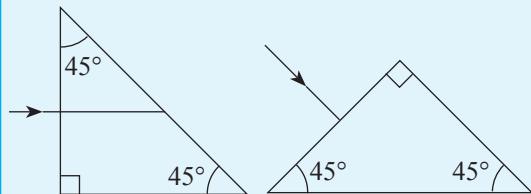


Revision Exercise 20

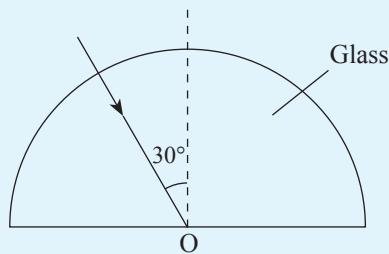
1. (a) The following diagram shows a light signal travelling through an optical fibre:



- (i) State the two changes that happen to the light when it passes from air into the fibre at B.
(ii) Explain why the light follows the path shown after hitting the wall at P.
- (b) (i) Complete the path of light in the following diagram:

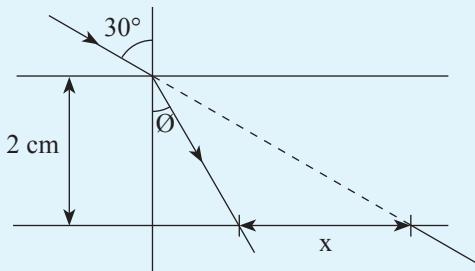


- (ii) Using ray diagram construction, show how an object can be viewed using a prism periscope.
(iii) State the advantages of using glass prisms over mirrors in a periscope.
2. The figure below shows a ray of light through a glass material.

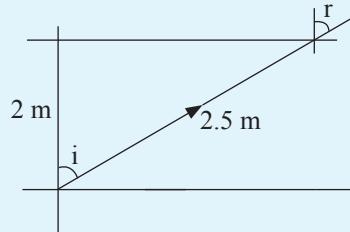


- (a) (i) What happens to the direction of light as the angle is increased beyond the critical angle?
(ii) Complete the ray diagram if the ray is a beam of red light of refractive index of 1.4 in glass.

- (iii) Draw on the same diagram the refracted ray for blue light of refractive index 1.403.
- (b) Light has a speed of $2 \times 10^8 \text{ ms}^{-1}$ in ice and $3 \times 10^8 \text{ ms}^{-1}$ in air. Determine the refractive index of the ice and the critical angle c for light travelling from the ice to air.
3. The figure shows a ray of light travelling from air to a medium of refractive index $n = \frac{3}{2}$. Calculate the angle of refraction θ and lateral displacement x .



4. A light source is put under the surface of water of depth 2 m as shown below.



If the length of the ray in water is 2.5 m, determine:

- the angles i and r .
- the depth at which the source appears to be, (take refractive index of water as $\frac{4}{3}$).

UNIT**21**

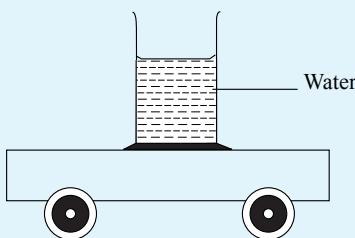
Newton's Laws of Motion

Key Points

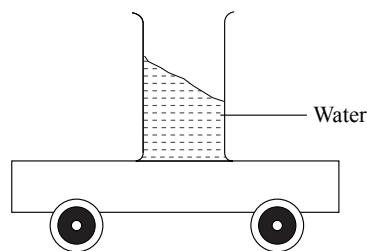
- Newton's laws of motion relate to the effects of force on either stationary or moving objects.
- Newton's first law of motion is also known as the law of inertia. Inertia is the property of a body to remain at rest or if moving, continue doing so in a straight line.
- Impulse of a force is the sudden change in momentum due to short-lived impact of force on a body, as in a collision. It is, therefore, a product of force and time.
Impulse of force = Force \times time (Ft)
Ft = Change in momentum
The SI unit is newton-second (Ns).
- Action and reaction are equal and opposite.

Revision Questions 21

- (a) State Newton's first law of motion.
(b) Explain why passengers in a vehicle are lurched forward when the vehicle suddenly decelerates.
(c) The figure below shows water in container firmly placed on a trolley. With the aid of a diagram, show and explain what would happen if the trolley is suddenly moved to the right.

**Answer**

- (a) A body continues in its state of rest or uniform motion in a straight line unless acted upon by external forces.
(b) The passengers are in a motion at the same speed as the vehicle. When the vehicle suddenly decelerates, the passengers tend to continue moving at the original speed, hence the lurching forward.
(c) As the trolley begins to move, some water particles resist movement due to inertia, thus exhibiting the shape shown.



- (a) What is meant by momentum of a body? State its SI unit.
(b) State Newton's second law of motion. Hence, derive the equation $F = ma$.

Answer

- (a) Momentum is the product of mass and velocity of a body. Its SI unit is kilogram metre per second.
(b) The rate of change of momentum is directly proportional to the resultant force and takes place in the direction in which the force acts.

Consider a body of mass m kg acted upon by force newtons F , causing its velocity to change from initial velocity (u) to final velocity (v) in time t seconds.

Then, initial momentum is mu and final momentum is mv

The change in momentum = $mv - mu$

From the law, the rate of change of momentum is proportional to the force that is,

$$F \propto \frac{mv - mu}{t}$$

$$F \propto \frac{m(v - u)}{t}$$

$$\text{But } a = \frac{v - u}{t}$$

Thus $F \propto ma$

$F = kma$, where k is a constant of proportion

Experimentally the value of $k = 1$.

Hence, $F = ma$

3. (a) The figure shows a body of mass 4 kg placed on a smooth horizontal table and acted upon by two forces.



Determine:

- (i) the resultant force.
- (ii) the resulting acceleration.
- (b) (i) When a force of 8 N acts on a trolley of mass 2 kg, it accelerates at 2 m/s^2 . Calculate the retarding force on the trolley.
- (ii) What name is given to this retarding force?

Answer

- (a) (i) Resultant force = $(12 - 6)$

= 6 N, this is in the direction of 12 N force.

$$\begin{aligned} \text{(ii) Acceleration} &= \frac{F}{m} \\ a &= \frac{6}{4} \\ &= 1.5 \text{ m/s}^2 \end{aligned}$$

- (b) (i) Resultant force = Applied – retarding force

$$ma = 8 - F$$

$$F = 8 - ma$$

$$F = 8 - (2 \times 2)$$

$$= 4 \text{ N}$$

4. (a) Define the following terms:

- (i) Elastic collision
- (ii) Inelastic collision

- (b) A force of 200 N acts for 5 s on an object of mass 40 kg.

- (i) What is the momentum change per second?
- (ii) Find the impulse.
- (iii) Determine the change in velocity.

Answer

- (a) (i) Elastic collision is where the bodies bounce and move with different velocities without any loss of kinetic energy (that is, KE is conserved).

- (ii) Inelastic collision is where the bodies collide and lose kinetic energy. In a perfectly inelastic collision, the bodies fuse and move together with a common velocity.

- (b) (i) Momentum change = Force per second

$$= 200 \text{ N}$$

- (ii) Impulse = $F \times t$

$$= 200 \times 5$$

$$= 1000 \text{ Ns}$$

(iii) Impulse = Change in momentum

$$1000 = 40 \times \text{change in velocity}$$

$$\text{Change in velocity} = 25 \text{ m/s}$$

5. (a) State Newton's third law of motion.
- (b) Name the conditions necessary for a pair of forces to qualify as action and reaction.
- (c) State the law of conservation of linear momentum.
- (d) A van of mass 1600 kg moving at a velocity of 72 km/h approaches a stationary car of mass 1050 kg. If the van collides head-on with the car and the impact takes 0.3 seconds before the two move together at a constant velocity for 3 seconds. Calculate:
 - (i) The common velocity.
 - (ii) The distance moved after impact.
 - (iii) The impulsive force.
 - (iv) The kinetic energy before and after impact. Comment on the KE values obtained.

Answer

- (a) For every action of body A on body B, there is an equal and opposite reaction of body B on body A (action and reaction are equal and opposite).
- (b) Two forces constitute action and reaction pairs if:
 - (i) They are equal in magnitude but act in opposite directions.
 - (ii) The forces act simultaneously.
 - (iii) The forces act on different interacting bodies.
- (c) When two or more bodies act on each

other, the total momentum remains constant provided no external forces act on them.

- (d) (i) By the law of conservation of momentum, momentum before collision equals momentum after collision.

$$m_1 u_1 + m_2 u_2 = (m_1 + m_2) v, \text{ where } v \text{ is the common (final) velocity}$$

$$(1\ 050 \times 0) + (1\ 600 \times 20)$$

$$= (1\ 050 + 1\ 600) v$$

$$v = \frac{32\ 000}{2\ 650}$$

$$= 12.08 \text{ m/s}$$

(ii) Distance moved = velocity \times time

$$= 12.08 \times 3$$

$$= 36.24 \text{ m}$$

(iii) Impulsive = $\frac{\text{change in momentum}}{\text{time}}$

$$= \frac{mv - mu}{t}$$

$$= \frac{12\ 680}{0.3}$$

$$= 42\ 267 \text{ N}$$

(iv) KE before collision = $\frac{1}{2} mu^2$

$$= \frac{1}{2} \times 1\ 600 \times (20)^2$$

$$= 320\ 000 \text{ J}$$

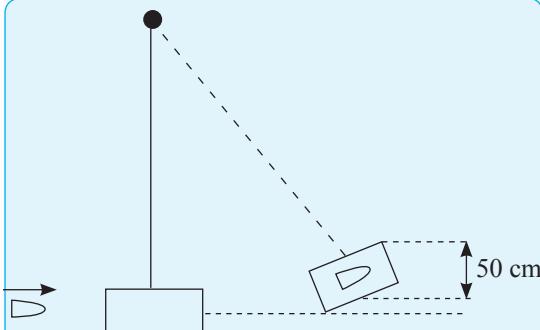
$$\text{KE after collision} = \frac{1}{2} mv^2$$

$$= \frac{1}{2} \times 2\ 650 \times (12.08)^2$$

$$= 193\ 352.48 \text{ J}$$

Some energy is lost in the form of heat and sound on impact.

6. The figure below shows a 10 g bullet fired horizontally into a 1.99 kg block of wood suspended by a long string:



The bullet is embedded into the block and causes it to swing to a height of 10 cm above the rest position. Determine the initial velocity of the bullet.

Answer

Loss in kinetic energy by bullet = gain in potential energy by the bullet and block

$$\frac{1}{2} \times 0.01 \times v^2 = (0.01 + 4.99) \times 10 \times 0.5$$

$$v^2 = \frac{10 \times 10 \times 0.5}{0.01}$$

$$= 5000$$

$$= 70.7 \text{ m/s}$$

7. A student of mass 50 kg dives from a high diving board. A table of his vertical velocity at different times is as shown below. (Take $g = 10 \text{ N/kg}$).

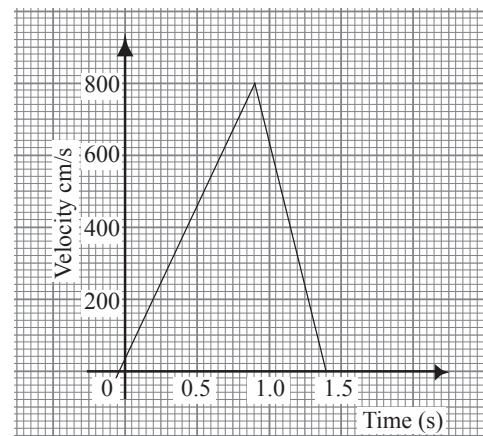
| Velocity (cm/s) | Time (sec) |
|-----------------|------------|
| 0 | 0 |
| 180 | 0.2 |
| 360 | 0.4 |
| 540 | 0.6 |
| 720 | 0.8 |
| 800 | 0.9 |
| 640 | 1.0 |
| 320 | 1.2 |
| 0 | 1.4 |

- (a) Draw a graph of velocity against time and use it to determine:

- (i) the time the student took to reach the water.
 - (ii) the height of the diving board.
 - (iii) the student deceleration into the water.
 - (iv) the retarding force of the student by the water.
 - (v) the depth of the water reached by the student.
- (b) (i) How far did the student move in the first 0.5 s of the dive?
- (ii) What is the loss in the student's potential energy after falling through this distance?
- (iii) Determine the student's kinetic energy within the 0.5 s of the dive.
- (iv) Account for the difference in the energies above.

Answer

(a)



- (i) Time is 0.9 s
- (ii) Height = area below the graph

$$= \frac{1}{2} bh$$

$$= \frac{1}{2} \times 8 \times 0.9$$

$$= 3.6 \text{ m}$$

$$\begin{aligned} \text{(iii) Deceleration} &= \frac{v - u}{t} \\ &= \frac{8 - 0}{0.5} \\ &= 16 \text{ m/s}^2 \end{aligned}$$

$$\begin{aligned} \text{(iv) Retarding force, } F &= ma \\ &= 50 \times 16 \\ &= 800 \text{ N} \end{aligned}$$

$$\begin{aligned} \text{(v) Depth} &= \text{area below the graph} \\ &= \frac{1}{2} \times 8 \times (1.4 - 0.9) \\ &= \frac{1}{2} \times 8 \times 0.5 \\ &= 2.0 \text{ m} \end{aligned}$$

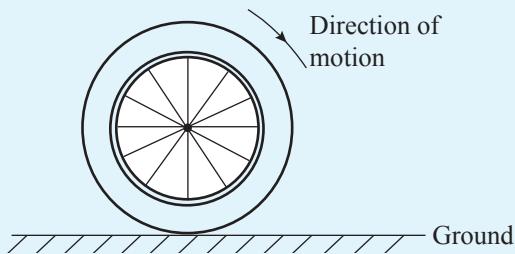
$$\begin{aligned} \text{(b) (i) Area below} &= \frac{1}{2} \times 0.5 \times 4.4 \\ &= 1.1 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{(ii) Loss in PE} &= mgh \\ &= 50 \times 10 \times 1.1 \\ &= 550 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{(iii) Kinetic energy} &= \frac{1}{2} mv^2 \\ &= \frac{1}{2} \times 50 \times (4.4)^2 \\ &= 484 \text{ J} \end{aligned}$$

(iv) Some energy is lost due to air resistance (upthrust).

8. (a) (i) Define the term friction.
(ii) The figure shows a vehicle tyre rotating in the direction given:



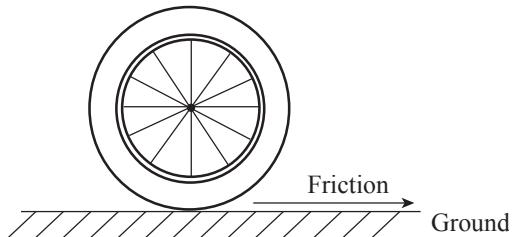
On the figure, indicate the direction of frictional force.

- (iii) How is the design of the tyres useful on a wet road?
(b) Why would a vehicle skid more easily on a murram road than on tarmac?
(c) State two advantages and two disadvantages of friction.

Answer

(a) (i) Friction is the force that opposes relative motion between two surfaces.

(ii)



(iii) On a wet day, some water fills the tyre grooves. This enhances proper contact between the road and tyre hence frictional force is increased.

(b) Because the pebbles (murram) act as rollers.

(c) Advantages

- Enables people to walk and vehicles to move due to contact between the ground and feet/tyre.
- Braking of automobiles is made possible.
- Lighting a matchstick.
- Motor-car jack to lift vehicles.
- Writing with chalk on chalkboard.

Disadvantages

- Causes wear and tear on the moving parts of a machine.

- Reduces efficiency of machines as a result of loss of energy.
9. A student of mass 60 kg stands on a weighing machine inside a lift. When the lift starts to ascend vertically upwards, its acceleration is 2 m/s^2 .
- What is the weight of the student?
 - What would be the weight when the lift:
 - is moving with uniform velocity?
 - descends with acceleration of 3.2 m/s^2 ?

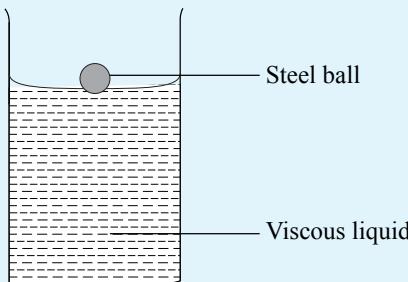
Answer

(a) $W = mg + ma$
 $= (60 \times 10) + (60 \times 2)$
 $= 720 \text{ N}$

(b) (i) $W = mg$
 $= 60 \times 10$
 $= 600 \text{ N}$

(ii) $W = m(g - a)$
 $= 60 \times (10 - 3.2)$
 $= 408 \text{ N}$

10. (a) Define viscosity.
- (b) The figure shows a steel ball placed in tall cylinder below containing a viscous liquid:

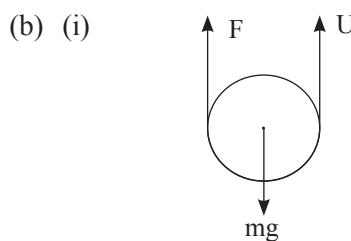


- (i) Show all the forces acting on the ball when completely immersed in the liquid.

- (ii) State the relationship between the forces acting on the ball as:
- it just starts to move through the liquid.
 - it attains terminal velocity.
- (iii) Sketch a graph showing the variation of velocity with time. Explain the shape of the graph.

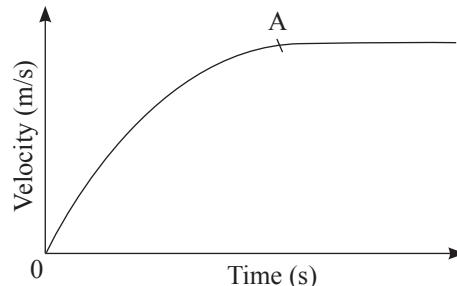
Answer

(a) Viscosity of a fluid is its internal resistance to fluid flow. It is considered as fluid friction and is caused by the intermolecular forces between the molecules resisting the relative movement of neighbouring molecules.



- (ii) • $mg > F + U$
• $mg = F + U$

- (iii)



As the ball freely falls through the liquid, its weight is greater than the sum of upthrust and viscosity. The resultant force provides the acceleration through the liquid as shown in part OA. When

terminal velocity is attained, the sum of upthrust and viscosity equals the weight and there is thus, no resultant force on the ball (shown by part beyond A).

Revision Exercise 21

1. Explain the following:
 - (a) Passengers in a vehicle are advised to wear safety belts.
 - (b) In pole-vault event, a thick soft mattress is usually provided for landing. How does the mattress help to reduce the force of impact?
 - (c) In rowing, straight movement is achieved by rowing both sides of the boat.
2. A body H of mass 0.20 kg and moving at a speed of 6.0 m/s, collides with a stationary body G of mass 1.0 kg. H rebounds with a speed of 4.0 m/s and G is driven forwards with a speed of 2.0 m/s.

(a) Show that the collision is elastic.
(b) Calculate the impulse applied to G by H.
3. A bullet of mass 20 g travelling at a velocity of 15 m/s penetrates a sand bag and is brought to rest in 0.25 seconds. Find:
 - (a) the depth of penetration in metres.
 - (b) the average retarding force of the sand.
4. A force acting on a block of mass 1.2 kg causes it to move on a horizontal table with a uniform speed. Determine the normal reaction if the co-efficient of friction between the block and the table is 0.6.
5. A van of mass 1 600 kg moving at 30 m/s collides with a 3 600 kg truck moving at 20 m/s in the opposite direction. The vehicles interlock and move together. Find their common velocity.

**UNIT
22**

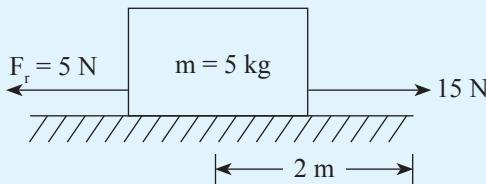
Work, Power, Energy and Machines

Key Points

- Work is a scalar quantity.
- The area under force-distance graph gives work done.
- Kinetic and potential energy are examples of mechanical energy and can be defined in terms of work.
- Energy cannot be created or destroyed but can be transformed from one form to the other.
- A machine is a device that makes work easier. Examples of machines are pulleys, hydraulic lift, wheel and axle, gear-wheels, the screw and the incline plane.

Revision Questions 22

1. (a) Define work and state its SI units.
(b) A force of 15 N pulls a mass of 5 kg, some 2 m along a surface that offers friction of 5 N.



Determine work done:

- (i) by the 15 N force.
- (ii) against friction.

Answer

1. (a) Work is done when a force moves an object through some distance, i.e.,
 $\text{work done} = \text{force} \times \text{distance}$

The SI unit of work done is newton-metre or joule (J).

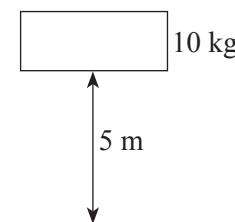
- (b) (i) $\text{Work done by the force} = 15 \times 2 = 30 \text{ J}$
(ii) $\text{Work done by friction} = -5 \times 2 = -10 \text{ J}$
2. (a) Define gravitational potential energy (PE) and kinetic energy (KE) in terms of work done.
(b) Mary lifts a mass of 10 kg vertically upwards through a distance of 5 m. Determine the gain in potential energy and work done.
(c) A van of mass 1 tonne is moving at speed of 72 kmh^{-1} . Calculate kinetic energy and the work done to stop the van.

Answer

- (a) Potential energy is the work done in lifting an object against gravitational force from a reference point.

Kinetic energy of a body is the work done by a moving body before it comes to rest.

- (b)



$$\begin{aligned}\text{PE} &= \text{mgh} \\ &= 10 \times 10 \times 5 \\ &= 500 \text{ J}\end{aligned}$$

(c) $1 \text{ tonne} = 1000 \text{ kg}$

$$72 \text{ kmh}^{-1} = 20 \text{ ms}^{-1}$$

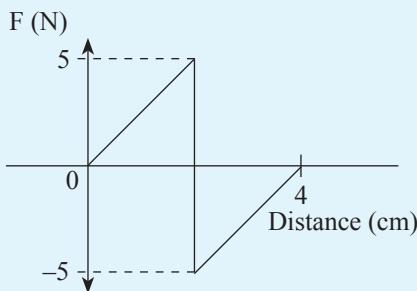
$$\text{KE} = \frac{1}{2} \text{mv}^2$$

$$= \frac{1}{2} \times 1000 \times 20 \times 20$$

$$= 2 \times 10^5 \text{ J}$$

This is the work done.

3. The diagram below shows the force acting on an object against the distance it moves as a result:



Calculate the work done:

- (a) between 0 m and 2 m
- (b) between 2 m and 4 m
- (c) between 0 m and 4 m

Answer

- (a) Work done = area under the graph

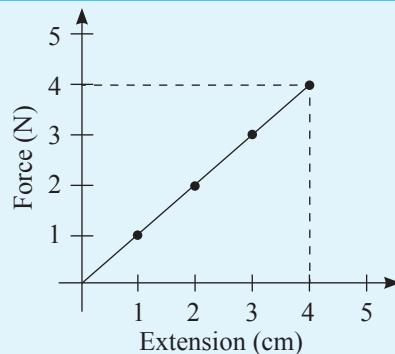
$$= \frac{1}{2} \times 2 \times 5 \\ = 5 \text{ J}$$

(b) $\frac{1}{2} \times (2) \times (-5) = -5 \text{ J}$

(c) Total work done $(0 - 4 \text{ m}) = 5 + (-5)$
 $= 0 \text{ J}$

4. (a) What is elastic potential energy?

- (b) The following figure shows a graph of force against extensions for a spring stretched to its elastic limit:



Determine the:

- (i) spring constant.
- (ii) work done in stretching the spring to its elastic limit.

Answer

- (a) Elastic potential energy is the work done in stretching or compressing an elastic material.

- (b) (i) $F = ke$

$$k = \frac{F}{e}$$

k = gradient

$$= \frac{\Delta F}{\Delta e} \\ = \frac{4}{4 \times 10^{-2}} \\ = 100 \text{ Nm}^{-1}$$

- (ii) Work done = $\frac{1}{2} Fe$

$$\frac{1}{2} Fe = \text{area under the graph.} \\ = \frac{1}{2} \times 4 \times 4 \times 10^{-2} \\ = 8 \times 10^{-2} \text{ J}$$

Alternatively;

Since $F = ke$

$$\text{Work done} = \frac{1}{2} ke^2 \\ = \frac{1}{2} \times 100 \times 4^2 \times 10^{-4} \\ = 8 \times 10^{-2} \text{ J}$$

5. (a) (i) State the principle of conservation of energy.
- (ii) Distinguish between non-renewable and renewable energy sources, giving examples of each.
- (b) A mass m kg is dropped from a height of h metres above the ground. Describe the energy changes that take place and determine expression for the velocity at which the mass hits the ground.

Answer

- (a) (i) Energy cannot be created or destroyed but can be changed from one form to another.
- (ii) Non-renewable energy source is that whose energy dwindles with time and eventually gets exhausted. Examples include petroleum and natural gas. Renewable energy sources can be replaced within a short time. Examples include solar, geothermal and wind energy.
- (b) The mass has potential energy due to its height above the ground. This PE is converted into KE as the mass falls which in turn is converted to heat, sound and may do some work as the mass makes contact with the ground.

From the law of conservation of energy, the loss in potential energy is equal to gain in kinetic energy.

Loss in PE = gain in KE

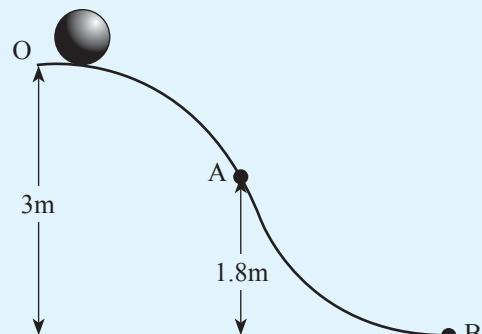
$$mgh = \frac{1}{2} mv^2$$

$$v = \sqrt{2gh}$$

6. (a) State the work-energy principle.
 (b) A bullet travelling at 100 ms^{-1} crashes

through a 0.5 m plank of wood and emerges at 80 ms^{-1} . If the mass of bullet is 50 g , determine the work done in slowing down the bullet and the resistive force offered by the plank.

- (c) A ball of mass 2 kg slides on a frictionless surface as shown in the diagram below:



Determine:

- Potential energy at point O, A and B.
- Gain in kinetic energy and velocity at A.
- Velocity at B.

Answer

- (a) Work done is equal to change in energy.

$$\begin{aligned} \text{(b)} \quad \text{Initial KE} &= \frac{1}{2} mv^2 \\ &= \frac{1}{2} \times (50 \times 10^{-3}) \times (100)^2 \\ &= 2.5 \times 10^2 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{Final KE} &= \frac{1}{2} \times 50 \times 10^{-2} \times (80)^2 \\ &= \frac{1}{2} \times 5 \times 10^{-2} \times 64 \times 10^2 \\ &= 160 \text{ J} \end{aligned}$$

ΔKE = resistive work done

$$= (250 - 160)\text{J}$$

$$= 90 \text{ J}$$

Resistive \times thickness of force (F) = 90
the plank (s)

$$F = \frac{90}{0.5}$$

$$= 180 \text{ N}$$

(c) (i) Potential energy at O is;

$$mgh = 2 \times 10 \times 3$$

$$= 60 \text{ J}$$

Potential energy at A;

$$mgh = 2 \times 10 \times 1.8$$

$$= 36 \text{ J}$$

Potential Energy at B;

$$mgh = 2 \times 10 \times 0$$

$$= 0 \text{ J}$$

(ii) Gain in kinetic = loss in potential
energy at A energy from O
to A

$$= mg(\Delta h)$$

$$= 2 \times 10 (3 - 1.8)$$

$$= 2 \times 10 \times 1.2$$

$$= 24 \text{ J}$$

$$\text{KE} = 24 \text{ J}$$

$$24 = \frac{1}{2} mv^2$$

$$\therefore v^2 = \frac{48}{2}$$

$$= 24$$

$$v = \sqrt{24}$$

$$= 4.899 \text{ ms}^{-1}$$

(iii) Loss in potential = gain in kinetic
energy from O to B energy

$$\text{KE} = 2 \times 10 \times 3$$

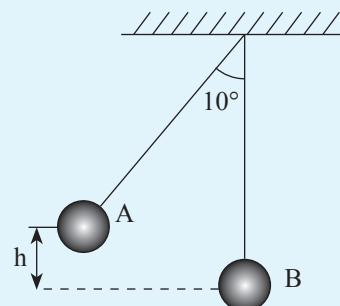
$$= \frac{1}{2} \times 2 \times v^2$$

$$v^2 = 60$$

$$v = \sqrt{60}$$

$$= 7.746 \text{ ms}^{-1}$$

7. A student suspended small mass of 20 g on a string of length 1.5 m. She then displaced the mass such that the string made 10° to the vertical as shown in the diagram below.



(a) Determine the:

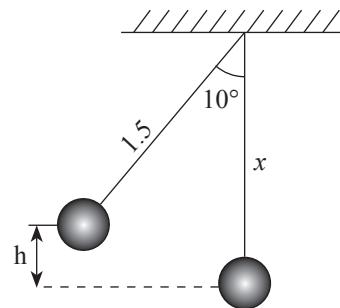
(i) Vertical displacement h through which the stone is displaced.

(ii) Potential Energy gained at A.

(iii) Maximum velocity by which the ball passed point B when released freely from A.

(b) On the same axes, sketch a graph of kinetic energy and potential energy against time for two oscillations starting from A.

Answer



$$(i) \cos 10^\circ = \frac{x}{1.5}$$

$$x = 1.5 \cos 10$$

$$h = 1.5 - 1.5 \cos 10$$

$$= 0.0228 \text{ m}$$

$$(ii) \text{ Potential energy} = mgh$$

$$= (20 \times 10^{-3}) \times 10 \times 0.0228$$

$$= 4.56 \times 10^{-3} \text{ J}$$

$$(iii) \text{ Loss in potential energy} = \text{gain in kinetic energy}$$

$$\text{KE max} = \frac{1}{2} mv^2$$

At B, all the PE is lost and converted to KE.

$$4.56 \times 10^{-3} = \frac{1}{2} \times 20 \times 10^{-3} \times v^2$$

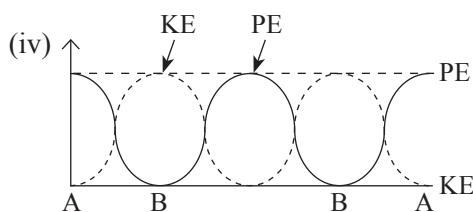
$$v = \sqrt{4.56 \times 10^{-3}}$$

$$v = 0.675 \text{ ms}^{-1}$$

$$\text{Alternatively, } v = \sqrt{2gh}$$

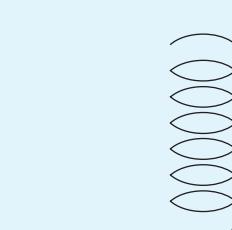
$$= \sqrt{2 \times 10 \times 0.0228}$$

$$v = 0.675 \text{ ms}^{-1}$$



8. A student releases a block of mass $m = 0.5 \text{ kg}$ from a height of 4 m . The block falls on a spring of length 20 cm and momentarily compresses it to a length of 18.4 cm .

Block \longrightarrow 0.5 kg



Calculate the:

- Initial PE of the block.
- KE and velocity of the block just before making contact with the spring.
- Work done in compressing the spring, if the spring constant is 100 Nm^{-1} .
- Energy that could have been converted to thermal and sound energy.

Answer

$$(a) \text{ Initial PE of the block} = 0.5 \times 4 \times 10 \\ = 20 \text{ J}$$

$$(b) \text{ KE} = \text{Loss in PE}$$

$$= 0.5 \times 10 \times (4 - 0.2) \\ = 0.5 \times 10 \times 3.8 \\ = 19 \text{ J}$$

$$(c) \text{ Velocity} = \sqrt{2gh} \\ = \sqrt{2 \times 10 \times 3.8} \\ = \sqrt{76} \\ = 8.718 \text{ ms}^{-1}$$

$$\text{Work done} = \frac{1}{2} ke^2 \\ = \frac{1}{2} \times 100 (0.2 - 0.184)^2 \\ = \frac{1}{2} \times 100 \times (0.016)^2 \\ = \frac{1}{2} \times 100 \times 2.56 \times 10^{-4} \\ = 0.0128 \text{ J}$$

- (d) Energy converted to other form, for example, thermal and sound.

$$E = 19 - 0.0128$$

$$= 18.9872 \text{ J}$$

$$= 60 \times 10 \times (0.25 \times 80)$$

$$= 1.2 \times 10^4 \text{ J}$$

9. (a) (i) Define the term power, as used in machines, and state its SI unit.

(ii) Show that power can be expressed as $P = F \times v$, where F is force and the v speed or velocity.

- (b) A student of mass 60 kg climbs 80 steps in 10 seconds. If each step is 25 cm high, determine the:
- (i) work done in climbing the steps.
 - (ii) power developed by the student.

$$\text{(ii) Power} = \frac{1.2 \times 10^4}{10} \text{ J}$$

$$= 1.2 \times 10^3$$

$$= 1200 \text{ W}$$

10. A 1 000 kg van accelerates from 0 ms^{-1} to 20 ms^{-1} in 10 seconds. Determine the:
- (i) change in KE.
 - (ii) average power.

Answer

$$\begin{aligned} \text{(i) } \Delta KE &= \frac{1}{2} m (v^2 - u^2) \\ &= \frac{1}{2} \times 1000 (20^2 - 0^2) \\ &= \frac{1}{2} \times 10^3 \times 400 \\ &= 2 \times 10^5 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{(ii) } \Delta KE &= \text{work done} \\ P &= \frac{2 \times 10^5}{10} \\ &= 2 \times 10^4 \text{ W} \end{aligned}$$

Alternatively,

$$\begin{aligned} a &= \frac{v - u}{t} \\ &= \frac{20}{10} \\ &= 2 \text{ ms}^{-2} \end{aligned}$$

$$\begin{aligned} F &= ma \\ &= 2 \times 10^3 \text{ N} \end{aligned}$$

$$\begin{aligned} s &= ut + \frac{1}{2} at^2 \\ s &= 0 \times 10 + \frac{1}{2} \times 2 \times 10^2 \\ &= 100 \text{ m} \end{aligned}$$

Answer

- (a) (i) Power is the rate at which work is done, i.e.,

$$\text{Power} = \frac{\text{work done}}{\text{time taken}}$$

or

$$\text{Power} = \frac{\text{energy expended}}{\text{time taken}}$$

The SI unit is joules per second or watts.

$$\text{(ii) Since power} = \frac{\text{work done}}{\text{time taken}}$$

and work done = force \times distance

$$\text{Then } P = F \times \frac{s}{t}$$

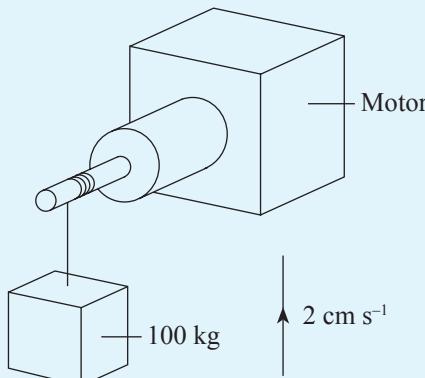
$$\text{but } v = \frac{s}{t}$$

$$\text{Therefore, } P = Fv$$

- (b) (i) Work done = mgh

$$\begin{aligned}\text{Work done} &= F \times s \\ &= 2 \times 10^5 \text{ J} \\ P &= \frac{2 \times 10^5}{10} \\ &= 2 \times 10^4 \text{ W}\end{aligned}$$

11. A motor lifts a mass of 100 kg at a constant speed of 2 cm s^{-1} , as below.



Calculate:

- (a) the upward force exerted by the motor.
- (b) the power developed by the motor.
- (c) work done by the motor per second.

Answer

$$\begin{aligned}(a) \quad F &= mg \\ &= 100 \times 10 \\ &= 1000 \text{ N} \\ (b) \quad P &= F \times v \\ &= 10^3 \times 2 \times 10^{-2} \\ &= 20 \text{ W} \\ (c) \quad \text{Work done} &= F \times s \\ &= 1000 \times 2 \times 10^{-2} \\ &= 20 \text{ J}\end{aligned}$$

Alternatively,

$$P = \frac{W}{t}$$

$$\begin{aligned}w &= P \times t \\ &= 20 \times 1 \\ &= 20 \text{ J}\end{aligned}$$

12. (a) Outline what is meant by each of the following:
- (i) Machine.
 - (ii) Work input of a machine.
 - (iii) Work output of a machine.
 - (iv) Mechanical advantage.
 - (v) Velocity ratio.
 - (vi) Efficiency.
- (b) Show that mechanical advantage equals velocity ratio for a machine that is 100% efficient.

Answer

- (a) (i) A machine is an implement that makes work easier. When a small force (effort) is applied to it, it produces a much larger force that moves or overcomes a larger resistive force (load).
- (ii) Work input (W_i) is the product of effort and distance moved by the effort, i.e.,
- $$W_i = \text{effort} \times \text{effort distance}$$
- (iii) Work output (W_o) is the product of load and the distance moved by the load. This is sometimes referred to as useful work.
- $$W_o = \text{load} \times \text{load distance (Joules)}$$
- (iv) Mechanical advantage (MA) is the ratio of the load to the effort, i.e,
- $$MA = \frac{\text{load}}{\text{effort}}$$

MA has no units and gives an indication of the usefulness of a machine. If MA is greater than one,

then a small force is used to overcome a bigger load.

- (v) Velocity ratio (VR) is the ratio of the distance moved by the effort (S_E) to the distance moved by the load (S_L),

$$\text{i.e., VR} = \frac{S_E}{S_L}$$

VR has no units.

- (vi) Efficiency (η) is the ratio of work output to work input, expressed as a percentage.

$$\text{i.e., } \eta = \frac{\text{work output}}{\text{work input}} \times 100\% \\ = \frac{W_o}{W_i} \times 100\%$$

For a machine that is 100% efficient, $W_o = W_i$

$$\text{But MA} = \frac{L}{E}, \text{ and VR} = \frac{S_E}{S_L}$$

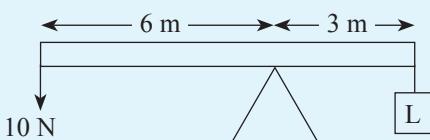
$$\text{Thus, } L \times S_L = E \times S_E$$

$$\text{So, } \frac{L}{E} = \frac{S_E}{S_L}$$

$$\text{MA} = \text{VR}$$

13. (a) Express efficiency in terms of MA and VR.

- (b) The diagram shows a lever in a balanced state:



Assuming no friction occurs, calculate the:

- (i) value of L.
- (ii) velocity ratio.

(iii) mechanical advantage.

(iv) efficiency.

Answer

$$(a) \eta = \frac{\text{work output}}{\text{work input}} \times 100\% \\ = \frac{L \times S_L}{E \times S_E} \times 100\%$$

$$\text{But MA} = \frac{L}{E} \text{ and VR} = \frac{S_E}{S_L}$$

$$\text{Hence } \eta = \frac{\text{MA}}{\text{VR}} \times 100\%$$

- (b) (i) From the principle of moments,

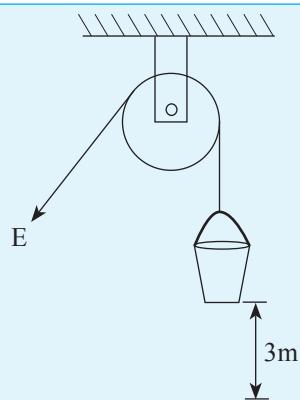
$$10 \times 6 = 3 \times L \\ L = \frac{10 \times 6}{3} \\ = 20 \text{ N}$$

$$(ii) \text{ VR} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}} \\ = \frac{6}{3} \\ = 2$$

$$(iii) \text{ MA} = \frac{L}{E} \\ = \frac{20}{10} \\ = 2$$

$$(iv) \eta = \frac{\text{MA}}{\text{VR}} \times 100\% \\ = \frac{2}{2} \times 100\% \\ = 100\%$$

14. A man uses the pulley shown in the following diagram to lift a bucket of 100 N through a distance of 3 m.



- (a) (i) State the function of the pulley.
(ii) If friction force is negligible, what is the value of effort E?
- (b) (i) If a friction force of 10 N is present, what would be the value of E?
(ii) What is the useful work done in raising the bucket through the height of 3 m?
(iii) What is the work done by effort?
(iv) What is the efficiency of this machine?
(v) What kind of energy is gained by the bucket?

Answer

- (a) (i) To change the direction of the effort in order to lift a load.
(ii) If friction is negligible, $E = 100 \text{ N}$.
- (b) (i) The value of $E = 100 + 10$
 $= 110 \text{ N}$.
(ii) Work done $= mgh$
 $= 100 \times 3$
 $= 300 \text{ J}$
(iii) The effort moves through a distance 3 m.

$$\text{Work input} = E \times S_E$$

$$= 110 \times 3$$

$$= 330 \text{ J.}$$

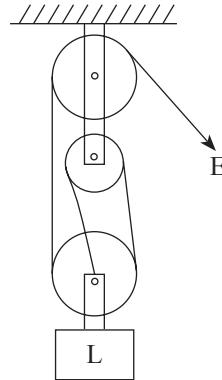
$$\begin{aligned} \text{(iv) Efficiency} &= \frac{W_o}{W_i} \times 100\% \\ &= \frac{300}{330} \times 100\% \\ &= 90.9\% \end{aligned}$$

(v) Potential energy.

15. A gold miner uses a pulley system of velocity ratio 3 to raise a weight of 100 N through a height 2 m in 2.5 s.
- (a) Draw and explain the arrangement.
(b) If he uses an effort of 50 N, determine the:
(i) distance moved by the effort.
(ii) work done by the effort.
(iii) mechanical advantage and efficiency of the system.
(iv) PE gained, and average power exerted.

Answer

(a)



Two pulleys are put in the fixed block and one in the movable section to minimise as much as possible the weight of the pulleys being part of load.

(b) (i) Velocity ratio = $\frac{S_E}{S_L}$,

$$3 = \frac{S_E}{2}$$

Thus, $S_E = 6$ m

(ii) Work done by effort = $W \times S_E$
 $= 50 \times 6$
 $= 300$ J

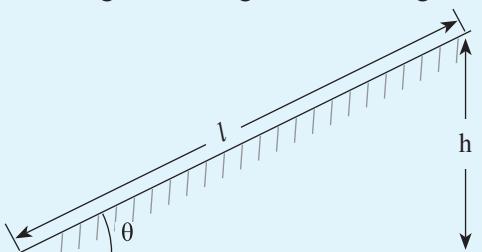
(iii) $MA = \frac{L}{E} = \frac{100}{50} = 2$

$$\begin{aligned}\eta &= \frac{MA}{VR} \times 100\% \\ &= \frac{2}{3} \times 100\% \\ &= 0.667 \times 100 \\ &= 66.67\%\end{aligned}$$

(iv) $PE = mgh$
 $= 100 \times 2$
 $= 200$ J

$$\begin{aligned}\text{Power} &= \frac{mgh}{t} \\ &= \frac{200}{2.5} \\ &= 80 \text{ W}\end{aligned}$$

16. The figure below shows an inclined plane of length l and height h above the ground:



- (a) Determine the velocity ratio and mechanical advantage in terms of $\sin \theta$ (assume no friction occurs).
(b) A barrel is rolled up a ramp 6 m long. The barrel weighs 400 N and is displaced through a height of 1.5 m.

If a force of 120 N is applied parallel to the inclined plane, calculate the:

- (i) useful work done.
- (ii) work input.
- (iii) work needed to overcome friction.
- (iv) efficiency

Answer

(a) Velocity Ratio = $\frac{1}{h}$ but $\sin \theta = \frac{h}{l}$

$$\text{Thus } VR = \frac{1}{\sin \theta}$$

If there is no friction, $\eta = 100\%$

$$\text{Thus from } \eta = \frac{MA}{VR} \times 100\%$$

$$MA = VR = \frac{1}{\sin \theta}$$

(b) (i) Useful work = mgh

$$\begin{aligned}&= 40 \times 10 \times 1.5 \\ &= 6.0 \times 10^2 \text{ J} \\ &= 600 \text{ J}\end{aligned}$$

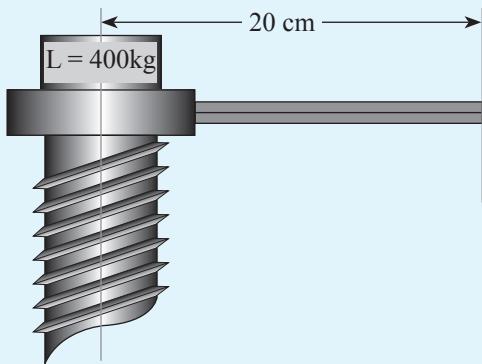
(ii) Work input = 120×6
 $= 720 \text{ J}$

(iii) Work needed to overcome friction
 $= 720 - 600$
 $= 120 \text{ J}$

(iv) Efficiency

$$\begin{aligned}\eta &= \frac{\text{useful work done}}{\text{work done by effort}} \times 100\% \\ &= \frac{600}{720} \times 100\% \\ &= 83.33\%\end{aligned}$$

17. The following diagram shows a handle of length 20 cm rotating a screw of pitch 20 mm. The load L is 400 kg and the efficiency is 40%.



- (a) (i) What do you understand by the pitch of a screw?
(ii) Determine an expression for velocity ratio of a screw of pitch p .
(b) Work out the:
(i) velocity ratio.
(ii) effort E .

Answer

(a) (i) The pitch of a screw is the distance between two adjacent threads. If a screw turns through one revolution, it advances (or retreats) through a distance equivalent to its pitch.

(ii) $VR = \frac{S_E}{S_L} = \frac{2\pi R}{p}$, where R is the perpendicular distance between the line of action of the effort and the axis of rotation of the screw and p the pitch.

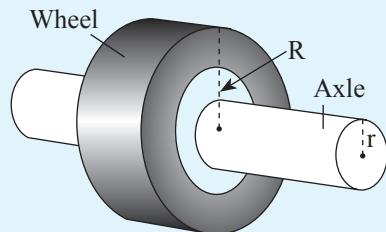
$$\begin{aligned}(b) (i) \text{ Velocity ratio } &= \frac{2\pi R}{p} \\ &= \frac{2 \times 3.142 \times 20}{20 \times 10^{-1}} \\ &= 20 \times 3.142 \\ &= 62.84\end{aligned}$$

$$(ii) \eta = \frac{MA}{VR} \times 100\%$$

$$0.4 = \frac{L}{E} \times \frac{1}{62.84}$$

$$\begin{aligned}E &= \frac{4000}{0.4 \times 62.84} \\ &= 159.2 \text{ N}\end{aligned}$$

18. (a) In the diagram below, the radius of the wheel is R and that of the axle r .



Obtain an expression for the velocity ratio of the system.

- (b) If $L = 300 \text{ N}$, $E = 30 \text{ N}$, $R = 80 \text{ cm}$ and $r = 4 \text{ cm}$, determine the velocity ratio, mechanical advantage and efficiency.

Answer

(a) For one revolution, $S_L = 2\pi R$

$$S_E = 2\pi R$$

$$\text{Velocity ratio} = \frac{2\pi R}{2\pi r} = \frac{R}{r}$$

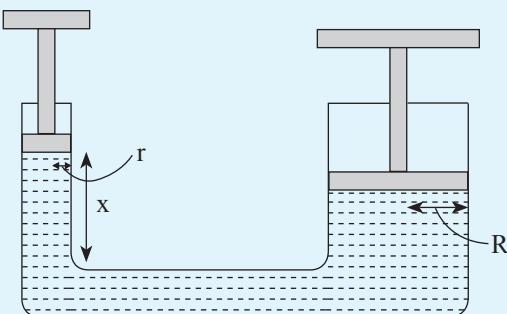
$$\begin{aligned}(b) \text{ Velocity ratio} &= \frac{80}{4} \\ &= 20\end{aligned}$$

Mechanical advantage

$$\begin{aligned}\frac{L}{E} &= \frac{300}{30} \\ &= 10\end{aligned}$$

$$\begin{aligned}\eta &= \frac{\text{mechanical advantage}}{\text{velocity ratio}} \times 100\% \\ &= \frac{10}{20} \times 100\% \\ &= 50\%\end{aligned}$$

19. In the hydraulic lift shown below, the small piston is of radius r while the big piston is of radius R .



- (a) If the small piston is pushed down through a distance x cm, determine the volume of the liquid displaced downwards.
- (b) Considering that the liquid is incompressible and that all the volume of liquid expelled by the small piston moves the large piston a distance y cm, determine the velocity ratio of the hydraulic lift.
- (c) A hydraulic system has a velocity ratio of 9. The radius of the small piston is 2 cm and it travels a distance of 10 cm per stroke. Determine:
- the radius R of the big piston.
 - distance moved by the big piston in two strokes.

Answer

(a) Volume displaced = $\pi r x^2$

(b) Volume moved = $\pi R^2 y$
by the big piston

But $\pi r^2 x = \pi R^2 y$

$$\therefore \frac{x}{y} = \frac{R^2}{r^2}$$

Since velocity ratio = $\frac{x}{y}$,

the velocity ratio = $\frac{R^2}{r^2} = \frac{R^2}{4}$

(c) (i) $9 = \frac{R^2}{r^2}$

$$R^2 = 36$$

$$R = 6 \text{ cm}$$

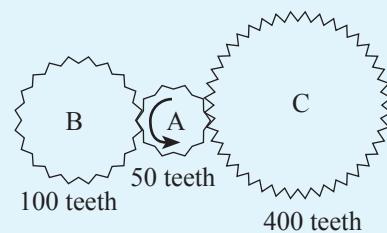
- (ii) Distance moved by the small piston in 2 strokes is $2 \times 10 = 20 \text{ cm}$

$$VR = 9 = \frac{20}{y}$$

$$y = \frac{20}{9}$$

$$= 2.222 \text{ cm}$$

20. The diagram below shows a system of gears A, B and C. A is the driving wheel, rotating in anti-clockwise direction.



- (a) In which direction does wheel C rotate?
 (b) What is the VR between A and B, and between A and C?
 (c) What is the VR of the system?

Answer

(i) C rotates in clockwise direction.

(ii) Between A and B

$$VR = \frac{\text{number of teeth on the driven wheel}}{\text{number of teeth on the driving wheel}}$$

$$= \frac{100}{50} \\ = 2$$

Between A and C;

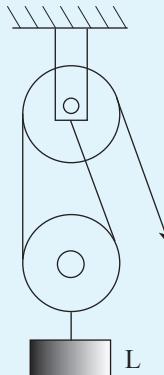
$$VR = \frac{400}{50} \\ = 8$$

(iii) VR of system is;

$$\begin{aligned}(\text{VR})_{AB} \times (\text{VR})_{AC} &= 2 \times 8 \\&= 16\end{aligned}$$

Revision Exercise 22

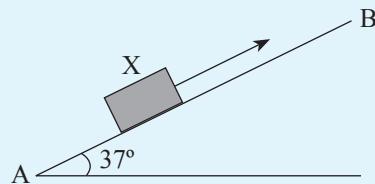
1. An elevator lifts grain 3 kg through a distance of 15 m and discharges it at 2 ms^{-1} . Determine the:
 - (a) PE per second gained by the grain.
 - (b) KE per second of the ejected grain.
 - (c) Power output of the grain elevator.
2. A worker uses pulleys as shown below to lift a load of 200 N.



- (a) What is efficiency and velocity ratio if both pulleys have negligible weight, are frictionless and the cord is light?
 - (b) What is the new value of efficiency and mechanical advantage if the weight of pulley is 10 N (friction still ignored).
3. A boy made a catapult using two rubber bands, each of stretching constant of 5 Nm^{-1} . He held a stone of mass 20 g at

one end and stretched the bands by 10 cm. Determine the stretching constant of the combined bands and the velocity at which the stone is released from the catapult when the stretching force is removed.

4. A crate X is to be pulled up a ramp inclined at 37° from point A to B as in the figure below:



If efficiency is 80%, calculate the:

- (a) mechanical advantage.
 - (b) velocity ratio.
 - (c) power required if the crate has a mass of 80 kg and it takes 50 s to pull the crate from A to B.
5. A box of mass 60 kg is lifted by a wheel and axle arrangement. The wheel has a diameter of 500 mm while the axle has a diameter of 100 mm. If a force of 200 N is applied on the wheel, determine the:
 - (a) mechanical advantage.
 - (b) velocity ratio.
 - (c) efficiency.
6. A car jack has a pitch of 2 mm and handle of 50 cm. A force of 200 N when applied lifts a load of 20000 N. Determine the:
 - (a) mechanical advantage.
 - (b) velocity ratio.
 - (c) efficiency.

**UNIT
23**

Current Electricity

Key Points

- Cells are responsible for flow of charge in a simple electric circuit.
- In a series arrangement, the components are connected to form a single path so that the same current flows through each of them.
- In a parallel arrangement, the components are connected such that they form alternative paths to flow of current.

Revision Questions 23

- (a) Define potential difference and state its SI units.
(b) Explain why ammeters are always connected in series and voltmeters in parallel with the components in electrical circuits.

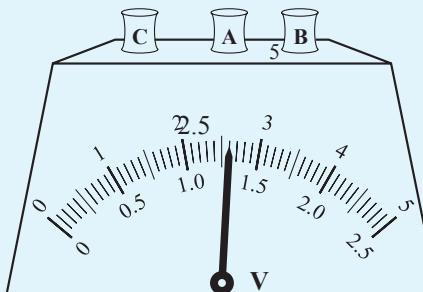
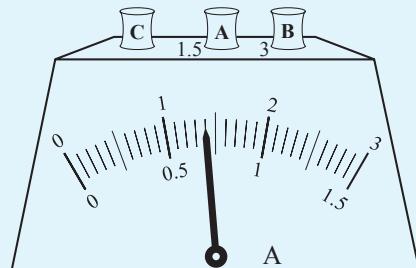
Answer

- (a) Potential difference is energy per unit charge flowing between two points in a circuit. Its SI unit is the volt.
- (b) An ammeter is used for measuring current flowing through components in a circuit, while a voltmeter measures potential difference across components in a circuit. An ammeter is connected in series with other electrical components in a circuit. It is, therefore, designed to have a negligible resistance to flow of current.

A voltmeter is used for measuring voltage across two points in a circuit and is always connected in parallel to a

component (for example, bulb) across which voltage is to be measured. It is designed to have high resistance so that it draws negligible current.

2. A student connected an ammeter and voltmeter in a circuit and obtained the results as shown in the meters below:



Determine the reading on each of the instruments if he used:

- the common terminal C and terminal A for the ammeter.
- the common terminal C and terminal B for the voltmeter.

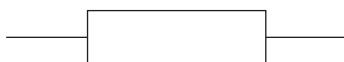
Answer

- Current $I = 0.7 \text{ A}$, on the $0 - 1.5 \text{ A}$ scale.
- Voltage $V = 2.6 \text{ V}$, on the $0 - 5 \text{ V}$ scale.

3. (a) Define electrical resistance and state its SI unit. Sketch the symbol for electrical resistance.
- (b) (i) State Ohm's law.
(ii) With the help of a diagram, describe an experiment to verify Ohm's law.
- (c) What current flows through an $80\ \Omega$ lamp operating on 240 V supply?

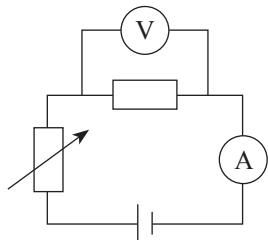
Answer

- (a) Electrical resistance is the opposition to flow of current in a material. The SI unit is the Ohm (Ω). Resistance is represented in an electric circuit as below.

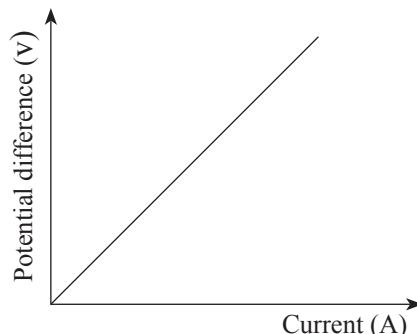


- (b) The current flowing through a conductor is directly proportional to the potential difference across its ends provided temperature and other physical conditions remain constant.

The circuit shown below can be used to verify Ohm's law.



- The current is increased in steps by varying the resistance using the variable resistor.
- Readings of the ammeter and the voltmeter are taken and the results tabulated.
- A graph of V against I is plotted.
- The graph is found to be a straight line through the origin.



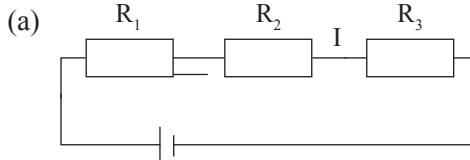
$$\text{Gradient} = \frac{\Delta V}{\Delta I} = R$$

(c) $V = IR$

$$I = \frac{V}{R} = \frac{240}{80} = 3\text{A}$$

4. (a) Draw a circuit diagram comprising a cell and three resistors R_1 , R_2 and R_3 connected in series.
- (b) When resistors are in series, the same current flows through them. State the relationship between the voltage drop across the resistances in a circuit and the total voltage.
- (c) Show that the total resistance R_T of the three resistors connected in series is given by;
- $$R_T = R_1 + R_2 + R_3$$

Answer



- (b) If V_1 is the voltage across R_1 , V_2 voltage across R_2 and V_3 voltage across R_3 , then;
 $V_T = V_1 + V_2 + V_3$
Total voltage equals the sum of individual voltage drops across the resistances.

(c) $V_T = V_1 + V_2 + V_3$

But

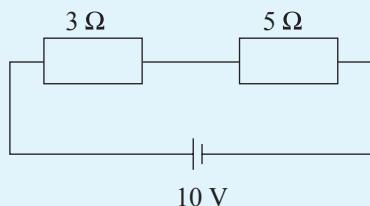
$$V_T = IR_T, V_1 = IR_1, V_2 = IR_2 \text{ and } V_3 = IR_3$$

$$\text{So, } IR_T = IR_1 + IR_2 + IR_3$$

$$IR_T = I(R_1 + R_2 + R_3)$$

$$\text{Hence, } R_T = R_1 + R_2 + R_3$$

5. The figure below shows a circuit comprising two resistors and a power source of terminal voltage 10 V.



Determine the:

- (a) total resistance.
- (b) total current.
- (c) voltage across each resistor.

Answer

$$(a) R_T = 3 + 5 \\ = 8 \Omega$$

$$(b) I_T = \frac{V_T}{R_T} \\ = \frac{10}{8} \\ = 1.25 \text{ A}$$

$$(c) V_{3\Omega} = I \times R \\ = 1.25 \times 3 \\ = 3.75 \text{ V}$$

$$V_{5\Omega} = 1.25 \times 5 \\ = 6.25 \text{ V}$$

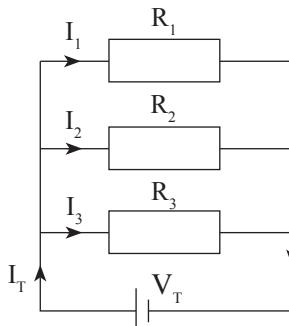
Note: $V_{3\Omega} + V_{5\Omega} = 10 \text{ V}$

6. (a) Draw a circuit showing a cell and three resistors R_1 , R_2 and R_3 connected in parallel to the cell.

- (b) If the current through R_1 is I_1 , that through R_2 is I_2 , that through R_3 is I_3 and total current is I_T , show that $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$, where R_T is the effective resistance.

Answer

- (a)



$$(b) I_T = I_1 + I_2 + I_3$$

$$(c) I_T = \frac{V_T}{R_T} \quad I_1 = \frac{V_T}{R_1} \quad I_2 = \frac{V_T}{R_2} \text{ and } I_3 = \frac{V_T}{R_3}$$

$$\text{Thus, } \frac{V_T}{R_T} = \frac{V_T}{R_1} + \frac{V_T}{R_2} + \frac{V_T}{R_3}$$

Dividing through by V_T

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

7. (a) Three resistors of 3Ω , 6Ω and 9Ω are connected in parallel. Determine the total resistance.
- (b) If the resistances above are connected to an 18 V supply, determine the current through each resistor and the total current.

Answer

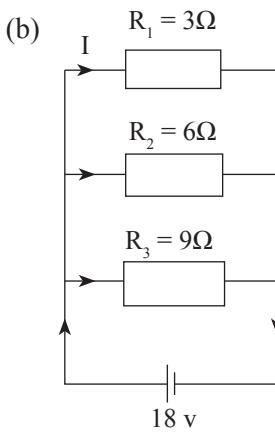
$$(a) \frac{1}{R_T} = \frac{1}{3} + \frac{1}{6} + \frac{1}{9}$$

$$\frac{1}{R_T} = \frac{6+3+2}{18}$$

$$= \frac{11}{18}$$

$$R_T = \frac{18}{11}$$

$$= 1.6436\Omega$$



$$I_{3\Omega} = \frac{18}{3} = 6\text{ A}$$

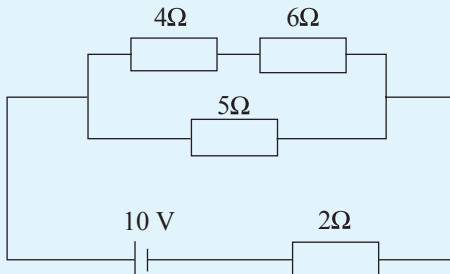
$$I_{6\Omega} = \frac{18}{6} = 3\text{ A}$$

$$I_{9\Omega} = \frac{18}{9} = 2\text{ A}$$

$$I_T = 6 + 3 + 2$$

$$= 11\text{ A}$$

8. The diagram below shows four resistors connected to a 10 V power supply:



Determine the:

- (a) total resistance.
- (b) total current.
- (c) voltage across the 2 Ω, 5 Ω and 4 Ω resistors.

Answer

- (a) Effective resistance of the 4 Ω and 6 Ω resistors in series is $6 + 4 = 10\Omega$

Effective resistance of the 4 Ω, 6 Ω and 6 Ω resistors in series is;

$$\begin{aligned}\frac{1}{R} &= \frac{1}{10} + \frac{1}{5} \\ &= \frac{3}{10} \\ \Rightarrow R &= \frac{10}{3} \\ &= 3.333\Omega\end{aligned}$$

$$\begin{aligned}\text{So total resistance } R_T &= 3.333 + 2 \\ &= 5.333\Omega\end{aligned}$$

$$\begin{aligned}\text{(b) Total current } &= \frac{10}{5.333} \\ &= 1.875\text{ A}\end{aligned}$$

$$\begin{aligned}\text{(c) Voltage across } 2\Omega \text{ resistor} &= 1.875 \times 2 \\ &= 3.75\text{ V}\end{aligned}$$

Voltage across the 5 Ω resistor;

$$10 - 3.75 = 6.25\text{ V}$$

$$\begin{aligned}\text{Current through } 5\Omega \text{ resistance} &= \frac{6.25}{5} \\ &= 1.250\text{ A}\end{aligned}$$

$$\begin{aligned}\text{Current through } 4\Omega \text{ resistor} &= 1.875 - 1.250 \\ &= 0.625\text{ A}\end{aligned}$$

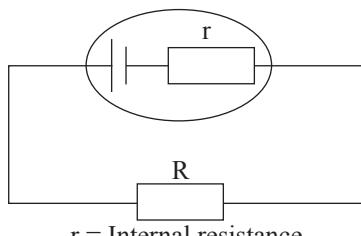
$$\begin{aligned}\text{Voltage across } 4\Omega \text{ resistor} &= 0.625 \times 4 \\ &= 2.50\text{ V}\end{aligned}$$

9. (a) (i) Define EMF of a cell.
(ii) Explain internal resistance of a cell.
(iii) What effect does internal resistance have on terminal voltage and emf of a cell?
(b) A cell has an EMF of 6 V and internal resistance of $1\ \Omega$. Determine the terminal voltage if it is delivering a current of 3 A.

Answer

- (a) (i) EMF of a cell is the energy converted to electrical form by the cell per unit charge passing through it. EMF of a cell is also defined as terminal voltage when it is in an open circuit.

(ii) This is the resistance a cell offers to flow of an electric charge through it. The resistance is caused by the components of the cell. Thus, in a circuit a cell behaves as a source of EMF in series with its internal resistance, see the figure below.



r = Internal resistance

- (iii) When no current is being drawn from a cell (cell in open circuit), there is no voltage drop across its internal resistance. Hence, the terminal voltage of the cell V is equal to its EMF. If, however, the cell is connected to an external circuit of, say R resistance, and a current I flows, then a voltage drop across the internal resistance (lost volts) is experienced. This is given by Ir ,

where r is the internal resistance.

Terminal voltage $V = IR$

Thus,

Terminal voltage = EMF – lost volts

$$V = E - Ir$$

Thus, if I increases, there is a corresponding drop in terminal voltage.

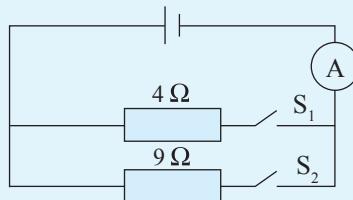
$$(b) \quad V = E - Ir$$

$$V = 6 - (3 \times 1)$$

$$= 3V$$

10. (a) A new dry cell (1.5 V) delivers a current of 1.5 A when short-circuited. Determine internal resistance of the cell.

(b) In the circuit below, when the s_1 is closed and s_2 open, the ammeter reads 0.6 A. When s_2 is closed and s_1 open, it reads 0.3 A.



Determine E and r.

Answer

$$(a) \quad R = \frac{V}{I} = \frac{1.5}{1.5} = 1 \Omega$$

(b) $E \equiv IR + Ir$

When s_1 is closed and s_2 open, we have

When s_1 is open and s_2 is closed

$$E = 2.4 + 0.6r \quad \dots \dots \dots (3)$$

Subtracting (4) from (3);

$$0 = -0.3 + 0.3r$$

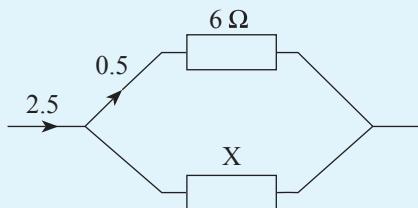
$$r = 1 \Omega$$

$$E = (2.4 + 0.6) \times 1$$

$$= 3 \text{ V}$$

Revision Exercise 23

- In the figure shown below, the total current is 2.5 A and current through the 6Ω resistor is 0.5 A.



Determine:

- current through resistor X.
- value of X.

- You are provided with a variable resistor, a voltmeter, an ammeter, a cell and connecting wires. With the help of a circuit diagram, describe an experiment that you would carry out to determine the EMF of the cell and its internal resistance.
- (a) A cell has an EMF of 1.5 V and internal resistance 1Ω . Determine the combined EMF and internal

resistance if two such cells are connected in:

(i) series

(ii) parallel

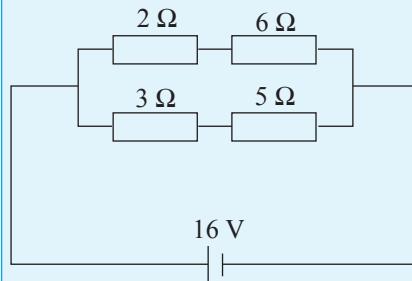
- Three such cells as the one in part (a) above are connected in series with an external resistance of 12Ω . Determine the:

(i) combined EMF and internal resistance.

(ii) current in the circuit.

(iii) terminal voltage.

- A circuit is connected as below:



Determine the:

- total resistance and total current.
- current through the 2Ω and 3Ω resistors.
- voltage drop across the 6Ω and 5Ω resistors.

UNIT**24****Waves II****Key Points**

- All waves exhibit reflection, refraction, diffraction and interference.
- When a wave undergoes reflection, diffraction and interference, its wavelength remains unchanged, while in refraction, both speed and wavelength change, often resulting to change in direction.
- Waves interfere constructively or destructively, depending on the relative phase.
- Stationary waves do not move through the medium and therefore do not transfer any energy from the source.

Revision Questions 24

1. Describe how the following can be produced in a ripple tank:
 - (a) Plane waves.
 - (b) Circular waves.

Answer

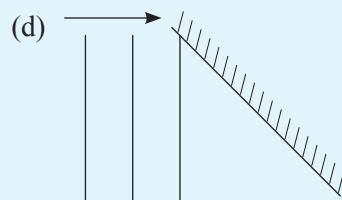
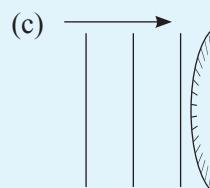
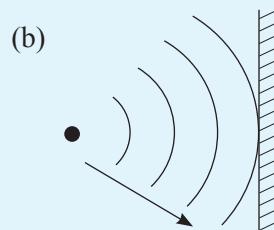
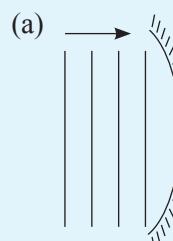
- (a) Plane waves may be produced by using a straight edge as the dipper.
- (b) Circular waves are produced by using a spherical dipper.

2. Define the term wavefront as applied to waves.

Answer

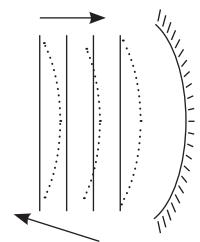
A wavefront is a surface containing all points in a medium that are in phase at a given time as the wave progresses.

3. In each of the figures below, waves are approaching a reflector. Complete the diagrams, indicating at least 3 wavefronts after reflection.

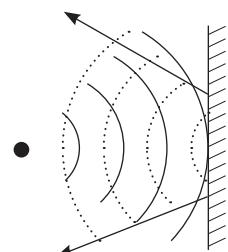


Answers

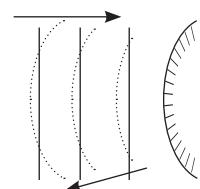
(a)



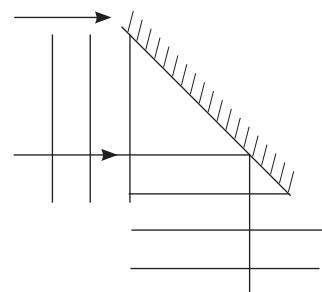
(b)



(c)



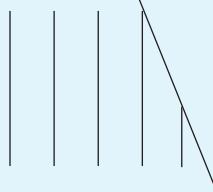
(d)



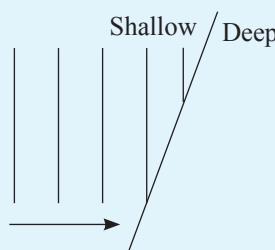
4. (a) Explain what is meant by the term refraction.
 (b) In the figure below, waves are shown crossing from a region of a given depth to one of a different depth in a ripple tank. Indicate in the diagram how the waves proceed as they enter into the second region.

(i)

Deep Shallow



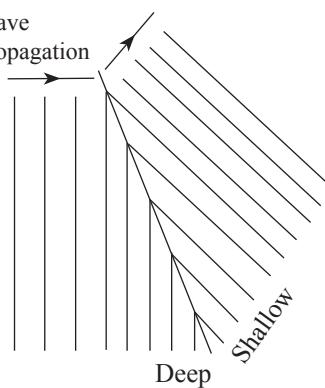
(ii)

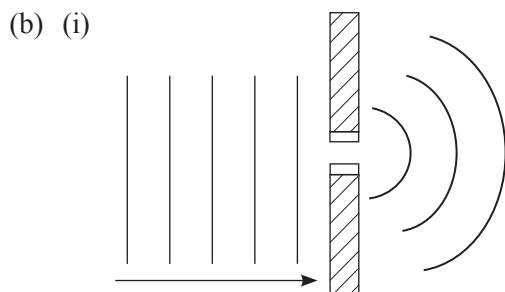
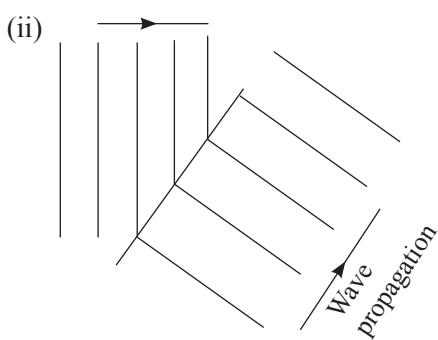


Answer

- (a) Refraction is the change in speed of waves as they pass from one medium to another. In the case of water waves, there is change in speed when they traverse deep to shallow regions, or vice versa.
 (b) Refraction – water waves slow down as they cross from deep to shallow regions. This results in a decrease in wavelength and when the angle of incidence is greater than zero, there is change in direction of propagation, see the figure below.

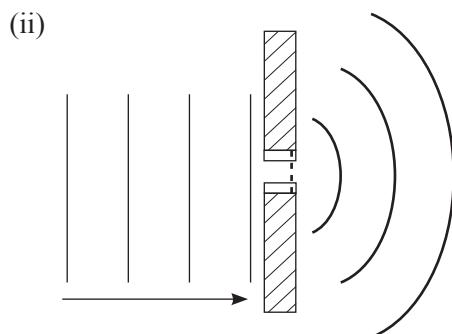
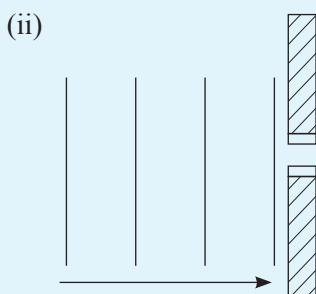
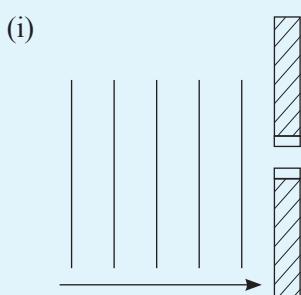
(i) Wave propagation



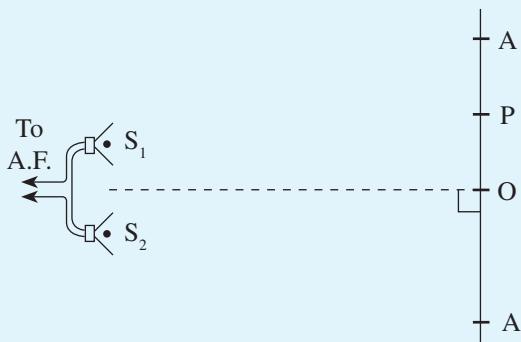


5. (a) State two factors that affect the extent of diffraction.

(b) The figure below shows water waves in a ripple tank just when they are to cross the point where there is a barrier. Show the wavefronts as they cross and after crossing the barrier.



6. In an experiment to study interference in sound waves, two identical loudspeakers are connected to an audio frequency generator so that they act as coherent sources S_1 and S_2 as shown in the figure below.



Answer

- (a) The factors that affect the extent of diffraction are:
- wavelength.
 - size of aperture.

An observer walking several metres ahead and along a line parallel to S_1S_2 identifies points A and A' as the first positions of loud sound on either side after the loud sound at the middle position O between the two sources.

- What is meant by the term coherent sources?
- Name the type of interference occurring at points O, A and A'.
- What name is given to the interference that occurs at point P exactly midway between O and A?
- State in terms of wavelengths the path difference of the waves from the two sources S₁ and S₂ at:
 - O
 - P
 - A

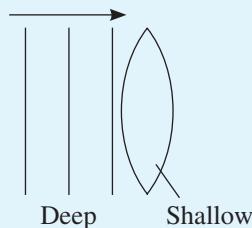
Answer

- Sources of waves are said to be coherent if they have same frequency and constant phase difference between them. For an interference pattern to be observable, the waveforms in addition to being coherent must have same or nearly same amplitudes.
- All the three are points of constructive interference.
- A point P in between two successive points of constructive interference would be a point of destructive interference, giving a soft sound.
- Path difference at points:
 - O – path difference is 0 λ
 - A – path difference is 1 λ
 - P – path difference is $\frac{1}{2} \lambda$

Note: Constructive interference occurs when path difference is a whole number of wavelengths and destructive interference where path difference is $\frac{1}{2}, 1 \frac{1}{2}, 2 \frac{1}{2}$ wavelengths.

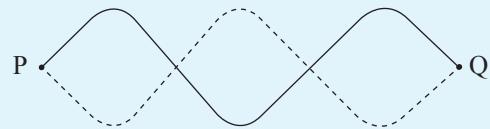
Revision Exercise 24

- The figure below shows plane wave fronts incident on a deep to shallow water region in a ripple tank:



Indicate on the diagram the wavefronts as they cross through and after crossing the region.

- The figure illustrates the formation of a stationary wave in a string vibrating between two fixed points P and Q.



Given that the length PQ is 1.2 m, determine the wavelength.

- Two round dippers S₁ and S₂ in a ripple tank are driven by the same motion to send out circular waves.

S₁ •

S₂ •

- Given that the waves generated have a wavelength of 0.5 cm, draw wavefronts as they come from the sources to illustrate the expected interference pattern.

- (b) In the diagram in (a) above, draw:
- A line joining points of constructive interference.
 - A line joining points of destructive interference.
4. A student studying water ripples observes
- 10 crests spread between two points that are 45 cm apart.
- What is the wavelength of the ripples?
 - If the dipper producing them makes 25 vibrations per second, what is the speed of the wave form?

UNIT**25****Electrostatics II****Key Points**

- Electric field is a region around a charged particle where its influence is exerted.
- Capacitors store electric charge and can be arranged in parallel or in series.

Revision Questions 25

- (a) (i) What is an electric field line?
(ii) State the properties of electric field lines.
(iii) Using appropriate diagrams, distinguish between a weak and a strong uniform field.
(b) Sketch the electric field patterns in the following situations:
 - (i)
 - (ii)
 - (iii)
 - (iv)

Answer

- (a) (i) An electric field line is a line drawn to represent the path that would be taken by a small free positive charge placed in an electric field.

(ii) Electric field lines have the following properties:

- Are directed away from a positive charge, and towards a negative charge.
- Never cross each other.
- Repel each other.
- Do not pass through a conductor.

(iii) A uniform field is where the field patterns are drawn parallel to each other. For a weak field, the lines are apart, compared to a strong field.

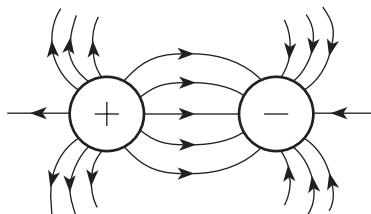


Weak electric field

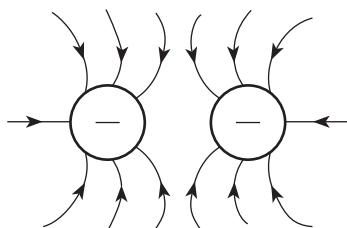


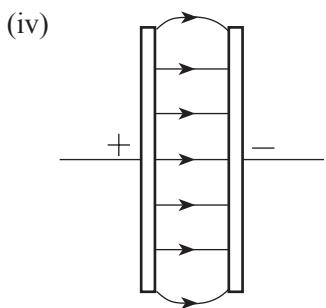
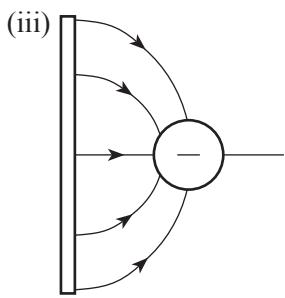
Strong electric field

(b) (i)

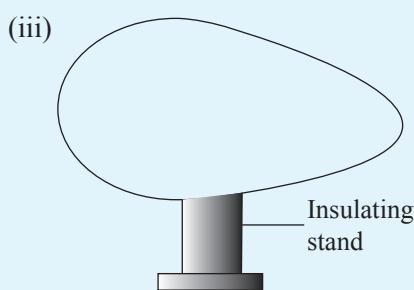
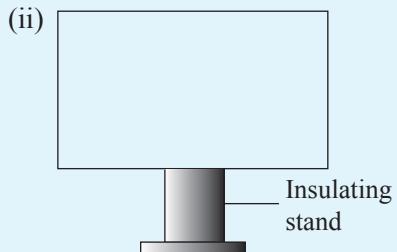
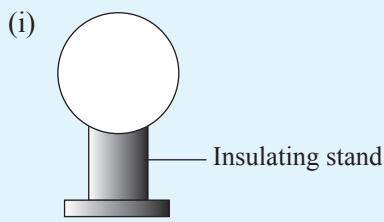


(ii)



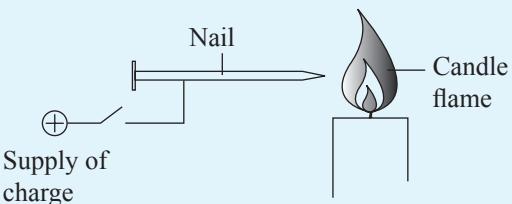


2. (a) The following figures show positively-charged conductors mounted on insulating stands. Indicate the charge distribution on each conductor:



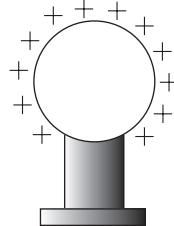
(b) Explain how you would investigate charge distribution in each of the cases in part (a) above.

(c) In the arrangement shown below, when the switch is closed, the candle flame is blown away from the tip of the nail:

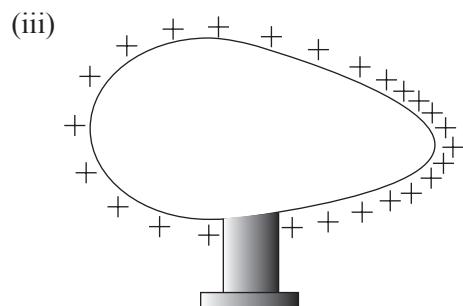
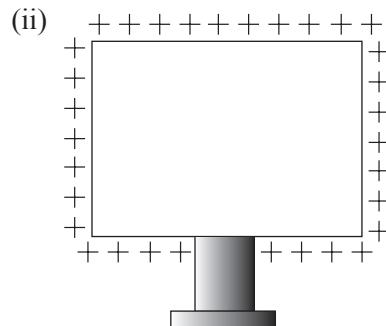


Answer

- (a) (i)

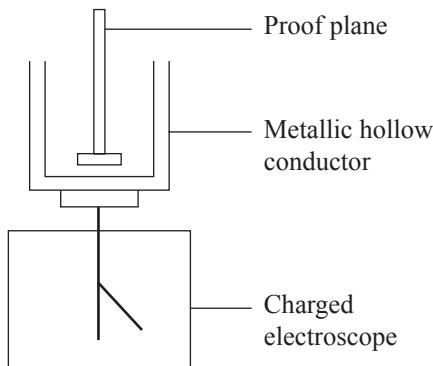


Uniform charge distribution



(b) A proof-plane can be used to touch

various parts of the charged body and then lowered inside a hollow conductor resting an uncharged electroscope.



The divergence of the leaf is noted. The greater the divergence, the more the concentration of charge (high charge density).

- (c) The nail, being sharp-pointed, has a high positive charge concentration at its tip. This high charge density ionises the air around the tip, with the positive ions rapidly moving away from the tip of the nail, blowing the candle flame away.

3. Explain how lightning arrestors work.

Answer

A lightning arrestor comprises thick copper strip with sharp spikes at the top end. It is placed vertically along the height of the structure with the spiked end protruding above the top of the building. The bottom end is connected to a thick copper plate buried into the ground.

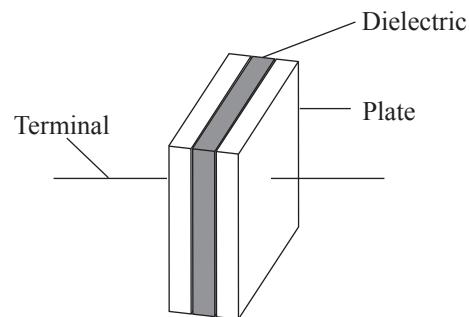
When a highly, say negatively, charged cloud passes over the arrestor, it induces positive charge on the spikes. Due to point action, there is high charge density at the spiked ends. This results in a strong electric field between the cloud and the spikes. The strong field ionises the surrounding air. The negative charges are

attracted to the positively-charged spikes and thus conducted to the ground. In this manner, the arrestor provides a safe path for the charge to be conducted to the ground, rendering the building safe from damage.

4. (a) Describe a capacitor, showing its symbol.
- (b) Define capacitance of a capacitor and state its SI unit.
- (c) A potential difference of 4 V charges a capacitor to store charge of $30 \mu\text{C}$. Calculate the capacitance of the capacitor.

Answer

- (a) A capacitor is a device used to store electric charge. It consists of two metallic plates separated by an insulating material called the dielectric.



The circuit symbol of a capacitor is shown below:



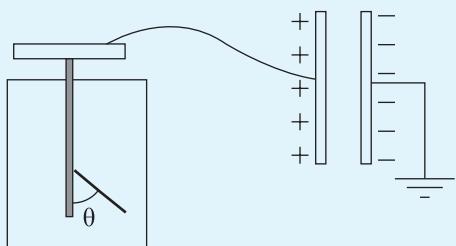
- (b) The capacitance C of a capacitor is the ratio of the charge Q that it stores to the potential V to which it is raised. The SI unit of capacitance is the farad (F).

$$\text{Capacitance } C = \frac{\text{charge } Q}{\text{potential difference, } V}$$

$$(c) C = \frac{Q}{V}$$

$$= \frac{30 \times 10^{-6}}{4} \\ = 7.5 \times 10^{-6} \text{ F} \\ = 7.5 \mu\text{F}$$

5. (a) A parallel-plate capacitor is connected to a charged electroscope as shown below.



How is capacitance related to the angle of divergence?

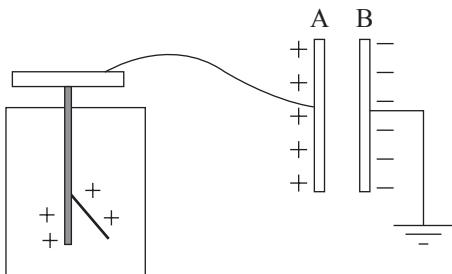
- (b) Describe an experiment to determine how the area of the plates overlap and the distance between the plates affect the capacitance of a capacitor.
- (c) Show that the capacitance of a capacitor is given by $C = k \frac{A}{d}$ where k is a constant, A the area of each plate and the distance between them.

Answer

- (a) The voltage across the capacitor V is directly proportional to the angle divergence θ . Thus $V \propto \theta$ and $V = k\theta$. From $C = \frac{Q}{V}$, then $C = \frac{Q}{k\theta}$. Hence, $C \propto \frac{1}{\theta}$.

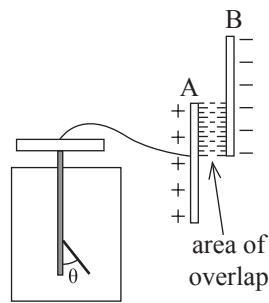
Thus, the smaller the angle of divergence θ , the greater the capacitance, and vice versa.

- (b) An electroscope and a charged parallel-plate capacitor is used. One plate is connected to the cap of the electroscope as shown in the figure.



- (i) Capacitance and area (A) of overlap:

Plate A is moved sideways, keeping d constant. It is observed that the divergence on the leaf increases when the effective area of overlap decreases thus.



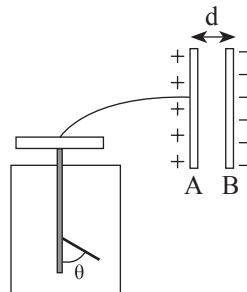
$$A \propto \frac{1}{\theta}$$

Since $C \propto \frac{1}{\theta}$ it follows that $C \propto A$

Thus, increase in area of overlap increases capacitance.

- (ii) Effect of the distance, d , between the plates:

The area of overlap is kept constant and the distance d increased by moving the plate (A) away from plate B.



As d increases, θ also increases. Thus
 $d \propto \theta$

$$\text{Since } C \propto \frac{1}{\theta}, C \propto \frac{1}{d}$$

Thus, the smaller the distance, the higher the capacitance.

In summary;

$$C \propto A \dots\dots\dots(1)$$

$$C \propto \frac{1}{d} \dots\dots\dots(2)$$

Combining (1) and (2);

$$C \propto \frac{A}{d} \Rightarrow C = \frac{kA}{d}$$

where k is permitivity constant.

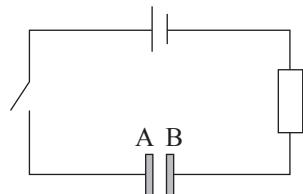
6. Describe how a capacitor is:

- (a) charged.
- (b) discharged.

For each case, sketch graphs of I against t , and V against t .

Answer

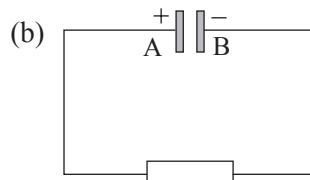
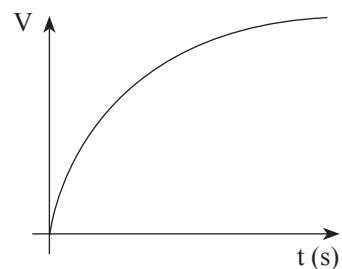
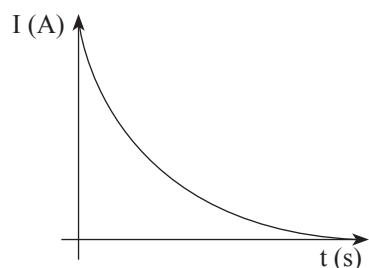
(a) A capacitor gets charged when it is connected on a direct voltage supply.



When the switch is closed, the positive terminal of the cell attracts electrons from plate A leaving it with positive charge, while the negative terminal repels an equal number of electrons to plate B, making it negatively charged. As the charge accumulates, the voltage gradually builds up across the capacitor in opposition to the charging voltage. This continues until the capacitor voltage is equivalent to charging voltage.

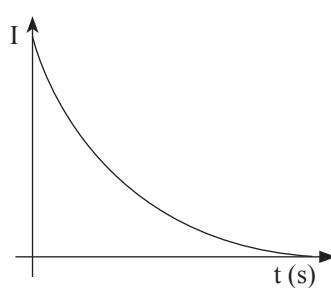
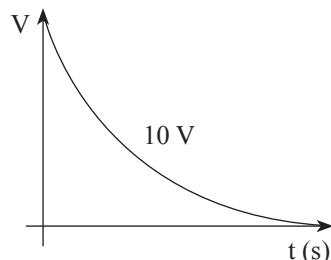
The capacitor is then said to be fully charged. During charging, therefore, the charge gradually increases from a zero to maximum until the capacitor voltage is equivalent to charging voltage. The current decreases with time as this charging capacitor opposes the charging current. The capacitor is said to be fully charged.

The voltage across the capacitor increases until it is fully charged, as below.



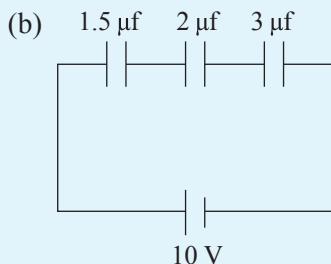
When the plates A and B are connected through a resistor, excess electrons from plate B flow through the resistor to neutralise the positive charge on plate A. This process continues until the capacitor is fully discharged. The higher the value of the resistor, the slower the discharge. If the plates are shorted with, say, a copper wire, a lot of current flows through the wire, causing heating and sparking at the plates. Voltage across the capacitor

decreases until it falls to zero. The current also decreases to zero after some time.



7. (a) Show that when capacitors are connected in series, the total capacitance is given by:

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$



In the circuit, determine:

- (i) total capacitance.
- (ii) voltage across the 2 μF capacitor.
- (iii) energy stored by the 3 μF capacitor.

Answer

- (a) Consider capacitors C_1 , C_2 and C_3

connected in series. Total voltage across the capacitors;

$$V_T = V_1 + V_2 + V_3$$

Charge Q is same on each capacitor.

$$\text{Thus } V_T = \frac{Q}{C_T}, V_1 = \frac{Q}{C_1}, V_2 = \frac{Q}{C_2}, V_3 = \frac{Q}{C_3}$$

$$\text{and } \frac{Q}{C_T} = Q \left\{ \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right\}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\begin{aligned} \text{(b) (i)} \quad \frac{1}{C_T} &= \frac{1}{1.5} + \frac{1}{2} + \frac{1}{3} \\ &= \frac{20 + 15 + 10}{30} \end{aligned}$$

$$\frac{1}{C_T} = \frac{45}{30}$$

$$\text{Thus, } C_T = 0.6667 \mu\text{F}$$

$$\text{(ii) Total charge } Q_T = CV_T$$

$$\begin{aligned} Q &= 0.6667 \times 10^{-6} \times 10 \\ &= 6.667 \times 10^{-6} \text{ C} \end{aligned}$$

$$\begin{aligned} \text{Voltage across} \quad &= \frac{Q}{C_2} \\ \text{the } 2 \mu\text{F capacitor} \quad &= \frac{6.667 \times 10^{-6}}{2 \times 10^{-6}} \\ &= 3.334 \text{ V} \end{aligned}$$

$$\text{(iii) } E = \frac{1}{2} QV$$

$$= \frac{1}{2} \frac{Q^2}{C}$$

$$= \frac{1}{2} \times \frac{(6.667 \times 10^{-6})^2}{3 \times 10^{-6}}$$

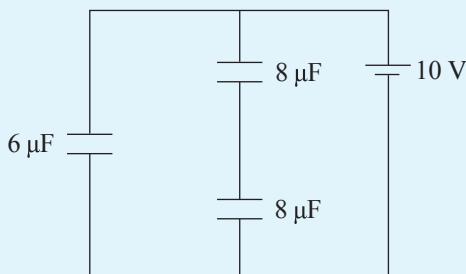
$$= 7.408 \times 10^{-6} \text{ J}$$

8. (a) Show that when capacitors are connected in parallel, the total capacitance is given by;

$$C_T = C_1 + C_2 + C_3$$

- (b) In the circuit shown below, determine the:

- (i) total capacitance.
- (ii) charge on the 6 μF and 8 μF capacitors.
- (iii) energy stored in the system.



Answer

- (a) When capacitors are in parallel,

$$(i) Q_T = Q_1 + Q_2 + Q_3$$

$$\begin{aligned} \text{But } Q_T &= C_T V_T; Q_1 = C_1 V_1, Q_2 \\ &= C_2 V_2 \text{ and } Q_3 = C_3 V_3 \end{aligned}$$

$$\text{Thus } C_T V_T = C_1 V_1 + C_2 V_2 + C_3 V_3$$

$$\text{But } V_T = V_1 = V_2 = V_3$$

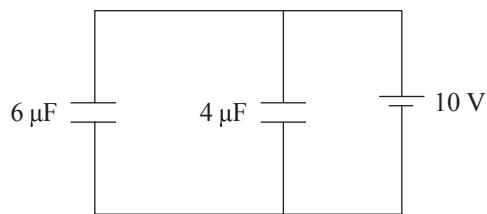
$$\text{Thus, } C_T = C_1 + C_2 + C_3$$

- (b) For the capacitors in series,

$$\frac{1}{C_T} = \frac{1}{8} + \frac{1}{8} = \frac{2}{8}$$

$$C = 4 \mu\text{F}$$

Circuit can be re-drawn as;



$$C_T = 6 + 4 = 10 \mu\text{F}$$

$$(ii) \text{ Charge on } 6 \mu\text{F} = C \times V$$

$$= 6 \times 10^{-6} \times 10$$

$$= 6 \times 10^{-5} \text{ C}$$

For the series circuit;

$$C_T = 4 \mu\text{F}$$

$$\text{Charge} = 4 \times 10^{-6} \times 10$$

$$= 4 \times 10^{-5} \text{ C}$$

Hence, charge on the 8 μF is $4 \times 10^{-5} \text{ C}$

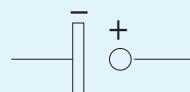
$$(iii) \text{ Energy stored} = \frac{1}{2} C_T V^2 \text{ in the system}$$

$$= \frac{1}{2} \times 10 \times 10^{-6} \times 10^2$$

$$= 5 \times 10^{-4} \text{ J}$$

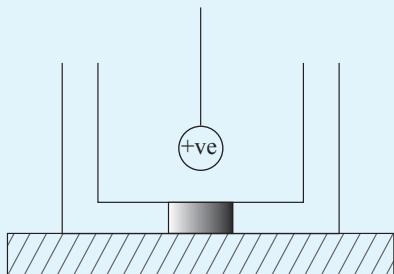
Revision Exercise 25

1. Sketch an electric field pattern in the following situation:



2. Indicate the distribution of charge on the following:

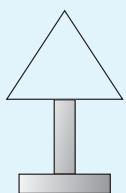
- (a) Positive charge suspended in a hollow conductor placed inside and insulated from an external container:



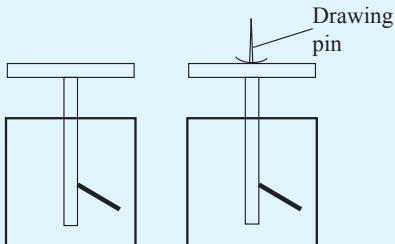
- (b) An airplane flying below a charged cloud.



- (c) A positively charged triangular metal block on an insulating stand.



3. (a) Two electroscopes are given same amount of charge. If a drawing pin is put on the cap of one of the electroscopes, state and explain the observations made.



- (b) Explain each of the following:

- (i) A tanker carrying fuel has chain hanging below it.

- (ii) Wings of an aircraft have small metal rods fitted.

- (iii) It may be risky to shelter under a tall tree in a lightning-prone area.

4. (a) Explain why it is not possible to charge a capacitor using an alternating voltage.

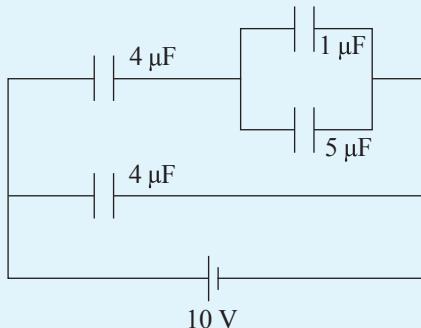
- (b) You are given three identical capacitors of capacitance $2\ \mu\text{F}$. Work out the different capacitance values you can obtain by connecting them in:

(i) series

(ii) parallel

- (c) What is the charge on a $30\ \mu\text{F}$ capacitor when it is charged to a voltage of 1 kV ?

5. A circuit is arranged as below.



Determine the:

- (a) total capacitance.
 (b) total charge.
 (c) charge and voltage across each $4\ \mu\text{F}$.
 (d) charge on the $5\ \mu\text{F}$ capacitor.

UNIT
26

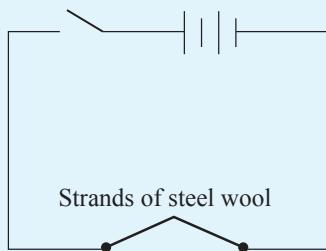
The Heating Effect of an Electric Current

Key Points

- When current flows through a conductor, some of the electrical energy is converted to heat.
- Heat developed is given by the formula
Heat = I^2Rt

Revision Questions 26

1. (a) The figure below shows a circuit used to demonstrate the heating effect.



State the observations made when the circuit is switched on.

- (b) A current of 2A is kept flowing through 20 cm lengths of copper and nichrome wires. State and explain observation made when one touches the wires for 5 minutes.

Answer

- (a) The strands of steel wool glow red-hot and burn out.
- (b) Nichrome wire feels hot while the copper remains cold. As the current of 2 A flows through the circuit, the nichrome wire develops a lot of heat due to its high resistance while copper remains fairly cold due to much lower resistance.

2. State factors determining heating by an electric current.

Answer

The factors are:

- Resistance, R.
- The amount of the current, I.
- Time t during which the current flows.

3. A heating coil rated 240 V, 1 kW is used to supply heat energy to 2 litres of water for five minutes. If the heater is working normally, determine the:
(a) current it draws.
(b) heat energy dissipated.

Answer

$$\begin{aligned} \text{(a) Current} &= \frac{\text{power}}{\text{voltage}} \\ &= \frac{1 \times 10^3}{240} \\ &= 4.167 \text{ A} \end{aligned}$$

$$\begin{aligned} \text{(b) Heat energy} &= \text{Power} \times \text{time} \\ &= 1 \times 10^3 \times 5 \times 60 \\ &= 300\,000 \text{ J or } 300 \text{ kJ} \end{aligned}$$

4. (a) Identify three devices which are used to convert electrical energy to heat energy.
(b) A current of 1.2 A flows through a 12Ω resistance wire. What is the power dissipated?

Answer

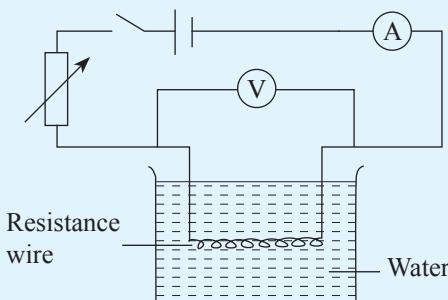
(a) Devices making use of the heating effect of an electric current include electric kettle, electric iron and electric heater.

(b) Power = I^2R

$$\begin{aligned} &= (1.2^2 \times 12) \\ &= 17.28 \text{ W} \end{aligned}$$

Revision Exercise 26

1. A filament lamp has either an ordinary tungsten coil or coiled coil. Explain:
 - (a) why tungsten is preferred as the material for filament.
 - (b) why coiled coil is preferable to ordinary coil.
2. 50 cm of resistance wire of cross-sectional area 0.07 mm^2 is coiled up and used to heat 0.5 kg of water in a beaker, as in the figure below:



The circuit is switched on for 30 minutes. Throughout this period, the voltage and current values are maintained at 5.0 V and 1.0 A respectively. Determine the:

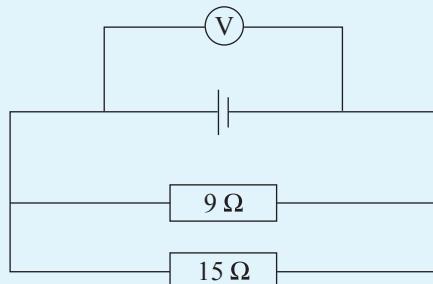
- (a) (i) resistivity of the wire.
(ii) power dissipated in the coil.

(iii) total heat energy expended.

(iv) temperature change in the water (assume no energy losses and specific heat capacity of water is 4200 J/kgK)

(b) Copper has resistivity of $1.7 \times 10^{-8} \Omega\text{m}$. What would be the equivalent resistance for copper wire of the same dimensions as the resistance wire in (a) above?

3. A filament bulb is rated 60 W 240 V.
 - (a) What is the resistance of the filament when operating normally?
 - (b) Given that the filament wire is of cross section area 0.03 mm^2 and resistivity $5.5 \times 10^{-8} \Omega\text{m}$, determine the length of the wire of the filament.
4. In the circuit below, a battery is connected to a parallel network of resistors 9Ω and 15Ω .



- (a) Given that V reads 12 V, determine power dissipated in the resistors:
(b) What will be the stated power developed if the resistors are now connected in series?

UNIT**27**

Quantity of Heat

Key Points

- Whenever there is change in temperature, there is an associated absorption or release of heat energy.
- In some cases, heat may be released or absorbed without change in temperature, for example, during melting or boiling.
- The temperature change in a body due to change in heat energy depends on the mass of the body and the nature of the substance of which it is composed.
- Temperature change affects the average energy (kinetic and potential) of particles in the body, thus effecting changes of state.

Revision Questions 27

- (a) Define the term heat capacity, giving the SI unit.
(b) A block of aluminium requires 5 000 J of heat energy to raise its temperature by 11.1°C . Determine the heat capacity of the block.

Answer

(a) Heat capacity is the quantity of heat required to change the temperature of a body by 1°C . The SI unit is joules per kelvin (J/K).

(b) Heat capacity

$$\begin{aligned} &= \frac{\text{Quantity of heat}}{\text{Temperature change}} \\ &= \frac{5000}{11.1} \\ &= 450.4 \text{ J/K} \end{aligned}$$

- (a) State the factors that determine the amount of heat energy released by a body as its temperature drops.
(b) A liquid of mass 0.8 kg requires 4 000 J of heat energy to raise its temperature through 2°C . Determine the specific heat capacity of the liquid.

Answer

- (a) The factors are:
 - Mass of the body, m.
 - Temperature change, θ .
 - Specific heat capacity of the body, c.
(b) Quantity of heat = $mc\theta$
Thus, $4000 = 0.8 \times 2 \times c$
 $\therefore c = 2500 \text{ J kg}^{-1}\text{K}^{-1}$
- (a) Describe how you can determine the specific heat capacity of a metal block using the method of mixtures.
(b) An 80 g iron block is quickly transferred from hot boiling water to 100 g of water in a well-lagged brass calorimeter of mass 300 g. Given that the initial and final temperatures of water in the calorimeter are 22°C and 27°C respectively, determine the specific heat capacity of iron (specific heat capacity of water and brass are 4 200 J/kgK and 400 J/kgK respectively).
(c) State the likely sources of error.

Answer

- (a) To determine the specific heat capacity using the method of mixtures.

A hot block of a known mass and temperature is introduced into a liquid of known specific heat capacity whose mass and initial temperature are already determined. The liquid is contained in a well-lagged calorimeter whose mass and specific heat capacity are also predetermined. The hot block loses heat energy while the liquid and calorimeter gain heat energy until a steady state is reached where temperature remains fairly constant. This final steady temperature is noted.

Calculations are set out as:

$$\text{Heat lost by hot block} = \text{Heat gained by liquid} + \text{heat gained by calorimeter}$$

(b) Heat gain by water = $mc\theta$

$$\begin{aligned} &= 0.1 \times 4200 \times 5 \\ &= 2100 \text{ J} \end{aligned}$$

Heat gain by calorimeter = $mc\theta$

$$\begin{aligned} &= 0.3 \times 400 \times 5 \\ &= 600 \text{ J} \end{aligned}$$

Total heat gain = $2100 + 600 = 2700 \text{ J}$

Heat loss by iron block = $mc\theta$

$$\begin{aligned} &= 0.08 \times 73 \times c \\ &= 5.84 c \end{aligned}$$

$$\text{Heat lost by metal block} = \text{Heat gained by water} + \text{heat gained by calorimeter}$$

$$\therefore 5.84 c = 2700$$

$$c = 462.3 \text{ J kg}^{-1} \text{ K}^{-1}$$

- (c) Sources of error are:

- Loss of heat by the block as it is transferred from the hot water to water in the calorimeter.
- Loss of heat due to evaporation,

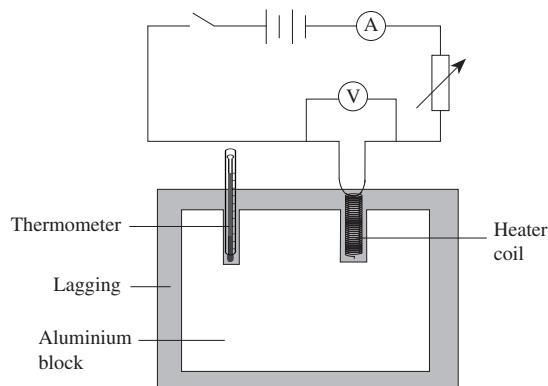
conduction and radiation, despite the lagging.

4. An experiment is conducted to determine the specific heat capacity of an aluminium block by electrical method.
- (a) Describe the experiment.
- (b) In the experiment, a potential difference of 12 V is used to supply a steady current of 2 A through the heater coil for 10 minutes. The block is well-lagged and temperature rises from 19°C to 35.1°C within this period. Using the values given, determine:
- the total electrical energy supplied by the heater.
 - the specific heat capacity of aluminium.
- (c) State the likely sources of error in the experiment.

Answer

- (a) Electrical method:

A heating coil is connected to an electric circuit which can be controlled to supply constant voltage V and current I over the required period, as shown in the figure below.



The mass of the solid m and its initial temperature θ_1 is noted.

If a steady current I flows through the heater under a potential difference of V for a time t , the electrical energy used is given by VIt . This energy is converted into heat energy in the solid, which makes the temperature of the solid increase by, say, θ_2 . Heat energy gained is given by $mc\Delta\theta$, where c is the specific heat capacity of the solid.

$$mc\Delta\theta = VIt$$

$$\therefore c = \frac{VIt}{m\Delta\theta}$$

$$\begin{aligned} \text{(b) (i) Total electrical energy supplied} &= VIt \\ &= 12 \times 2 \times 10 \times 60 \\ &= 14400 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{(ii) Temperature change in the block} &= (35.1 - 19) \\ &= 16.1^\circ\text{C} \end{aligned}$$

The block is lagged. Thus, assuming no energy losses,

$$VIt = mc\theta$$

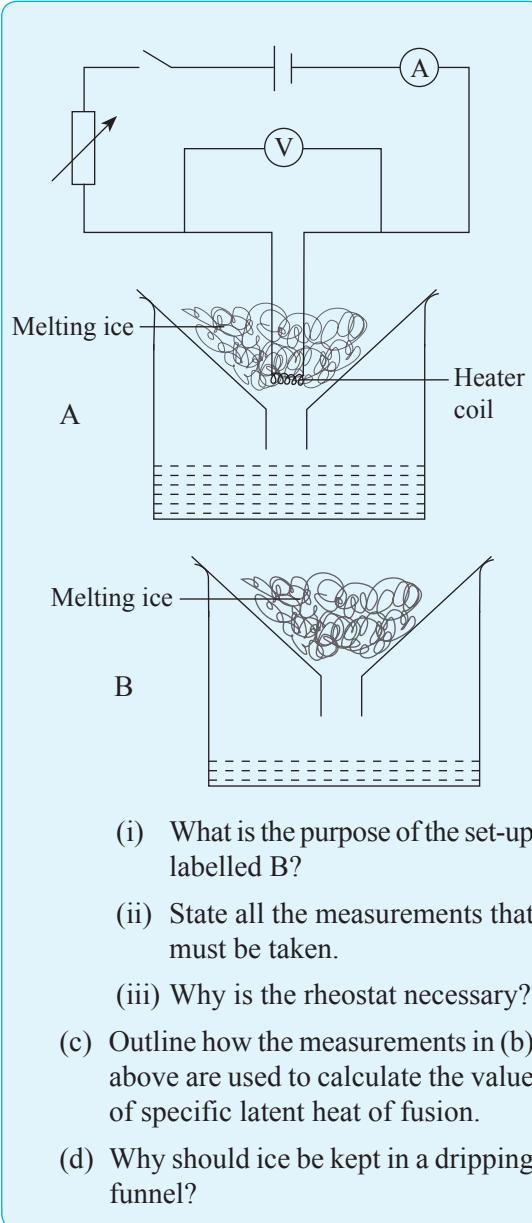
$$14400 = 1 \times 16.1 \times c$$

$$\therefore c = 894.4 \text{ J kg}^{-1}\text{K}^{-1}$$

(iii) Sources of energy loss are:

- Heat energy that goes into heating up the little oil in the holes.
- The little heat loss to the surrounding, despite the lagging.

5. (a) Define the term specific latent heat of fusion.
 (b) The figure below illustrates the set-up that may be used to determine the specific latent heat of fusion of ice.



(i) What is the purpose of the set-up labelled B?

(ii) State all the measurements that must be taken.

(iii) Why is the rheostat necessary?

(c) Outline how the measurements in (b) above are used to calculate the value of specific latent heat of fusion.

(d) Why should ice be kept in a dripping funnel?

Answer

- (a) Specific latent heat of fusion is the quantity of heat energy required to convert 1kg of a substance from solid to liquid state without change in temperature.
- (b) (i) The set-up B is for determining the mass of the ice that melts due to the gain of heat from the surroundings.

(ii) Voltage V

Current I

Time of heating t

Mass of empty beaker in A, m_a

Mass of empty beaker in B, m_b

Mass of melted water in A, m_{wa}

Mass of melted water in B, m_{wb}

(iii) The rheostat is used to maintain the values of voltage V and current I constant throughout the period of heating.

(c) Quantity of electrical energy delivered = VIt

Mass of ice melted by heat from surrounding = $m_{wb} - m_b$

Mass of ice

melted by electrical heating = $(m_{wa} - m_a) - (m_{wb} - m_b)$

Denoting specific latent heat of fusion L_f

Quantity of electrical heat absorbed to cause melting

$$= (m_{wa} - m_a) - (m_{wb} - m_b) \times L_f$$

Assuming no heat losses;

$$VIt = (m_{wa} - m_a) - (m_{wb} - m_b) \times L_f$$

$$L_f = \frac{VIt}{(m_{wa} - m_a) - (m_{wb} - m_b)}$$

(d) This is to ensure that any melting water is quickly drained away from the ice, hence the ice remains at its melting point, i.e., the change of state occurs without change in temperature.

6. In an experiment to determine the specific latent heat of ice, a 50 W heater coil is used to supply electrical heating to ice in a dripping funnel for 5 minutes. The total amount of water melted in the funnel with

the coil is 53 g, while that collected from the funnel without the coil is 9 g. Using these results, calculate the specific latent heat of fusion of ice.

Answer

$$\text{Total energy converted} = \text{power} \times \text{time}$$

$$= 50 \times 5 \times 60$$

$$= 15\,000 \text{ J}$$

$$\begin{aligned} \text{Mass of ice melted} \\ \text{by the heater coil } m &= (53 - 9) \\ &= 44 \text{ g} \end{aligned}$$

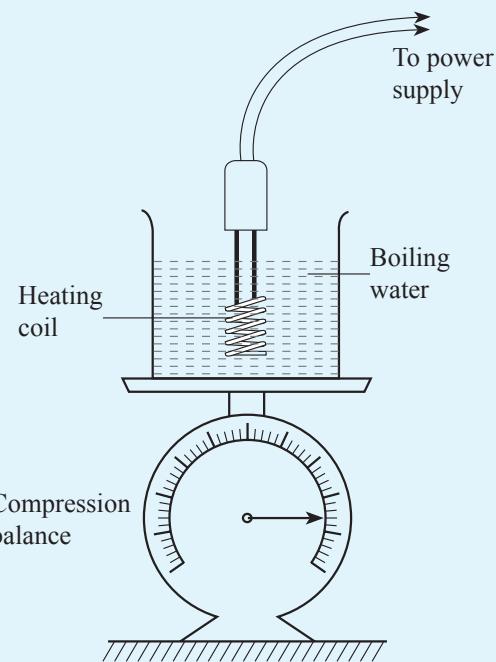
$$\begin{aligned} \text{Quantity of heat} \\ \text{required to melt the ice} &= mL_f \\ &= 44 \times 10^{-3} \end{aligned}$$

Assuming no heat losses,

$$15\,000 = 44 \times 10^{-3} \times L_f$$

$$L_f = 340\,909 \text{ J/kg}$$

7. The figure below shows a set-up that can be used to determine the specific latent heat of vaporisation of water.



The heater is switched on and the water kept boiling steadily.

- State all the measurements that should be taken.
- Describe how the measurements in (a) are used to determine the specific latent heat of vaporisation of water.

Answer

- (a) The initial mass of the boiling water m_1 .

The time interval through which the heater is kept on boiling the water away t .

The final mass of the water in the beaker m_2 .

- (b) Quantity of heat delivered by the heater is given by;

$$\text{Power (P)} \times \text{time (t)} = Pt$$

Denoting the specific latent of heat of vaporisation as L_v ;

$$\text{Heat energy taken up by evaporating water} = (m_2 - m_1)L_v$$

Assuming no energy losses;

$$Pt = (m_2 - m_1)L_v$$

8. In an experiment to determine the specific latent heat of vaporisation of water, a heater rated 24 W was used to supply heat to keep water boiling steadily. The initial mass of the boiling water was 125 g and after 5 minutes, the mass had dropped to 121.9 g. Using the information given, determine the value for the specific latent heat of vaporisation of water.

Answer

$$\text{Electrical energy delivered} = \text{power} \times \text{time}$$

$$= 24 \times 5 \times 60$$

$$= 7200 \text{ J}$$

$$\begin{aligned}\text{Energy taken up by evaporating water} &= mL_v \\ &= (125 - 121.9)L_v \\ &= 3.1L_v\end{aligned}$$

$$7200 = 3.1L_v$$

$$L_v = 2323 \text{ J/g}$$

$$= 2323000 \text{ J/kg}$$

9. State the factors affecting:

- melting point of ice.
- boiling point of water.

Answer

- (a)
- Pressure – Increased pressure lowers the melting point of ice.
 - Presence of impurities – Impurities lower the melting point.

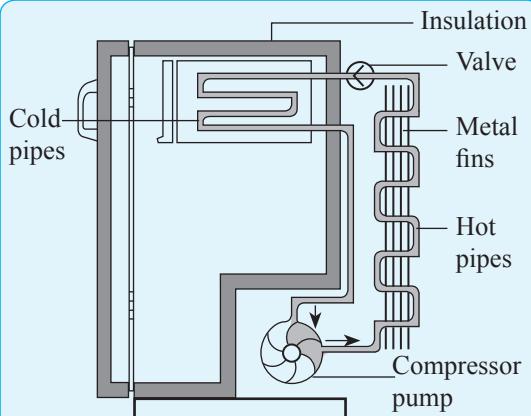
- (b) Pressure – Increase of pressure raises the boiling point of water.

10. Explain why food cooks faster in a pressure cooker.

Answer

The air-tight cover causes the pressure of steam formed to build up to values beyond the normal atmospheric pressure. At this pressure, the boiling point of water rises beyond 100 °C. Food boiled at the high temperature cooks faster.

11. In the refrigerator shown, the circulating liquid is forced through the valve into the cold coils.



With reference to the figure shown, answer the following questions:

- What change of state occurs to the liquid as it goes past the valve?
- How does the process in (a) above enhance the drawing out of heat from the contents of the fridge?
- What change of state does the work of the pump achieve on the refrigerant?
- How does this change of state enhance the required process at the hot coil?

Answer

- Sudden expansion as the liquid passes through the valve to the cold coils results in vaporisation.
- The evaporating liquid draws its latent heat of vaporisation from the surrounding in the cold compartment, thus effecting cooling.
- Compression of the warm vapour as it is worked on by the pump resulting in condensation.
- The condensing vapour releases latent heat of vaporisation, which is promptly conducted away by the cooling fins encompassing the hot coils on the outside of the refrigeration chamber.

Revision Exercise 27

- Determine the quantity of heat required to raise the temperature of an aluminium block from $300\text{ }^{\circ}\text{C}$ to $308\text{ }^{\circ}\text{C}$. (specific heat capacity of aluminium is $900\text{ J/kg}^{-1}\text{K}^{-1}$).
- A 50 g block of iron removed from hot boiling water at $100\text{ }^{\circ}\text{C}$ is quickly transferred into 200 g of water in a well-lagged brass calorimeter. Given that the initial temperature of water is $22\text{ }^{\circ}\text{C}$, determine the final temperature of the contents in the calorimeter, take specific heat capacity values as:
Iron $460\text{ Jkg}^{-1}\text{K}^{-1}$
Brass $400\text{ Jkg}^{-1}\text{K}^{-1}$
Water $4\ 200\text{ Jkg}^{-1}\text{K}^{-1}$
- Steam at $100\text{ }^{\circ}\text{C}$ is continually passed through 200 g of water of initial temperature $15\text{ }^{\circ}\text{C}$. The water is held in a 40 g brass calorimeter. At the end of the process, the total mass of water is 205 g and its temperature is T . (specific latent heat of vaporisation of water is $2.3 \times 10^6\text{ J/kg}^{-1}\text{K}^{-1}$, specific heat capacity of water is $4\ 200\text{ Jkg}^{-1}\text{K}^{-1}$). Using this information. Calculate the:
(a) mass of steam converted to water
(b) quantity of heat energy released by:
(i) condensing steam.
(ii) cooling water from condensed steam.
(c) final temperature T .
- A 60 W heating coil supplies steady power to a 500 g well-lagged iron block whose initial temperature is $20\text{ }^{\circ}\text{C}$. The temperature rises to $520\text{ }^{\circ}\text{C}$ in two minutes. What is the specific heat capacity of iron? State the likely sources

of error.

5. In an experiment to determine specific latent heat of fusion of ice, a 75 W power heater is kept on for 5 minutes and the mass of water collected is 67 g. Use this information to determine the specific latent heat of fusion of ice.
6. (a) What is evaporation?
(b) State any three factors that can be applied to speed up evaporation.
7. In an experiment to determine the specific heat capacity of water, a heater coil rated 24 W is used to supply heat to 200 g of water in a light calorimeter which is well-lagged. The heater is kept on for

6 minutes and the temperature rises from 17 °C to 27 °C. Use these values to determine the specific heat capacity of water. State any assumptions made.

8. In an experiment to determine the specific heat capacity of a liquid, an aluminium block of mass 500 g is transferred from hot boiling water to 150 g of the liquid in a brass calorimeter of mass 200 g. The temperature of the liquid rises from 21°C to 27°C. Using these values, determine the specific heat capacity of the liquid l . (take specific heat capacity of aluminium as $900 \text{ Jkg}^{-1}\text{K}^{-1}$, specific capacity of brass as $380 \text{ Jkg}^{-1}\text{K}^{-1}$).

UNIT**28****Gas Laws****Key Points**

- Collisions in ideal gases occur in accordance with Newton's laws of motion. The force at impact, speed and frequency of collision depend on such factors as temperature and density of the gas.
- Under kinetic theory, molecules of gases are assumed to be masses with zero volume and their collisions are elastic resulting in no loss of kinetic energy.

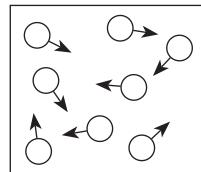
Revision Questions 28

1. (a) Explain how gas trapped in a container exerts pressure.
(b) State Boyle's law and explain it in terms of behaviour of molecules.
(c) For a fixed mass of gas, sketch graphs of:
 - (i) P against V.
 - (ii) P against $\frac{1}{V}$
 - (iii) PV against P.
(d) For each of the cases in (c) above, sketch on the same axes the graphs that would be obtained if the temperature was raised to a higher value.

Answer

- (a) Molecules of a gas are considered to move freely, colliding with each other and the walls of container in which the gas is trapped. The collisions result in continual change in momentum, thereby

generating a force in accordance with Newton's second law of motion.



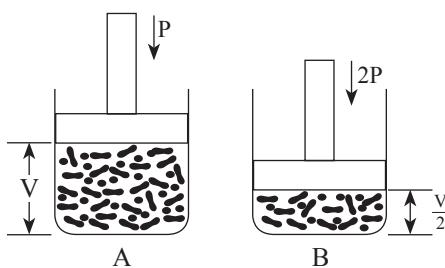
Since pressure is force per unit area, gas pressure is generated.

- (b) Boyle's law states that pressure of a fixed mass of a gas is inversely proportional to its volume provided temperature is kept constant. This can be expressed as;

$$P \propto \frac{1}{V}, \text{ from which } P = \frac{k}{V} \text{ and } PV = k.$$

This leads to $P_1 V_1 = P_2 V_2$.

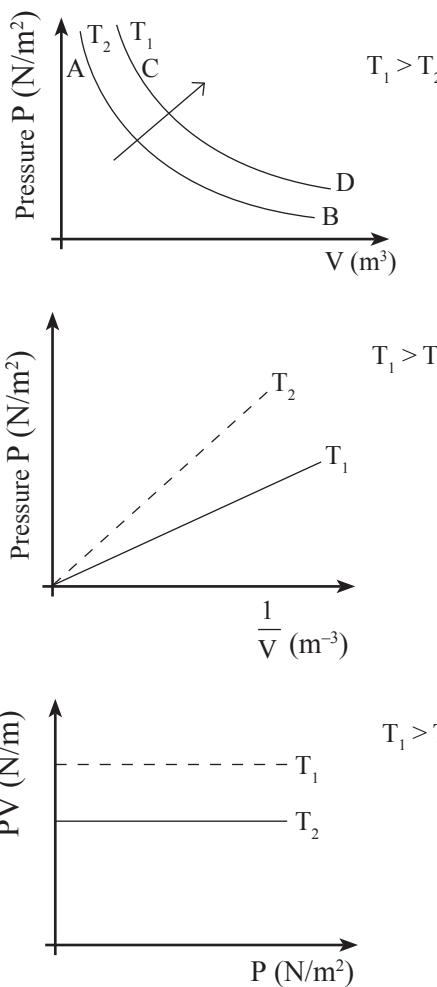
It follows that if the volume of a fixed mass of a gas is halved, the pressure is doubled. The frequency at which the molecules collide with themselves, and walls of the container also doubles.



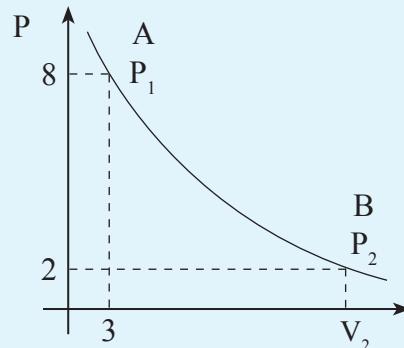
Pressure in B is twice that in A.

- (c) (i) Graph of P against V

As the volume of the gas increases, the pressure decreases. At a higher temperature, the curve shifts from AB to CD.



2. (a) (i) Explain why mass and temperature should be held constant in Boyle's law.
(ii) In a P against V graph, what is the significance of the area under the graph?
(b) From an experiment performed at constant temperature, values of P (Atm) against V were plotted to give the graph shown.



Determine the value of V_2

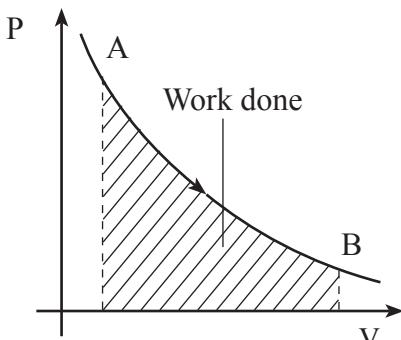
- (c) An air bubble of volume 1×10^{-3} m 3 is released by a fish at a depth of 20 m in a lake. The bubble rises to the surface at a constant temperature. If the atmospheric pressure is 100 kPa and the density of water is 1.2×10^3 kgm $^{-3}$, calculate:
- Total pressure 20 m below water surface.
 - The volume V of the bubble just before touching the surface.

Answer

- (a) (i) If the mass is not held constant, then the number of molecules of gas involved in collision will not be constant, hence pressure variation cannot be explained in terms of change in volume only.

Temperature change varies the kinetic energy of the molecules, thus changing the force of collision and frequency of bombardment with the walls of the container in which the gas is trapped. This also varies the pressure.

- (ii) The area under the graph signifies the work done on or by the gas.



(b) $P_1 = 8 \text{ atm}$ $V_1 = 3 \text{ m}^3$

$P_2 = 2 \text{ atm}$ $V_2 =$

$PV = k, \quad P_1V_1 = P_2V_2$

Hence, $8 \times 3 = 2V_2$,

$V_2 = 12 \text{ m}^3$

(c) (i) Total pressure = $P_{\text{at}} + \text{Pressure due to depth of water} (\rho gh)$

$$= 100 \times 10^3 + 1.2 \times 10^3 \times 10 \times 20$$

$$= (1 \times 10^5) + (2.4 \times 10^5)$$

$$= 3.4 \times 10^5 \text{ Pa}$$

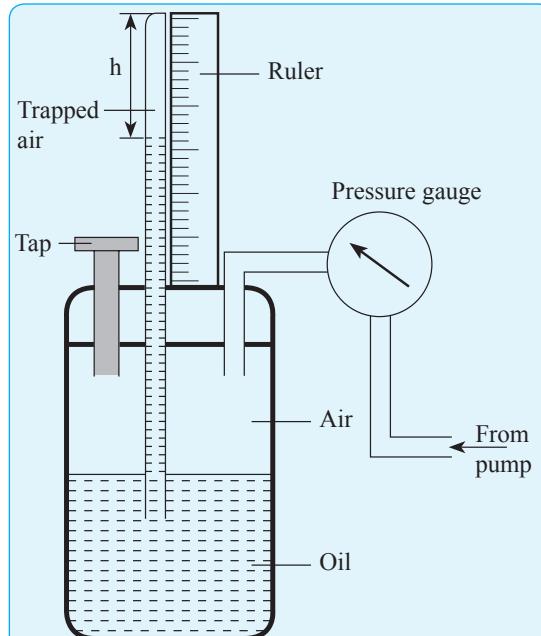
(ii) $P_1V_1 = P_2V_2$

$$3.4 \times 10^5 \times (1 \times 10^{-3}) = 100 \times 10^3 \times V_2$$

$$V_2 = \frac{3.4 \times 10^2}{1 \times 10^5}$$

$$= 3.4 \times 10^{-3} \text{ m}^3$$

3. (a) The set-up shown was used to verify Boyle's law.



(i) Explain why the value of h is equated to volume, and value of pressure recorded is an approximation.

(ii) Describe how a set of values can be obtained.

(iii) Give one factor why oil is preferred to water.

(iv) Explain why after taking a reading, there should be sufficient time lapse before the next reading is taken.

- (b) From a similar experiment carried out, the following results were obtained:

| | | | | |
|-------------------------------|-----|-----|-----|------|
| Pressure (Nm^{-2}) | 400 | 320 | 160 | 80 |
| Volume (m^3) | 2.0 | 2.5 | 5.0 | 10.0 |

(i) Plot a graph of P against $\frac{1}{V} (\text{m}^{-3})$.

(ii) From your graph, obtain values of V_1 when $P_1 = 300 \text{ Nm}^{-2}$ and V_2 when $P_2 = 150 \text{ Nm}^{-2}$. Comment on the values of P_1V_1 and P_2V_2 .

(iii) Determine the value of gradient K and state its SI units.

Answer

(a) (i) Since volume = $A \times h$ and the cross-section area is constant, the length h is proportional to the volume of the trapped gas. The value of pressure is not accurate since the reading on the gauge includes the pressure of gas and pressure due to the column of oil.

(ii) Starting from the pressure at the atmosphere, the value of h is noted. Pressure is decreased in steps as values of h are recorded.

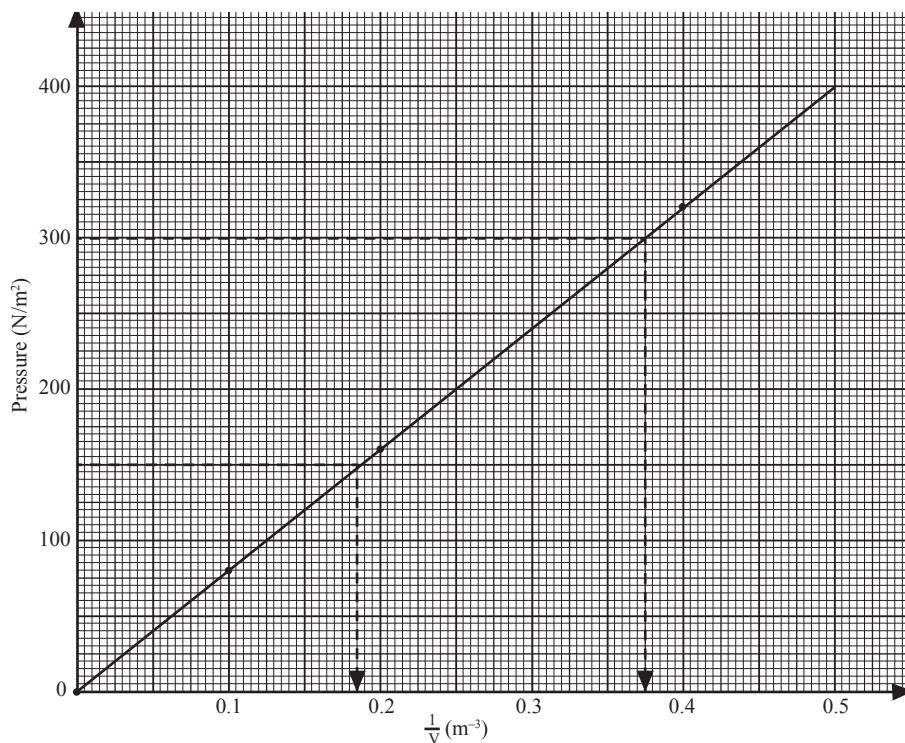
(iii) Oil is used in the experiment because it offers a uniform transmission of pressure and does not wet the

airspace above it.

(iv) There should be sufficient interval of time between one set of reading and the other due to possible decrease in temperature arising from the work done by the gas in expanding.

(b)

| | | | | |
|------------------------------|-----|-----|-----|-----|
| $P (\text{N m}^{-2})$ | 400 | 320 | 160 | 80 |
| $V (\text{m}^3)$ | 2 | 2.5 | 5.0 | 10 |
| $\frac{1}{V} \text{ m}^{-3}$ | 0.5 | 0.4 | 0.2 | 0.1 |



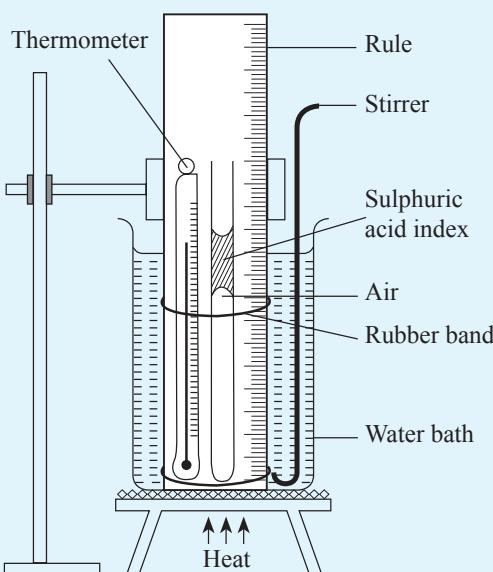
From the graph, $\frac{1}{V_1} = 0.38 \text{ m}^{-3}$;
 $V_1 = 2.632$; $P_1 V_1 = 789.5$
 $\frac{1}{V_1} = 0.19 \text{ m}^{-3}$; $V_2 = 5.263$; $P_2 V_2 = 789.48$

$$P_1 V_1 = P_2 V_2$$

$$\text{Slope} = \frac{(400 - 0)}{(0.5 - 0)}$$

$$= 800 \text{ J}$$

4. (a) (i) What is absolute zero temperature with regard to kinetic theory?
- (ii) State the relationship of the temperature θ taken on Celsius scale and that of absolute scale (Kelvin scale) T .
- (iii) What is the reading of temperature 0 K on Celsius scale?
- (b) (i) State Charles' law for a fixed mass of a gas and show that $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
- (ii) Use the behaviour of molecules of a fixed mass of a gas trapped in a container to explain Charles' law and explain why pressure is kept constant.
- (c) The diagram below shows apparatus for verifying Charles' law:



- (i) What is the purpose of the column of concentrated sulphuric acid?
- (ii) Why is a water bath used?

- (iii) Describe how the values are obtained and used to verify Charles' law.

Answer

- (a) (i) Absolute zero temperature is the temperature at which the kinetic energy of particles of matter is zero (0 K or -273°C). At this temperature, a gas has no pressure or volume.
- (ii) Temperature T in Kelvin is related to the reading on Celsius scale through the equation $T = \theta + 273$
- Therefore, at absolute zero temperature, $0\text{ K} = \theta + 273$
- $$\theta \equiv T - 273^{\circ}\text{C}$$
- Thus, when $T = 0$;
- $$\theta = 0 - 273^{\circ}\text{C}$$
- $$= -273^{\circ}\text{C}$$

- (b) (i) Charles' law states that the volume of a fixed mass of a gas is directly proportional to absolute temperature provided the pressure remains constant. Thus;

$$V \propto T$$

$$\therefore V = kT$$

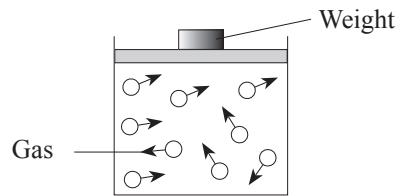
From which

$$\frac{V}{T} = k$$

$$\text{Hence } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

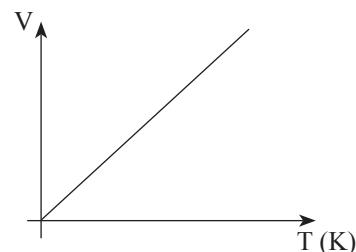
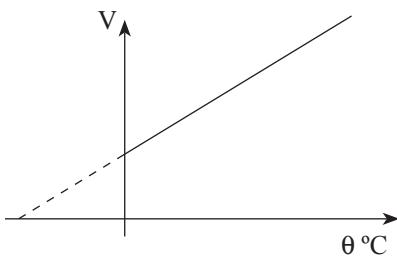
Note that the temperature must be in Kelvin when using this formula.

- (ii) Consider a gas trapped in a container as shown in the following figure.

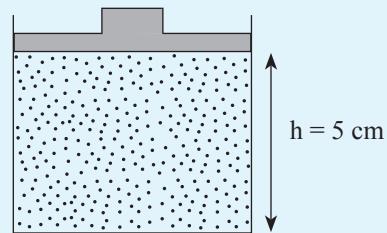


The weight ensures constant pressure. When the gas is heated, the molecules gain kinetic energy, hence require more room if they have to maintain the initial rate and number of collision between themselves and walls of the container. Thus, the volume of the gas must increase. The converse is true if the temperature is reduced.

- (c) (i) The column of acid is used to exert pressure on air trapped and remove any trace of water vapour from the air. Note that the total pressure on the gas is atmospheric pressure and the pressure due to sulphuric acid.
- (ii) Water bath is used to ensure uniform heating of the trapped gas.
- (iii) Starting with water at room temperature, the length L of the trapped gas is recorded. The water is then heated as the temperature and corresponding length of air column values are recorded at suitable intervals. A graph of length L (representing volume) is plotted against the temperature θ °C. A straight line graph is obtained and when extrapolated it is found to meet the temperature axis at a value -273 °C. If the temperature is converted to Kelvin the graph originates from the origin. This shows that volume is directly proportional to absolute temperature.



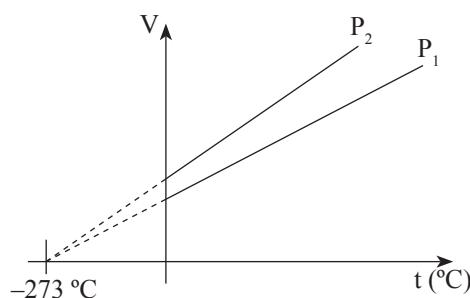
5. (a) Sketch a graph showing how volume varies with temperature at two pressure values P_1 and P_2 , where $P_1 > P_2$. Explain the difference.
- (b) A cylinder has a diameter of 3 m and contains air compressed by a piston of mass 15 kg which can slide freely. The arrangement is heated uniformly from a temperature of 27 °C to 87 °C.



Determine:

- (i) the pressure exerted on the gas.
- (ii) the height h at 87°C. What assumption did you make in the calculation?

Answer



From Boyle's law $P_1 V_1 = P_2 V_2$. At lower pressure, $P_2 V_2$ is higher hence starting at higher point than V_1 .

$$\begin{aligned}
 \text{(b) (i) Pressure } P &= \frac{\text{Force}}{\text{Area}} \\
 &= \frac{F}{A} \\
 &= \frac{15 \times 10}{3.142 \times 1.5^2} \\
 &= 21.22 \text{ Nm}^{-2}
 \end{aligned}$$

(ii) Assuming that area A is constant

$$V = Ah.$$

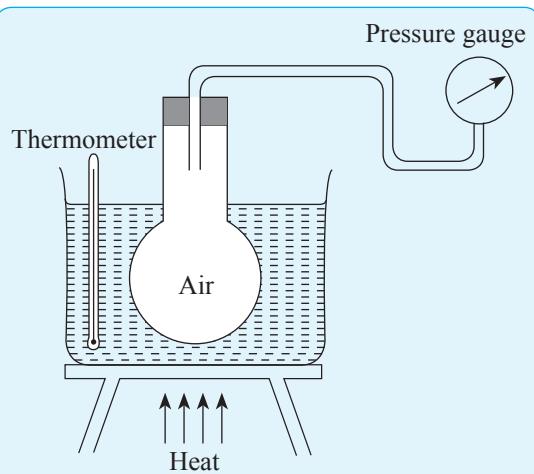
Therefore, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ becomes,

$$\frac{h_1}{T_1} = \frac{h_2}{T_2}$$

$$\begin{aligned}
 h_2 &= \frac{h_1}{T_1}, T_2 = \frac{5 \times 10^{-2} \times (273 + 87)}{273 + 27} \\
 &= \frac{5 \times 360}{300} \times 10^{-2} \\
 &= 6 \times 10^{-2} \text{ m} \\
 &= 6 \text{ cm}
 \end{aligned}$$

Assumption: Area and pressure are constant.

6. (a) (i) State the pressure law and show the behaviour of molecules of a fixed mass of a gas to explain it.
- (ii) Plot a graph of pressure against temperature on the Kelvin scale. On the same axes, sketch another graph for a gas of larger volume.
- (b) The set-up below is used to verify pressure law:



- (i) Describe how values are obtained and used to verify the law.
- (ii) The pressure in a tyre is 20 kNm^{-2} at 27°C . What will be the new pressure if the temperature of the tyre increases to 37°C ? Take the atmospheric pressure to be 100 kNm^{-2} .

Answer

- (a) (i) The pressure of a fixed mass of a gas is directly proportional to its absolute temperature at constant volume. Thus,

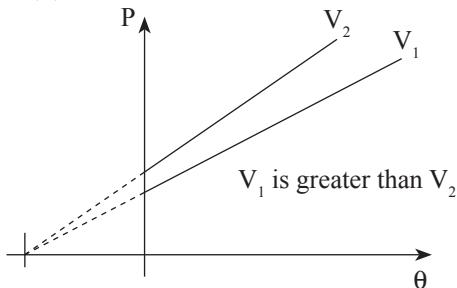
$$P \propto T, \text{ from which;}$$

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

Hence, $\frac{P}{T} = k$ or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ (temperature T must be in Kelvin)

When the temperature of the gas increases, it causes the kinetic energy of the molecules to increase. This increases the rate and force of collision among the molecules and the walls of the container, thereby increasing pressure.

(ii)



- (b) (i) Starting from room temperature, the air is heated as the values of temperature and corresponding values of pressure noted at suitable intervals. A graph of pressure P against temperature θ is plotted and is found to be a straight line, thus verifying the law.

$$\text{(ii)} \quad P_1 = (20 \times 10^3) + (100 \times 10^3) \\ = 120 \times 10^3$$

$$T_1 = 27 + 273 \\ = 300 \text{ K}$$

$$P_2 = ?$$

$$T_2 = 37 + 273 = 310 \text{ K}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = \frac{P_1}{T_1} \times T_2$$

$$= \frac{120 \times 10^3 \times 310}{300} \\ = 124 \times 10^3$$

The pressure in the tyre is thus 124 kNm^{-2} .

7. (a) (i) State the universal gas law.
(ii) 20 litres of a gas is kept at a pressure of $1 \times 10^3 \text{ kPa}$ and 27°C . The temperature is lowered to -183°C and pressure is increased to $2 \times 10^3 \text{ kPa}$.

Determine the new volume of the gas.

- (b) (i) State the kinetic theory of gases and its assumptions.
(ii) Distinguish between real and ideal gas.

Answer

- (a) (i) Universal gas law states that

$$\frac{PV}{T} = R, \text{ where } R \text{ is the universal gas constant. From this, } \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\text{(ii)} \quad V_1 = 20 \text{ l}$$

$$P_1 = 1 \times 10^6 \text{ Nm}^{-2}$$

$$T_1 = 300 \text{ K}$$

$$V_2 = ?$$

$$P_2 = 2 \times 10^6 \text{ Nm}^{-2}$$

$$T_2 = 90 \text{ K}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2}$$

$$= \frac{1 \times 10^6 \times 20 \times 90}{300 \times 2 \times 10^6}$$

$$= 3 \text{ litres}$$

- (b) (i) Molecules in gases are in constant random motion colliding with one another and the walls of the container in which they are constrained.

- (ii) The assumptions are:

- For a given gas, molecules are identical.
- The molecules collide with each other and the walls of the container without losing their

kinetic energy (perfect elastic collision).

- As molecules collide, they do not exert force on each other and move in straight lines and constant speed randomly.
 - A gas contains many molecules whose sizes are negligible compared to their separation.
 - Newton's laws of motion apply.
- (iii) An ideal gas is imaginary gas made up of molecules of mass with no volume. The molecules are believed not to attract each other. Ideal gases obey the equation
- $$\frac{PV}{T} = k.$$

In real gases, an increase in pressure does not cause proportional decrease in volume. Forces of cohesion are felt more significantly at low temperature—real gas at low temperature changes to liquid or even solid.

Revision Exercise 28

- Explain what happens to the density of a fixed mass of a gas when temperature is decreased:
 - At constant pressure.
 - At constant volume.
- In an experiment to verify Charles' law, the following results were obtained:

| | | | | | | |
|----------------------|----|----|----|----|----|-----|
| V (cm ³) | 31 | 33 | 35 | 38 | 40 | 43 |
| T (°C) | 0 | 20 | 40 | 60 | 80 | 100 |

- Draw a graph of V against T and explain how it verifies the law.
 - Determine the gradient K of the graph and suggest what it represents.
 - From the graph, find the value of V_1 at temperature $T_1 = 298$ K, and V_2 at temperature $T_2 = 338$ K. Establish whether $\frac{V_1}{T_1} = \frac{V_2}{T_2}$.
3. Air is trapped in a container at 27°C and 100 kPa. If the air is then heated to a temperature 87°C;
- Use the kinetic theory of gases to explain the change in pressure.
 - Determine the new pressure.
4. (a) (i) State the general gas equation.
(ii) Distinguish between real and ideal gas.
(iii) State at least two assumptions of the kinetic theory of gases.
- (b) In an experiment involving a fixed mass of a gas, the temperature is doubled while volume is halved. What is the new pressure and density of the gas?

UNIT**29****Thin Lenses****Key Points**

- A lens refracts (bends) light, resulting in a converging, diverging or parallel beam. Lenses may be made of glass, plastic or even liquid (for example, water droplets). Most lenses are spherical in nature, with the curved surfaces being parts of spheres.
- A lens is considered thin if its thickness is negligible compared to the focal length.
- Lenses are either convex (converging) or concave (diverging), as in the figures below.

Bi-convex



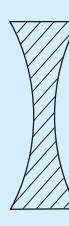
Piano-convex



Converging meniscus

*Converging lenses*

Bi-concave



Piano-concave



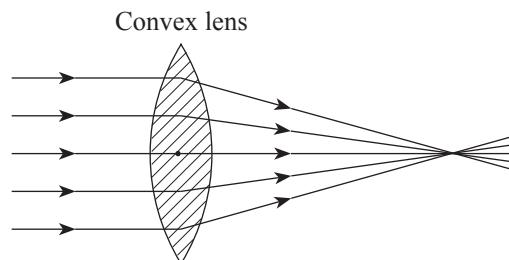
Diverging meniscus

*Diverging lenses***Revision Questions 29**

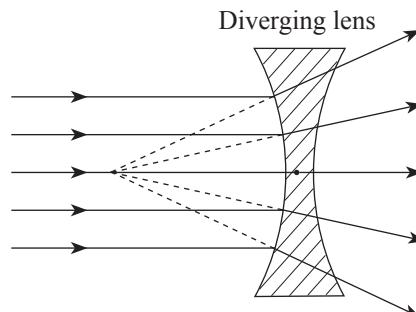
- Using diagrams, distinguish between converging and diverging lenses.

Answer

Converging (convex) lenses are thickest in the middle and thinnest at the edges. A parallel beam of light passing through a convex lens will be brought to a focus, as in the diagram below.



Diverging (concave) lenses are thinnest in the middle and thickest at the edges. A parallel beam of light passing through a concave lens will be diverged (spread out) as in the diagram below.

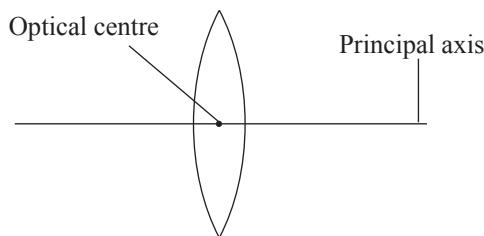


- (a) Define the terms principal axis and optical centre as applied to a lens.
(b) Using a ray diagram, distinguish between the principal focus and focal length of a lens.

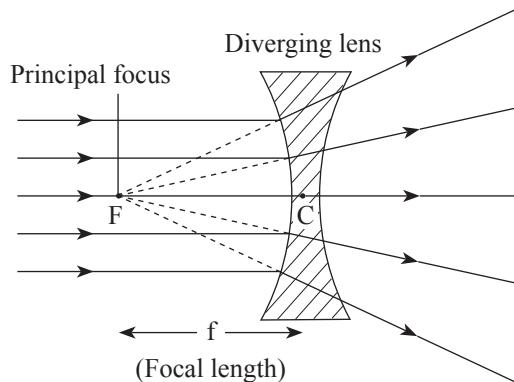
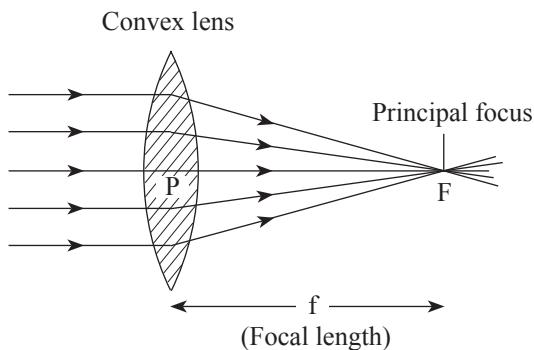
Answer

- (a) The principal axis of a lens is the line joining the centres of curvature of its surfaces.

The optical centre or the pole of a lens is its geometrical centre. The diagram below shows the principal axis and optical centre of a lens.



- (b) The principal focus F of a lens is the point on the principal axis to which all rays parallel and close to the principal axis converge (convex lens), or from which they appear to diverge (concave lens), after passing through the lens. A lens has two principal foci. The focal length f of a lens is the distance between its optical centre and the principal focus F , as shown in the diagram below.



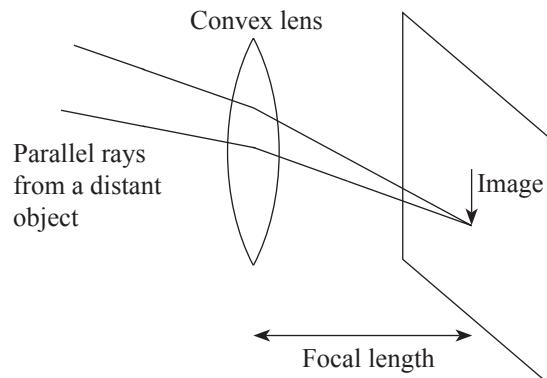
Note: The focal length of a convex lens is real while that of a concave lens is virtual.

3. Describe an experiment to:

- Find an approximate value of focal length of a convex lens.
- Determine accurately the focal length of a convex lens.

Answer

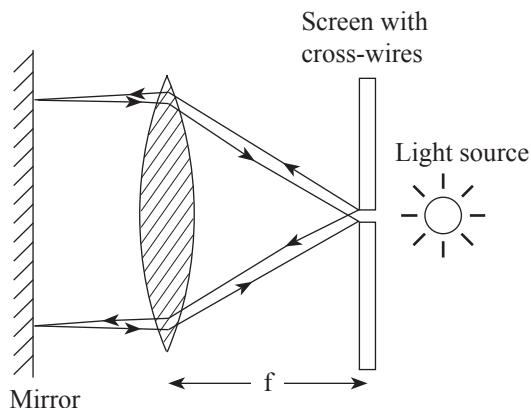
- (a) This experiment can be done out in the open, or next to the class window. A convex lens is held so that a sharp image of a distant object is focused on a screen, as below.



The distance between the lens and the screen is then the focal length of the lens.

(b) (i) *Using illuminated object and plane mirror*

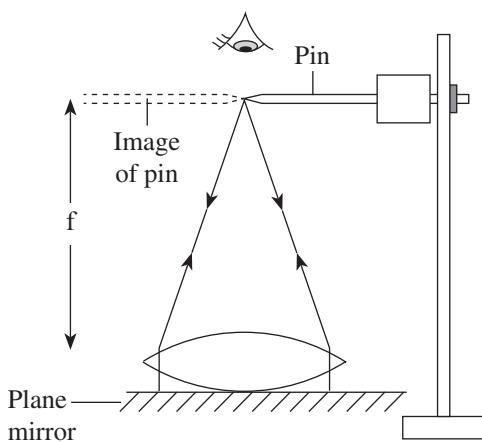
A light source (for example, a small electric lamp) is placed behind a screen with a hole and cross-wires, and a convex lens and plane mirror positioned on the other end, as below.



The lens position is adjusted until a sharp image of the cross wires is formed on the screen next to the cross wires themselves. In this situation, the object (cross wires) is on the focal plane of the lens. The distance f between the screen and the lens is then the focal length of the lens.

(ii) *Using a pin and a plane mirror*

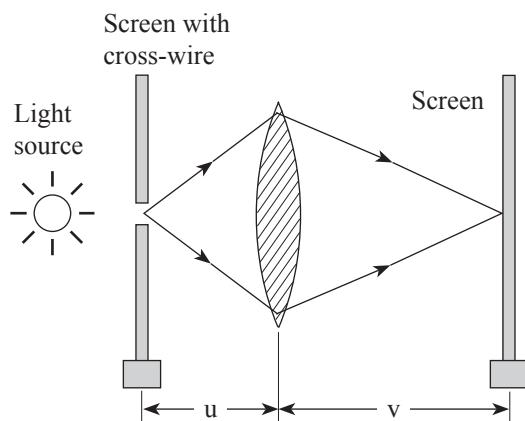
A pin is positioned above a lens placed on a plane mirror as in the figure below.



The position of the pin (object) is adjusted up and down until there is no parallax between it and its image. The distance between the pin and the mirror is then the focal length of the lens.

(iii) *Lens formula method*

With cross wires as the object as in the diagram below, the position of the lens and the screen are varied so that a real image is formed on a screen on the opposite end.



Several pairs of object distance u and image distance v are obtained for different lens positions, and these are entered in a table, as below.

| u (cm) | v (cm) | $\frac{1}{u}$ | $\frac{1}{v}$ | $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ |
|----------|----------|---------------|---------------|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Mean value of $\frac{1}{f}$ _____

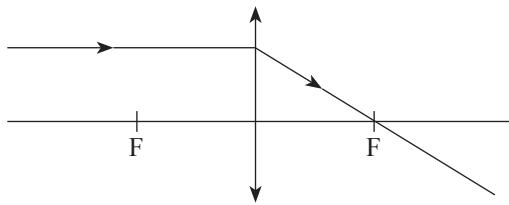
The average value of focal length of the lens is thus obtained.

4. (a) Using appropriate diagrams, describe the three main types of rays used to locate the image formed by a:
- converging lens.
 - diverging lens.
- (b) An object 1.2 cm tall is positioned on the principal axis of a converging lens of focal length 10 cm, at a distance of 16 cm from the lens. Using graphical construction, find the position, size and nature of the image formed.

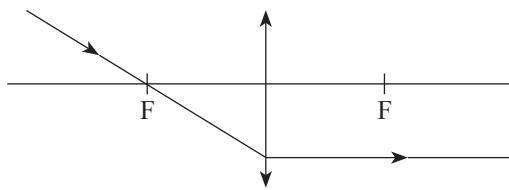
Answer

(a) (i) The three important rays used in the location of images formed by converging lenses are:

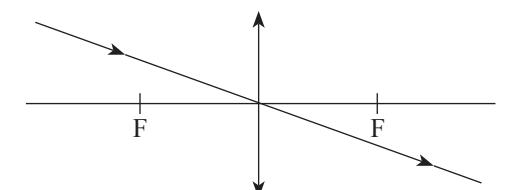
A ray parallel to the principal axis. This passes through the principal focus after refraction in the lens, see the figure below.



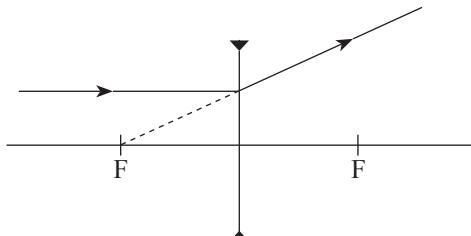
A ray through the principal focus. This emerges parallel to the principal axis after refraction through the lens, as below.



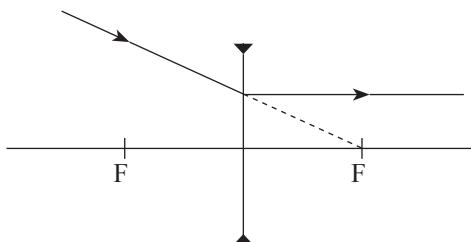
A ray through the optical centre. This proceeds undeviated, see the diagram below.



- (ii) A ray parallel to principal axis. This appears to diverge from F.

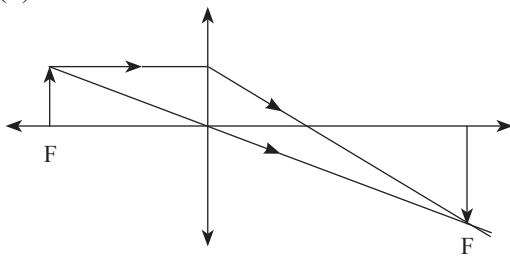


A ray that appears to pass through the principal focus. This is refracted parallel to the principal axis.



A ray through the optical centre at the lens. As with the convex lens, this ray emerges undeviated.

(b)

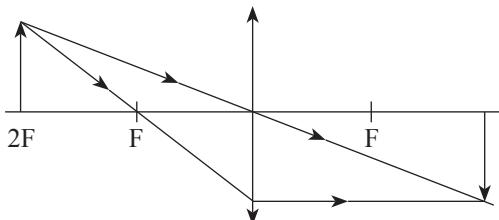


5. Describe the nature, size and distance of image formed by a convex lens for each of the following cases:

- Object at 2 F.
- Object between F and 2 F.

Answer

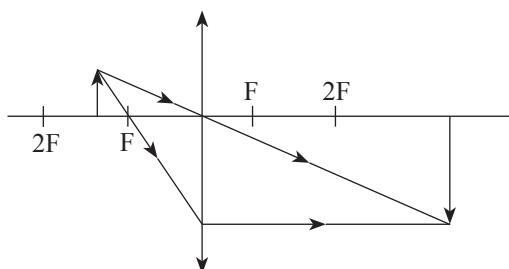
(a) Object at $2F$.



The image is:

- (i) Formed at $2F$.
- (ii) Real.
- (iii) Inverted.
- (iv) Same size as the object.

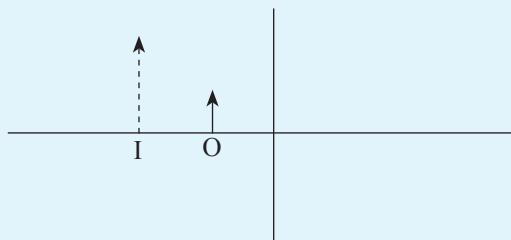
(b) Object between F and $2F$.



The image is:

- (i) Formed beyond $2F$.
- (ii) Real.
- (iii) Inverted.
- (iv) Larger than the object.

6. (a) The diagram below shows an object O and the image I it forms through a lens.



- (i) State the type of lens used.

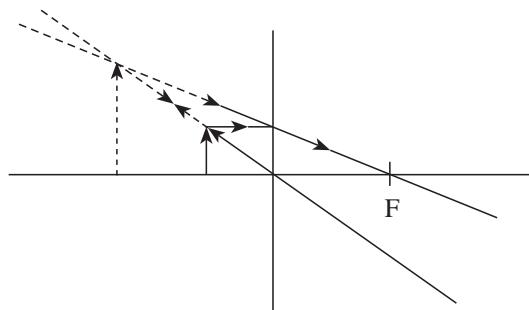
(ii) Using ray diagrams, locate the position of the principal focus F .

(b) State one practical application of the arrangement above.

Answer

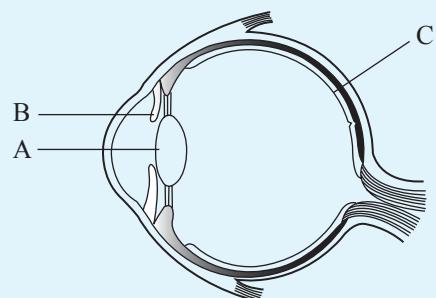
(a) (i) Convex lens

(ii)



(b) A practical application of the above is the use of a convex lens, as a simple microscope or magnifying glass.

7. The diagram shows the human eye.



Name the parts labelled A, B and C and state their functions.

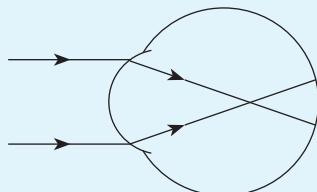
Answer

Part A is the lens, B the iris and C the retina.

The lens refracts and focuses the light traversing it, thus forming the image on the retina. The iris adjusts the size of

the pupil (the opening that admits light) according to the intensity of incident light i.e., the stronger the light, the smaller the pupil. The iris therefore controls the amount of light entering the eye. The retina acts as the ‘screen’ on which the image is formed. It is made up of complex receptors, known as rods and cones, that are capable of converting the light into electrical signals that are transmitted to the brain so as to decipher the image.

8. The figure below illustrates an eye defect:

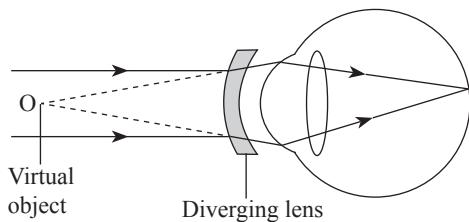


- (a) Identify the defect.
 (b) Show by using a diagram how the defect can be corrected.

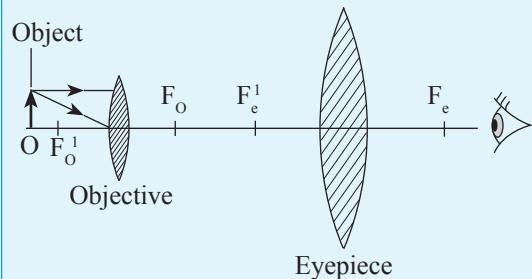
Answer

- (a) The defect is short sightedness or myopia.
 (b) Myopia is corrected using diverging lenses which spread out the light incident to the eye, as in the figure below.

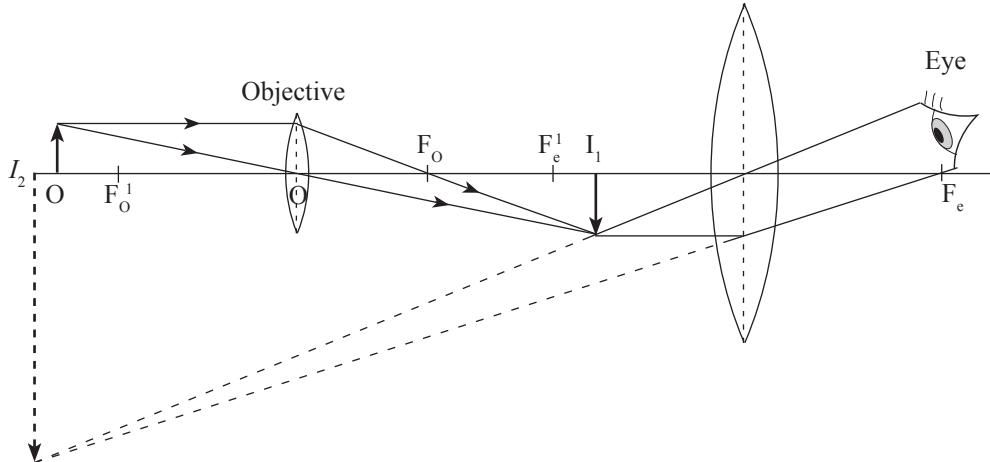
lenses which spread out the light incident to the eye, as in the figure below.



9. The diagram below shows a compound microscope with objective and eyepiece of principal foci F_o and F_e respectively. Complete the ray diagram to illustrate how the eye sees the final image.

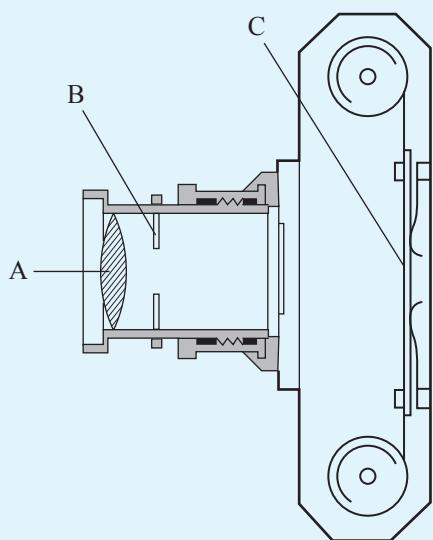


Answer 9



10. (a) Use a diagram to show how the simple microscope produces images.

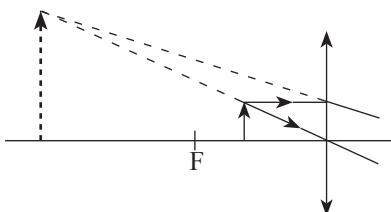
- (b) The diagram below shows a film camera:



- (i) Name the parts labelled A, B, C and state their functions.
(ii) State three similarities between the camera and the eye.

Answer

- (a) The simple microscope, also known as the magnifying glass, is a typical case of an object placed between the lens and the focal point of a converging lens as in the diagram below.



The image as seen by the observer is therefore virtual, erect and magnified (larger than the object).

- (b) (i) A is the lens, B the diaphragm and C the film.

The lens refracts the light and forms the image on the screen. The diaphragm controls the amount of light entering the camera and the film is the light-sensitive layer on which the image is formed.

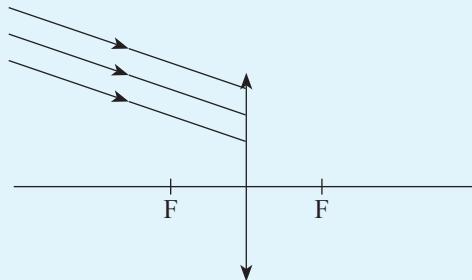
- (ii) Similarities between the camera and the eye:

- There is an opening for light to enter in both. In the eye, it is the pupil, in the camera it is the aperture.
- Both have mechanisms for controlling the amount of light entering. For the camera, the diaphragm controls the size of the aperture, in the eye, the iris does that.
- Both have a convex lens for refraction of light.
- Both have a screen on which the image is formed. The camera film has a layer of photosensitive chemicals on its surface while the eye has photoreceptors (rods and cones) on the retina.

Revision Exercise 29

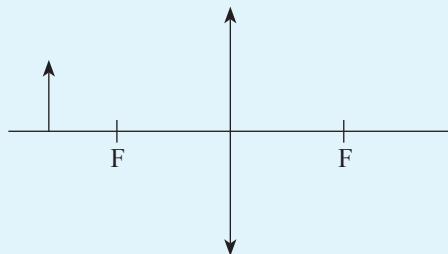
1. Describe the nature, size and distance of image formed by a convex lens for each of the following cases:
 - (a) Object beyond $2F$.
 - (b) Object at F .
2. (a) Using an appropriate diagram, illustrate what is meant by long sightedness.
(b) Show using a diagram how long sightedness can be corrected.

3. State three differences between the camera and the eye.
4. The figure below shows a parallel beam of rays incident on a convex lens whose principal focus F is shown:



5. An object is placed at a distance of 25 cm from a convex lens of focal length 10 cm. Determine by calculation:
- the image distance.
 - the magnification.

6. The incomplete diagram below shows an object placed in front of converging lens:



Complete the diagram to show the position of the image formed.

7. (a) An object of height 8 cm is placed 22 cm in front of a convex lens of focal length 9 cm. Determine:
- The distance of the image from the lens.
 - The height of the image.
- (b) State three characteristics of the image.

**UNIT
30**

Circular Motion

Key Points

- Uniform circular motion occurs when a body moves in a circular path at a constant speed.
- When a body describes a circular motion, it is kept in its path by centripetal force.
- When performing circular motion, a body accelerates without change of speed.

Revision Questions 30

1. (a) Define the terms angular displacement and angular velocity, stating the units.
(b) Distinguish between linear and angular velocity for a body moving in a circular path.

Answer

(a) Angular displacement, θ , is the angle through which point or a line has been rotated in a given direction, and about a given axis. The unit for angular displacement is radians.

Angular velocity, ω , is the change in angular displacement per unit time.

$$\text{i.e., } \omega = \frac{\Delta\theta}{\Delta t}$$

Angular velocity is measured in radians per second.

(b) Angular velocity is the angle swept out by the radius per unit time (measured in rads^{-1}), while linear velocity, v , is the speed of the body along the tangent to the circle at any instant (measured in ms^{-1}).

2. (a) A bucket of water is whirled in a vertical circle at a constant speed.

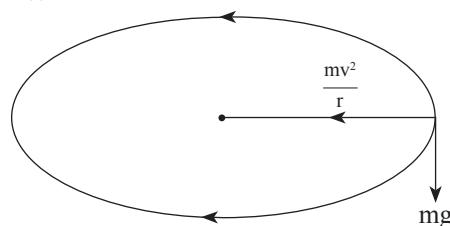
Explain why the water does not spill out when the bucket is upside down.

- (b) A stone attached at the end of a string is whirled in a horizontal circle.
- (i) Sketch the forces acting on the string.
 - (ii) Explain the forces that act on the string.

Answer

(a) The speed of the bucket is such that the centripetal force generated $\left(\frac{mv^2}{r}\right)$ is sufficient to overcome gravitational pull (mg). The bucket, therefore, arrests the water before it can fall off. The arm holding the string provides the centripetal force required to keep the bucket in motion. Thus, as long as the weight mg of the water and bucket is less than the centripetal force $\frac{mv^2}{r}$, the water stays without spilling off.

- (b) (i)



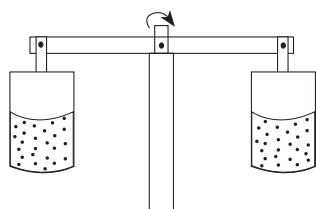
(ii) The forces acting on the stone are centripetal force $\frac{mv^2}{r}$, where m is the mass of the stone, v its speed and r

the length of the string (or radius of the path), and the weight mg .

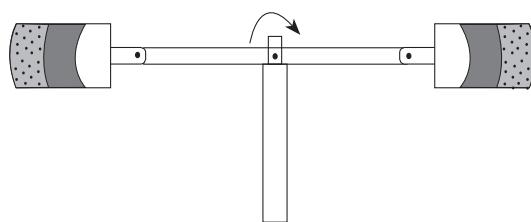
3. Explain the following applications of circular motion:
- Centrifuge.
 - Banked track.
 - Space shuttle.
 - Stone whirled in a vertical circle.

Answer

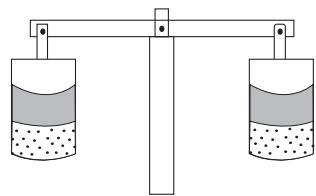
- (a) Centrifuges are used for separating solids that are suspended in liquids, or liquids with varying densities. The diagrams below show the centrifuge at rest, when rotating at high speed and at rest after rotation, with the components of the mixture separated.



Centrifuge at rest (before rotation)



Centrifuge rotating at high speed



Centrifuge at rest after rotation

As the centrifuge rotates, the matter with

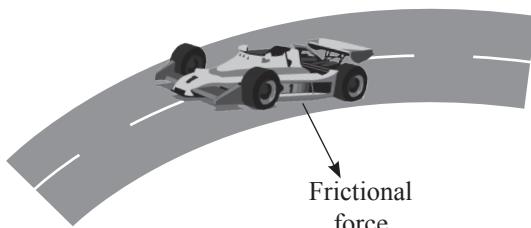
lower density moves toward the centre of the circular path while the denser matter moves away from the centre. When the centrifuge is stopped, the tubes settle in vertical position, with the material of lower density at the top.

When the centrifuge is in rotation, the closed ends of the tubes supply centripetal force towards the centre of the circular path. For particles of lower density in the mixture, the force has a higher impact thus displacing them closer to the centre leaving the denser matter on the outer end.

Centrifuges are used:

- For drying clothes.
- In water and waste-water treatment for drying sludge.
- In the oil industry, for removing solids from the drilling fluid.
- For removing cream from milk.
- As human centrifuges, for training astronauts.

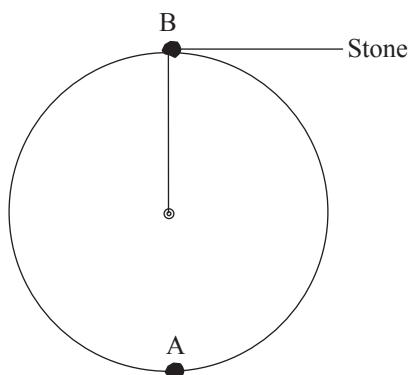
- (b) When a car is going round a circular bend at a constant speed, the centripetal force on it is directed towards the centre of the circle. This force is provided by frictional force acting inwards on the tyres of the car. The figure below illustrates this.



To prevent skidding, the tyres and the road surface must be able to provide sufficient friction, so that centripetal force is sufficient. To enable vehicles to negotiate bends without necessarily

relying on friction, roads are banked at an angle, so that the side towards the centre of the circular path is lower while the outer side is raised.

- (c) For a space shuttle, shown below, the centripetal force once it is launched into space is provided by the earth's gravitational pull. However, since the shuttle is moving parallel to the surface of the earth, it cannot be dragged to the earth's surface, and therefore continues orbiting the earth in the same path.
- (d) Consider the stone tied to a string and whirled in a vertical circle as in the diagram below.



Unlike the case of a stone whirled in a horizontal circle, the tension in the string is not uniform.

At the highest point B, tension T in the string is given by:

$$T + mg = \frac{mv^2}{r}$$

$$\text{Thus, } T = \frac{mv^2}{r} - mg$$

At the same (highest) point, the minimum speed for the string to remain taut (i.e., $T = 0$) is

$$0 = \frac{mv^2}{r} - mg$$

$$\frac{mv^2}{r} = mg$$

$$\text{so, } v = \sqrt{rg}$$

At the lowest point A, tension T in the string is given by:

$$T - mg = \frac{mv^2}{r}$$

$$\text{So, } T = mg + \frac{mv^2}{r}$$

It is at this point, therefore, that the string is most likely to snap for a given speed of rotation.

Revision Exercise 30

Where necessary, take $g = 10 \text{ m/s}^2$.

1. Define uniform circular motion, giving examples.
2. An object moving at a speed of 15 m/s in a circular path PQ of radius 10.5 cm traverses an angle of 120° at the centre of the circle. Calculate the:
 - (a) time the body will take to travel from P to Q.
 - (b) average velocity of the body.
 - (c) average acceleration.
3. A stone weighing 450 g is tied to the end of a string of length 60 cm and whirled in a horizontal circle. Calculate the velocity of the stone if the tension in the string is 90 N.
4. A point on a rotating turntable moving in a circle of radius 25 cm makes 10 revolutions per second. Determine its:
 - (a) angular velocity.
 - (b) centripetal acceleration.
5. A vehicle weighing 1.2 tons moving on a flat circular track of radius 30 m experiences a force of friction between its tyres and the tarmac of 3500 N. Determine the maximum speed at which the vehicle can be driven without skidding. Find the

velocity of the wheel at a point on its circumference.

6. (a) Explain the meaning of the term centripetal force. Give an example of application of the force.
(b) A stone of mass 400 g is attached to a string of length 2.5 m and whirled in a horizontal circle at a constant speed of 15 ms^{-1} . Calculate the angular velocity of the stone and the tension in the string.
(c) The stone is now whirled at the same speed in a vertical circle without changing the length of the string. Find

the maximum and minimum tension in the string.

7. A turntable of diameter 15 cm, rotates in a horizontal plane at a speed of 900 revolutions per minute. A small stone X weighing 50 g is placed on the edge of the turntable. Calculate the:
 - (a) angular velocity of X.
 - (b) acceleration of X.
 - (c) maximum angular velocity at which the X will remain on the turntable without flying off.

UNIT**31**

Floating and Sinking

Key Points

- When a body is in a fluid, the displaced fluid sets up forces to counter the body's weight.
- For a body to float, its average density must be less than the density of the fluid.

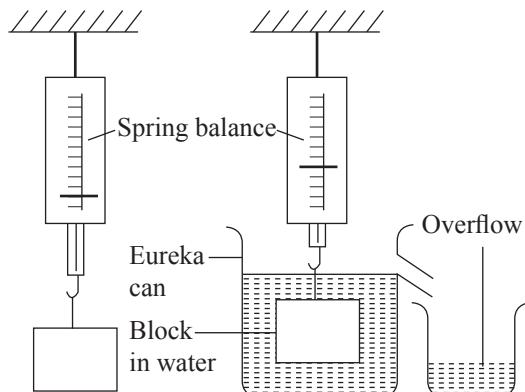
Revision Questions 31

- A student is given the following apparatus to carry out an experiment to verify Archimedes' principle: a spring balance, a Eureka can, a beaker, a weighing balance, water in a container and a 500 g metal block.
 - State Archimedes' principle.
 - Show the set-up of apparatus to be used.
 - State the measurements to be taken.

Answer

- (a) Archimedes principle states that when a body is partially or fully immersed in a fluid, it experiences an upthrust force equal to the weight of fluid displaced.

(b)



- (c) Measurements taken:

- Weight of block in air.
 - Weight of block when partially immersed.
 - Weight of overflow when block is partially immersed.
 - Weight of block when fully immersed.
 - Weight of overflow when block is fully immersed.
- A metal block of mass 500 g has an apparent weight of 4.4 N when fully immersed in water. Determine the:
 - upthrust force on the block.
 - volume of the block.
 - relative density of the block.

Answer

$$\text{(a) Weight in air} = \frac{500}{1000} \times 10 \\ = 5 \text{ N}$$

$$\text{Upthrust} = \text{weight in air} - \text{weight in water} \\ = 5.0 - 4.4 \\ = 0.6 \text{ N}$$

$$\text{(b) Volume of block} = \frac{\text{volume of water displaced}}{10} \\ \text{where weight of water displaced} = 0.6 \text{ N} \\ \text{Mass of water displaced} = \frac{0.6}{10} \\ = 0.06 \text{ kg}$$

$$\text{Volume of water displaced} = \frac{\text{mass}}{\text{density}}$$

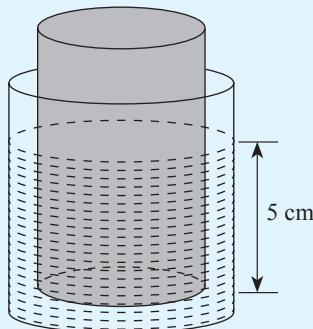
$$= \frac{0.06}{1000} \\ = 6 \times 10^{-5} \text{ m}^3$$

$$= \frac{0.15}{10} \\ = 0.015 \text{ kg}$$

(c) Relative density

$$\begin{aligned} &= \frac{\text{weight of block}}{\text{weight of equal volume of water}} \\ &= \frac{5.0}{6.0} \\ &= 8.333 \end{aligned}$$

3. (a) State the law of flotation.
 (b) A cylindrical wooden block of cross-section area 3 cm^2 and height 8 cm floats in water at a depth of 5 cm, as in the diagram below.



Given that the density of water is 1000 kg/m^3 , determine the mass of the block.

Answer

(a) The law of flotation states that a floating body displaces its own weight of fluid in which it floats.

(b) Block floats, hence;
 weight of block = upthrust

$$= 1000 \times 3 \times 10^{-4} \times 5 \times 10^{-2} \times 10 \\ = 0.15$$

$$\text{Mass of block} = \frac{W}{g}$$

4. Glycerine has relative density of 1.25.

- (a) Define the term relative density.
 (b) If 15 cm^3 of water has a mass of 15 g, what will be the mass of 15 cm^3 of glycerine?
 (c) An object of relative density 7.9 experiences an upthrust of 4.5 N when fully immersed in water. Calculate the:
 (i) actual weight of the object
 (ii) volume of the object.

Answer

(a) Relative density is the ratio of density of a material to that of water.

(b) Relative density

$$\begin{aligned} &= \frac{\text{mass of material}}{\text{mass of equal of volume of water}} \\ 1.25 &= \frac{\text{mass of glycerine}}{15} \end{aligned}$$

$$\begin{aligned} \text{Mass of } 15 \text{ cm}^3 &= 15 \times 1.25 \\ \text{of glycerine} \\ &= 18.75 \text{ g} \end{aligned}$$

(c) (i) Relative density = $\frac{\text{actual weight}}{\text{upthrust in water}}$

$$7.9 = \frac{\text{Actual weight}}{4.5}$$

$$\text{Actual weight} = 35.55 \text{ N}$$

(ii) Upthrust = 4.5 N

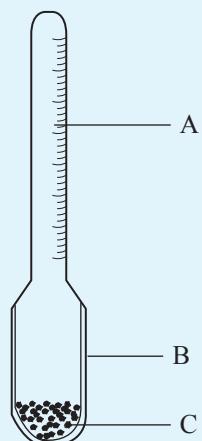
Mass of water displaced

$$= \frac{\text{weight of water displaced}}{g}$$

$$\frac{4.5}{10} = 0.45 \text{ kg}$$

$$\begin{aligned}\text{Volume} &= \frac{\text{mass}}{\text{density}} \\ &= \frac{0.45}{1000} \\ &= 4.5 \times 10^{-4} \text{ m}^3 \\ &= 450 \text{ cm}^3\end{aligned}$$

5. The figure below illustrates the main features of a hydrometer:



- (a) State the use of the instrument.
- (b) Label and explain the functions of the parts
A: _____
B: _____
C: _____
- (c) What would be the effect on the scale if:
(i) B was made wider.
(ii) A was made narrower.
- (d) Describe how the scale is marked on the instrument.

Answer

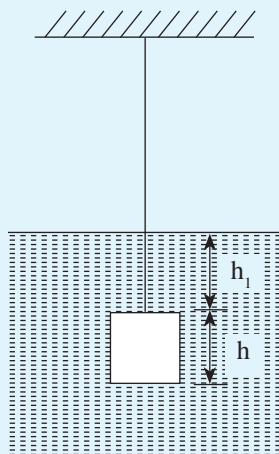
- (a) Hydrometer is an instrument for measuring the density of a liquid.
- (b) A: Stem: It is made narrow to allow for

large changes in level of floating for slight changes in density of liquid, hence giving an accurate scale.

- B: Bulb: It is made wide, so as to displace a large volume of liquid to obtain upthrust for floating.
- C: Lead shot: The lead shot increases the weight at the bottom, thus making it more stable for vertical balancing.
- (c) (i) If B is made wider, the hydrometer will float at a shallower depth.
- (ii) If A is made narrower the markings become farther apart for the same change in density giving a more accurate scale.
- (d) Take liquids of known relative densities, for example, water (1.0), paraffin (0.8), glycerine (1.25).

Float the instrument in each liquid on its turn and mark the floating level with the corresponding value of relative density. Note that the floating height is inversely proportional to density.

6. The figure shows a rectangular block suspended at a depth h_1 in a liquid of density ρ .



If the cross-section area is A and the block is of height h, write expressions for:

- (a) the liquid pressure on the top face.
- (b) the liquid pressure on the bottom face.
- (c) force on the top face.
- (d) force on the bottom face.
- (e) net force on the block. What is the significance of this force?

Answer

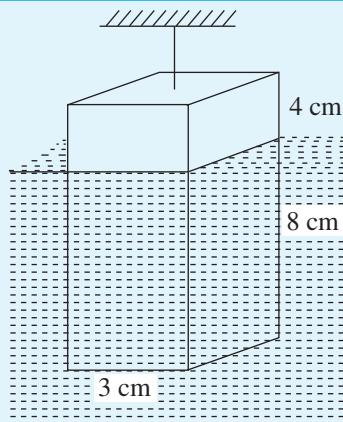
- (a) Liquid pressure on top face = $\rho h_1 g$
- (b) Liquid pressure on bottom face = $\rho(h_1 + h)g$
 $= \rho h_1 g + \rho hg$
- (c) Force on top face = pressure \times area
 $= \rho h_1 g A$
- (d) Force on bottom face = $A(\rho h_1 g + \rho hg)$
 $= \rho h_1 g A + \rho hg A$
- (e) Net force = $\rho h_1 g A + \rho hg A - \rho h_1 g A$
 $= \rho hg A$

But hA = volume of block
= volume of liquid displaced

Thus, $\rho hg A$ is the weight of liquid displaced.

Therefore, upthrust equals weight of liquid displaced.

7. A rectangular solid block is suspended on a string such that $\frac{3}{4}$ of its height lies in a liquid of density $1\ 300\ \text{kg/m}^3$, see the following figure.



- (a) Determine the upthrust on the block.
(b) Given that the block has a mass of 856 g, determine the tension in the string.

Answer

- (a) Upthrust on the block equals weight of the liquid displaced;
- $$\text{Upthrust} = \frac{3}{4} \times 8 \times 3 \times 4 \times 10^{-6} \times 1\ 300 \times 10$$
- $$= 0.936\ \text{N}$$

(b) Tension + upthrust = weight
 $T + 0.936 = 8.56$
 $T = 7.624\ \text{N}$

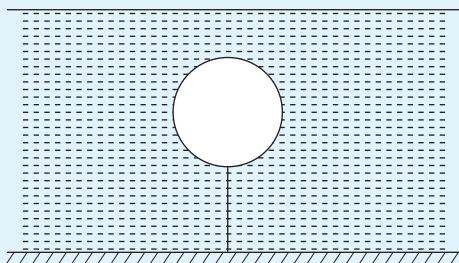
8. Explain how the following work:
- (a) A hot air balloon.
 - (b) Submarine.
 - (c) A hydrogen balloon.

Answer

- (a) In the hot air balloon, the hot air inside is less dense than the surrounding air. The upthrust U from the displaced air overcomes the weight mg of balloon plus cargo, giving it acceleration upwards.

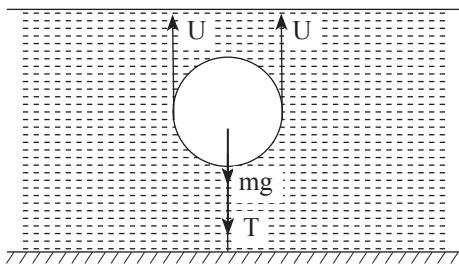
- (b) A submarine has ballast tanks which, when filled with water, raises the average density of the vessel, making it sink. To bring it afloat, the water is pumped out of the tanks.
- (c) In the hydrogen balloon, density of hydrogen (0.09 kg/m^3) is less dense than that of air (3 kg/m^3), hence the displaced air creates a net upward force on the balloon.

9. The figure below shows a body held below the surface of water by a cable fixed at the bottom:

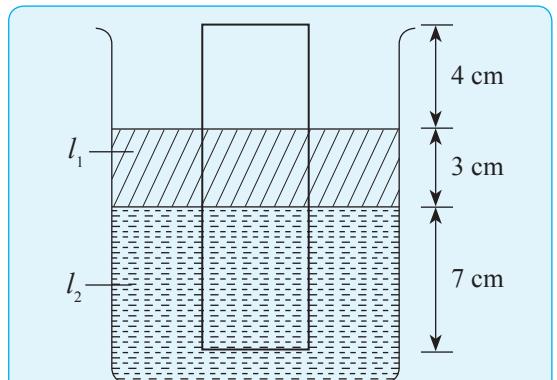


Label and indicate the forces acting on the body.

Answer



10. The figure below illustrates how a rectangular object cross-section area 4.5 cm^2 and height 14 cm floats in a beaker containing two immiscible liquids l_1 and l_2 of densities $1\ 000 \text{ kg/m}^3$ and $1\ 200 \text{ kg/m}^3$ respectively.



Study the diagram and determine the:

- (a) total upthrust on the object.
(b) density of the object.

Answer

$$\begin{aligned}\text{(a) Upthrust by } l_1 &= \text{volume in } l_1 \times \text{density} \times g \\ &= 3 \times 4.5 \times 10^{-6} \times 1000 \times 10 \\ &= 0.135 \text{ N}\end{aligned}$$

$$\begin{aligned}\text{Upthrust by } l_2 &= 7 \times 4.5 \times 10^{-6} \times 1200 \times 10 \\ &= 0.378 \text{ N}\end{aligned}$$

$$\text{Total upthrust} = 0.513 \text{ N}$$

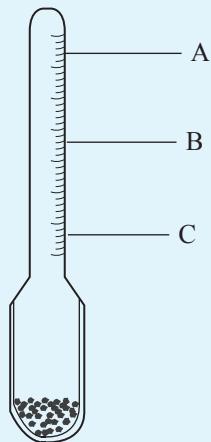
$$\begin{aligned}\text{(b) Volume of block} &= (7 + 3 + 4) \times 4.5 \times 10^{-6} \\ &= 63 \times 10^{-6} \text{ m}^3 \\ \text{Mass of block} &= \frac{\text{weight}}{g} \\ &= \frac{0.513}{10} \\ &= 0.0513 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Density of block} &= \frac{\text{mass}}{\text{volume}} \\ &= \frac{0.0513}{63 \times 10^{-6}} \\ &= 814.3 \text{ kg/m}^3\end{aligned}$$

Revision Exercise 31

1. A balloon filled with $1\ 500\ m^3$ of hydrogen is held to the ground by a tight rope. The balloon fabric plus other carriage contribute a total mass of 520 kg.
 - (a) Taking the densities of hydrogen and the surrounding air as $0.09\ kg/m^3$ and $1.28\ kg/m^3$ respectively, determine the:
 - (i) mass of hydrogen.
 - (ii) upthrust on the balloon.
 - (b) What will be the initial acceleration of the balloon when the rope is cut?
2. Large boulders of stone are easily moved downstream when a river overflows its banks. Explain.
3. State and explain the change that occurs to the level of floating of a ship as it crosses from fresh to salt water body.

4. The figure below shows a hydrometer with three points shown on its scale. Given that the three marks stand for the relative density values 1.0, 1.20 and 0.8. Indicate correctly the positions of these values.



UNIT**32**

Electromagnetic Spectrum

Key Points

- Electromagnetic waves are waves that carry electric and magnetic fields interacting at right angles to each other and to the direction of propagation.
- Electromagnetic spectrum is a continuous arrangement of electromagnetic waves in order of frequency or wavelengths.

Revision Questions 32

1. (a) List the individual radiations in the electromagnetic spectrum in order of decreasing wavelengths.
(b) Why is the electromagnetic spectrum referred to as a continuous spectrum.

Answer

- (a) Radio waves (between 10^5 – 10^{-3} m), infra-red (10^{-3} – 10^{-6} m), visible light (10^{-6} – 10^{-7} m), ultra-violet (10^{-7} – 10^{-9} m), X-rays (10^{-9} – 10^{-11} m) and gamma rays (10^{-11} – 10^{-14} m).
(b) This is because there are no distinct boundaries between any two neighbouring radiations, that is, the frequencies overlap at the boundaries.
2. State any five properties of electromagnetic waves.

Answer

- (i) They are transverse waves in nature, and travel at the speed of light ($c = 3.0 \times 10^8$ m/s) in vacuum.
- (ii) Under suitable conditions they obey all properties of waves; reflection,

refraction, diffraction, interference and polarisation.

- (iii) They do not require material medium for transmission (can travel through vacuum).
 - (iv) All the radiations obey the wave equation $c = f\lambda$, and possess energy in different amounts according to the relation $E = hf$, where h is Planck's constant and f the frequency of the wave.
 - (v) They carry no charge, hence are not affected by electric and magnetic fields.
 - (vi) Their intensity at a given point is inversely proportional to square of distance from the source.
3. (a) A certain radio station transmits broadcast at a frequency of 96.3 MHz. Calculate the wavelength of its radio waves.
(b) Given that the wavelength of red light is 4×10^{-7} m, calculate:
 - (i) its frequency.
 - (ii) the energy it possess. (Take $c = 3.0 \times 10^8$ m/s and $h = 6.63 \times 10^{-34}$ Js).

Answer

- (a) Given that $c = f\lambda$

$$\begin{aligned}\lambda &= \frac{c}{f} \\ &= \frac{3 \times 10^8}{96.3 \times 10^6} \\ &= 3.115 \text{ m}\end{aligned}$$

- (b) (i) From $c = f\lambda$

$$f = \frac{c}{\lambda}$$

$$= \frac{3 \times 10^8}{4 \times 10^{-7}}$$

$$= 7.5 \times 10^{14} \text{ Hz}$$

(ii) $E = hf$

$$= 6.63 \times 10^{-34} \times 7.5 \times 10^{14}$$

$$= 4.973 \times 10^{-19} \text{ J}$$

4. (a) Distinguish between the methods of production and detection of the following radiations:
- (i) Radio waves and microwaves.
 - (ii) Infra-red and ultra-violet radiations.
 - (iii) X-rays and gamma rays.
- (b) Other than the eye, state two detectors of visible light.

Answer

- (a) (i) Radio waves are produced by oscillating electrical circuits and detected by resonant circuits in radio receivers, while microwaves are produced by special vacuum tubes called magnetrons and are detected by crystal detectors or solid state diodes.
- (ii) Infra-red radiation is produced by the sun, fires or any hot body and is detected by thermometer with blackened bulb, the skin, thermopile or bolometer. Ultra-violet radiations are produced by the sun, sparks or mercury-vapour lamps, and detected by photographic films, photocells and fluorescent materials.
- (iii) X-rays are produced in X-ray tubes and detected by photographic films or fluorescent screen, while gamma rays are emitted by radioactive substances

and detected by photographic plates and radiation detectors like G-M tube and cloud chambers.

- (b) Other detectors of visible light include photographic films and photocells.

5. State the applications of the following electromagnetic radiations:

- (a) Radio waves.
- (b) Microwaves.
- (c) Infra-red radiation.
- (d) Ultra-violet radiation.
- (e) X-rays.

Answer

- (a) Radio-waves: In communications such as radio broadcasts, TV, satellite and cellular (mobile) phones.
- (b) Microwaves: Used in communication but much stronger than radio-waves because of their shorter wavelengths. Used in radar navigation, satellite communication, cooking (microwave cookers) and speed cameras.
- (c) Infra-red radiation: All hot objects generate infra-red waves and the radiation therefore has a heating effect. Infra-red is used:
- (i) in the treatment of muscular pains.
 - (ii) as heat sensor in burglar alarms, military equipment, photography and for fire-fighting.
 - (iii) Communication as remote controllers for electronic devices such as toys, TVs, radio and video players.
- (d) Ultra-violet radiation: For sterilization of medical equipment. Also used in:
- (i) security, to verify the authenticity of bank notes and documents.
 - (ii) fluorescent tubes and bulbs (glows).

- (iii) pest control and fly-traps.
 - (iv) stimulation of production of vitamin D (sunlight).
- (e) X-rays: This is a very high frequency radiation, used for:
- (i) medical purposes – Detecting fractures, malignant growth and foreign bodies in the body.
 - (ii) airport security – Scanning of luggage, etc.
 - (iii) detection of flaws in engineering.
6. State the hazards associated with some electromagnetic waves.

Answer

- Cancer, caused by UV, gamma rays and X-rays, due to damage of body cells.
- Gene mutation, caused by UV, gamma and X-rays.
- The eye (retina) can be damaged by UV.
- Sunburn caused by UV.

Revision Exercise 32

1. Consider the following types of waves; radio, UV, sound, blue light, X-rays and indigo light.
 - (a) Which wave is not an electromagnetic wave?
 - (b) Which wave has the shortest wavelength?
 - (c) Which wave has the lowest frequency?
 - (d) Which wave is unlikely to be detected by photographic method?
 - (e) Arrange the electromagnetic waves in order of increasing penetrating power.
2. What makes microwaves other than ordinary radio waves suitable for use in satellite communication?
3. A radio signal is transmitted at a frequency of 88.2×10^6 Hz. Calculate its wavelength (Take $c = 3.0 \times 10^8$ m/s).
4. Briefly explain how greenhouses become warm.
5. State the applications of visible light and gamma rays.

UNIT**33**

Electromagnetic Induction

Key Points

- A changing magnetic field linked with a conductor induces an electric current in the conductor.
- The direction of induced current is always such that it opposes the change in magnetic field causing it.
- The direction of induced current can be determined using Fleming's right-hand rule.
- Mutual inductance occurs when two coils are placed close together such that a change in the magnetic flux in one induces current in the other. This is the principle applied in the working of transformers.
- Selfinductance occurs when an alternating magnetic flux due to a changing current in a coil induces a current in that coil.

Revision Questions 33

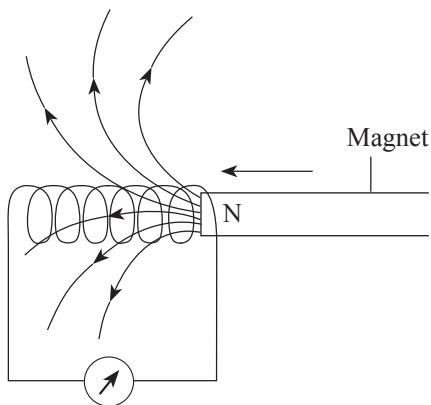
1. (a) State Faraday's law of electromagnetic induction.
(b) Describe an experiment to demonstrate induction of electric current in a conductor due to a changing magnetic field.
(c) A magnet is made to rotate inside a coil of several turns. State the factors that determine the amount of current induced in the coil.

Answer

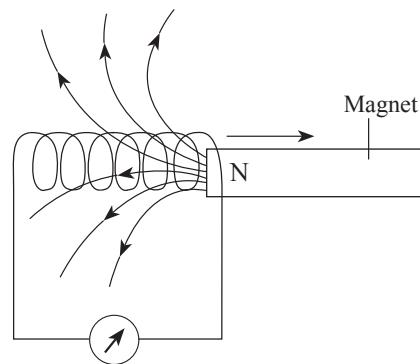
- (a) The magnitude of the induced emf is directly proportional to the rate of change of magnetic flux linkage.

- (b)
- A cylindrical coil is connected to the ends of a centre-zero galvanometer.
 - The pole of a magnet, say North pole, is then driven into the coil as in the diagram. The galvanometer deflects momentarily.

When the magnet is held stationary within the coil, no deflection is observed but when pulled out another deflection is seen in the opposite direction to the first. This shows that a changing magnet field linked with a conductor induces a current in it.



(i) Magnet driven into coil

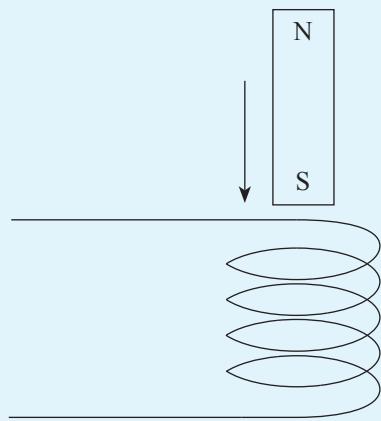


(ii) Magnet pulled out of coil

- (c) The strength of the current induced in the coil depends on:
- (i) The number of turns in the coil – the higher the number, the higher the induced current.
 - (ii) The strength of the magnet – the stronger the magnet, the higher the induced current.
 - (iii) The speed at which the magnet is rotated inside the coil – the higher the speed, the greater the induced current.

2. (a) State Lenz's law.

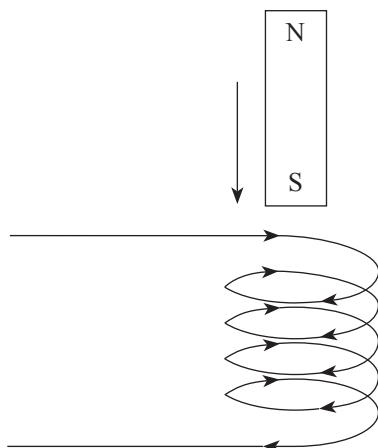
- (b) A magnet is driven into a coil as shown in the diagram below. State the polarity created at the end of the coil closer to the magnet. Hence, show the direction of flow of current in the coil.



Answer

- (a) Lenz's law states that the direction of the induced current is always such as to oppose the change producing it.

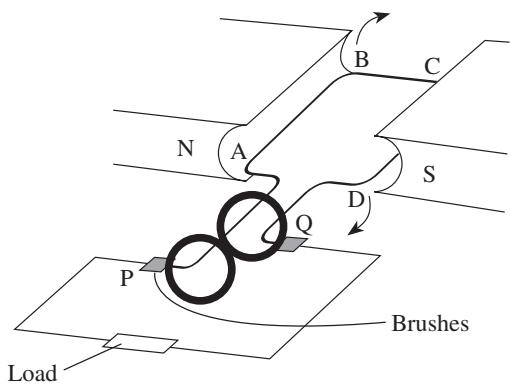
(b)



3. (a) State Fleming's right-hand rule.
- (b) Using a suitable diagram, describe the application of Fleming's right hand rule in the working of a simple alternating current generator.
- (c) Outline the adjustment that should be made on the generator in (b) above to make it produce direct current.
- (d) State two ways of increasing level of induced current in the coil.

Answer

- (a) If the thumb and the first two fingers of the right hand are held mutually at right angles with the first finger in the direction of field and the thumb pointing in the direction of motion, then the second finger points in the direction of induced current.
- (b) The diagram below shows a simple alternating current generator:



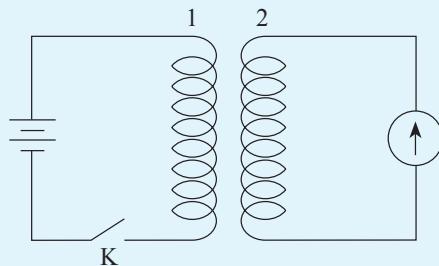
When the coil ABCD is turned clockwise as shown, the side AB of the coil moves up and the field is directed from left to right. Application of Fleming's right hand rule ends up with the second finger pointing in the direction AB. Current therefore flows in the direction ABCD in the coil, clockwise from Q to P in the external circuit.

When the coil turns through 180° so that side AB of the coil is now adjacent to the south pole of the magnet, current flows from B to A in the coil, but since AB is still linked to brush P, current flows anti-clockwise from P to Q in the external circuit. The end result is therefore a continually shifting direction of the induced current in the external circuit.

- (c) Replacing the slip rings with a split ring commutator, so that half-rings continually shift with the carbon brushes, thus maintaining the direction of current flow in the external circuit.
- (d) Current induced in the coil can be increased by:
 - (i) increasing the strength of the magnets.
 - (ii) increasing the speed of rotation of the coil.
 - (iii) increasing the number of turns in the coil.

4. (a) Explain what is meant by the term mutual inductance.

- (b) The diagram below shows two coils 1 and 2 of the same material and size placed close to each other. The first is connected to a power supply and the second to a centre-zero galvanometer.



- (i) State, with explanations, what happens to the galvanometer when the switch K is closed, and when opened again.
- (ii) Explain the effect of increasing the number of turns in coil 2.

Answer

- (a) Mutual inductance is said to occur when two coils (or circuits) are arranged in such a way that a change of current in one (primary coil/circuit) induces an electromotive force in the other (secondary coil/circuit).
- (b) (i) When switch K is closed, the galvanometer pointer in the secondary circuit deflects in one direction and in the opposite direction when the switch is opened.
- (ii) When K is closed, a build-up of electric current creates a varying magnetic field that cuts through the secondary coil, inducing a current in it. When the switch is opened, the current in the primary coil falls, and its magnetic field accordingly decreases. The induced current in the

secondary coil is as a result reversed, and the galvanometer deflects in the opposite direction.

(iii) Increasing the number of turns in coil 2 results in a stronger deflection on the galvanometer. This is due to increased flux linkage resulting from increased number of turns.

5. What are Eddy currents? Describe one positive use and one nuisance of Eddy currents.

Answer

Eddy currents are the induced currents that flow in a piece of metal when it is exposed to a varying magnetic field.

Positive uses of Eddy currents:

- Electromagnetic damping in moving coil instruments such as ammeter.
- Electromagnetic braking systems.
- Induction furnace for melting metals.

Eddy currents as a nuisance:

- Cause power losses in transformers and electric motors.
- Reduction of efficiency in high current AC cables.

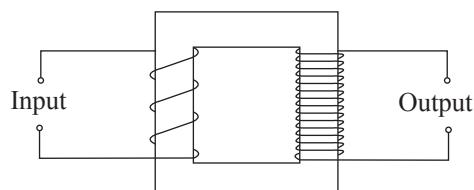
6. (a) Using a clearly-labelled diagram, explain the structure and working of a transformer.
(b) State and explain the main sources of power loss in a transformer. Explain briefly how power loss is minimised in each case.
(c) A transformer has primary and secondary coils with 300 and 1500 turns respectively. Calculate the voltage across the secondary if the primary coil is connected to a 20 V a.c. supply.

(d) A 95% efficient step-up transformer is connected to a 20 V supply and delivers 240 V on its output. Calculate the current in its primary coil when the output is connected to a 240 V 75 W lamp.

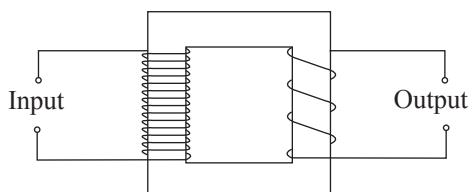
Answer

- (a) A transformer is made up of two insulated copper solenoids wound on a common soft iron core. An alternating voltage applied to the primary coil creates an alternating magnetic field, which links up with the secondary coil, inducing another alternating voltage whose value depends on the ratio of turns in the primary to the secondary coil.

There are two types of transformers, step-up and step-down transformers. In step-up transformer, the number of turns in the secondary coil is greater than that in the primary coil, resulting in the secondary (output) voltage being higher than the primary (input) voltage. In the step-down transformer the number of primary turns is greater than secondary turns, resulting in the output voltage being lower than the input voltage. The figure below represents the two types of transformers.



Step-up transformer



Step-down transformer

(b) The main sources of power losses in the transformer are as below:

- (i) Flux leakage – Not all magnetic flux generated in the primary coil is linked with the secondary coil.

This loss is minimised by efficient winding of coils in the transformer, with the secondary coil wound on top of the primary one, or the two coils wound side by side, close to each other. In both cases, the coils are wound on a common former (soft iron core).

- (ii) Resistance of the coils – The resistance of the coils causes heating, leading to considerable power loss.

This loss is minimised by the use of thick copper wires with very low resistance.

- (iii) Eddy currents in the core – The Eddy currents generate heat on the core, hence resulting in considerable power loss in the transformer.

Eddy current losses are minimised by the use of laminated core (thin soft iron plates insulated from each other).

- (iv) Hysteresis loss – This is heat lost in the process of magnetising and demagnetising the core when current changes direction.

Hysteresis loss is minimised by the use of a core of soft magnetic material that easily magnetises and demagnetises.

(c) The turns rule for the transformer:

$$\frac{\text{Secondary voltage}}{\text{Primary voltage}} = \frac{\text{Number of secondary turns}}{\text{Number of primary turns}}$$

Thus, the secondary voltage is V_s ,

$$\frac{V_s}{20} = \frac{1500}{300}$$

$$\text{So, } V_s = \frac{(1500 \times 20)}{300}$$

$$= 100 \text{ V}$$

- (d) Efficiency of $\frac{\text{power output}}{\text{power input}} \times 100\%$

$$= \frac{V_s \times I_s}{V_p \times I_p} \times 100\%$$

where V_s , I_s , V_p and I_p are secondary voltage, secondary current, primary voltage and primary current respectively.

For an ideal transformer,

power output = power input, so that;

$$V_s \times I_s = V_p \times I_p$$

Ideal transformers have an efficiency of 100:

95% efficiency implies:

Output power = 0.95 (input power)

$$\text{Thus, } 75 = 0.95(V_p \times I_p)$$

$$\begin{aligned} 75 &= 0.95 (20 \times I_p) \\ &= 19(I_p) \end{aligned}$$

$$\text{So, } I_p = \frac{75}{19}$$

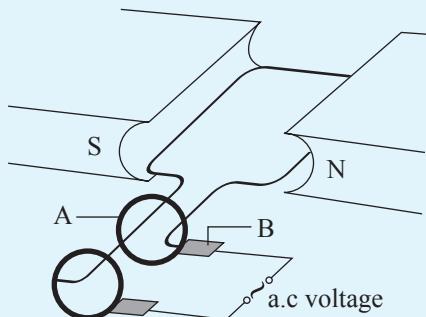
$$= 3.95 \text{ A}$$

Current in the primary coil is 3.95 A

Revision Exercise 33

- An ideal transformer with 4 000 turns in its primary coil and 800 turns in the secondary coil is connected to a 240 V a.c. source. It is established that the power in the secondary circuit is 1 000 W. Find the:
 - current in the secondary circuit.
 - current in the primary circuit.

2. (a) Describe a simple experiment to demonstrate Faraday's law of electromagnetic induction.
- (b) State the factors that determine the direction and magnitude of induced current in a coil.
3. A step-up transformer is designed to raise voltage from 18 V to 240 V. If the transformer is 95% efficient, find the current in its primary coil when the output is connected to a 240 V 150 W lamp.
4. The diagram below represents an alternating current generator.



- (a) Name the parts labelled A and B.
- (b) Sketch a graph of the electromotive force generated by the generator against time.
- (c) Explain the shape of the curve in (b) above.
5. (a) Explain how Faraday's laws of electromagnetic induction are applied in the construction and working of a transformer.
- (b) 80 kW of power is supplied to a manufacturing plant through cables of resistance $0.3\ \Omega$. Find the power lost in the cables if the voltage at the manufacturing plant is:
- (i) 240 V
- (ii) 11 000 V

UNIT**34**

Mains Electricity

Key Points

- Mains electricity broadly refers to supply of electrical power over a wide region.
- Mains electricity supply is effected through alternating current (a.c.). This is because a.c. can easily be stepped up or down with minimal power loss.

Revision Questions 34

1. State the common sources of mains electricity.

Answer

The main sources of mains electricity include hydro-electric sources (water in dams), geothermal sources, natural gas, coal or fossil oil, wind, solar and nuclear energy.

2. Describe the grid system of mains electricity.

Answer

In the grid system that is used in many countries, all power stations are linked together via high voltage cables before the power is distributed all over the country. The main advantage of this system is that power remains available even when one station breaks down or is shut down.

3. Various steps are involved in the transmission of mains electricity from the power station to the consumer.
(a) State the use of a step-up transformer.
(b) Explain why the power is transmitted at high voltage.

- (c) State the dangers of high voltage transmission.
- (d) State the advantages and disadvantages of overhead transmission cables over underground cables.
- (e) Overhead cables are mostly made of aluminium reinforced with steel.
 - (i) Explain why aluminium is preferred to copper, which is a better conductor.
 - (ii) Why is steel used?

Answer

- (a) Step-up transformer raises the generated voltage to the desired value before transmission.
- (b) High voltage implies low current, hence reduced power loss.
- (c) Dangers of high voltage transmission:
 - Risk of shock in case of contact with low-lying cables.
 - Risk of fire due to discharge on extra high tension cables.
 - Harmful electric fields (known as electric smog).
- (d) Advantages of overhead transmission cables over underground cables:
 - Cheaper to instal.
 - Faults are easily detected and repaired.Disadvantages of overhead transmission cables over underground cables:
 - Prone to damage resulting from severe weather conditions.

- The risk of emission of strong electromagnetic fields into the environment.
- (e) • Aluminium has a lower density than copper and therefore the cables are much lighter.
- Because of its strength. Aluminium is too weak to stand on its own.
4. Explain how power losses are minimised during transmission.

Answer

The power lost P during transmission is expressed by the formula $P = I^2R$, where I is the current flowing in the cables and R the resistance. Power loss, therefore, varies directly as the square of the current (I^2) and the resistance R of the cables. Additionally, from the transformer efficiency expression, $V_p I_p = V_s I_s$, very high output voltage will imply very low output (transmission) current. Overall, to minimise power loss in transmission, the voltage is kept very high, the current low and the resistance of the cable minimal.

5. (a) With respect to electric potentials, distinguish between live and neutral cables.
 (b) The wiring system comprises lighting circuit, power socket and cooker sockets. Explain the need for the categorisations.
 (c) Distinguish between electric fuse and a circuit breaker.

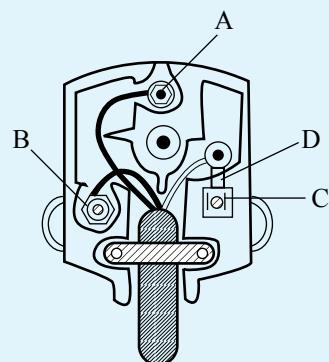
Answer

- (a) The live cable is at a much higher potential (usually 240V in Kenya) and the neutral is close to the earth potential (0 V).

- (b) The different circuits allow for the use of various electric appliances with different power ratings at the same time.
 (c) A fuse consists of a short thin wire of low melting point (usually tinned copper) designed to melt when the current exceeds a certain safe value.

A circuit breaker is an automatic switch made to protect a circuit from damage due to excessive current. Most circuit breakers consist of solenoid which, when the current exceeds a certain set limit, it attracts a magnetic strip in the process opening up contacts and interrupting the flow of current. A key difference between the circuit breaker and a fuse is that a fuse is used only once, after the melting or blowing out it has to be replaced, while a circuit breaker can be reset and put into operation again.

6. The figure below shows a three-pin plug:



- (a) Name the cables A, B, C and state their colours.
 (b) Name part D and state why it is connected to C.

Answer

- (a) A is the earth wire (green or yellow), B the neutral (blue or black) and C the live wire (brown or red).

- (b) D is the fuse connected to C so that when it blows due to excess current or short circuit, the socket is automatically disconnected from the live cable hence, it remains safe.

7. Define the following terms:

- (a) Electrical power, stating the SI unit.
(b) The kilowatt-hour.

Answer

- (a) Electrical power is the rate of consumption of electrical energy, or the product of voltage and current. The SI unit for electrical power is the watt.
(b) The kilowatt-hour (kWh) is the commercial unit of electrical energy. It is defined as the energy transferred at a rate of 1000 watts for 1 hour.

$$\begin{aligned}1 \text{ kWh} &= 1000 \text{ watts} \times 1 \text{ hour} \\&= 1000 \text{ J/s} \times 3600 \text{ s} \\(1 \text{ hr} &= 3600 \text{ s}) \\&= 3600000 \text{ J (3.6 MJ)}$$

8. An energy saving lamp is marked 12 W, 240 V.

- (a) Calculate the energy it consumes in one hour.
(b) Calculate the percentage energy saving in using this lamp rather than a filament lamp marked 60 W 240 V over the same period.
(c) Calculate the cost of using the energy saving lamp over a period of 20 days, 6 hours daily. Compare this with the cost of using the filament lamp in the same manner. (Take fixed charge as Ksh 120, cost per unit Ksh 7.5).
(d) What are the other advantages of using the energy saving lamp rather than the filament lamp apart from saving of energy?

Answer

(a) Energy = power × time
 $= (12 \times 60 \times 60) \text{ J}$
 $= 43200 \text{ J}$

(b) For a 60 W lamp;
energy consumed $= 60 \times 60 \times 60$
 $= 216000 \text{ J}$

$$\text{Percentage saving} = \frac{216000 - 43200}{216000} \times 100 \\= 80\%$$

(c) For the energy saving lamp, number of kilowatt hours
 $= 0.012 \times 6 \times 20$
 $= 1.44 \text{ kWh}$
Therefore, cost $= 120 + (7.5 \times 1.44)$
 $= \text{Ksh } 130.80$

For the 60 W lamp, number of kilowatt hours $= 0.060 \times 6 \times 20$
 $= 7.2 \text{ kWh}$

$$\begin{aligned}\text{Cost} &= 120 + (7.5 \times 7.2) \\&= 120 + 54 \\&= \text{Ksh } 174.00\end{aligned}$$

- (d) Advantages of energy saving lamps over the filament lamps.
- (i) They are energy-efficient compared to filament lamps.
 - (ii) Energy saving lamps generate far less heat than filament lamps. Rooms where energy saving lamps are used therefore remain cool over long periods.
 - (iii) Energy saving lamps have much longer lives, up to ten times that of filament lamps.
 - (iv) They are more environment-friendly,

since they don't need to be replaced frequently like filament lamps.

Revision Exercise 34

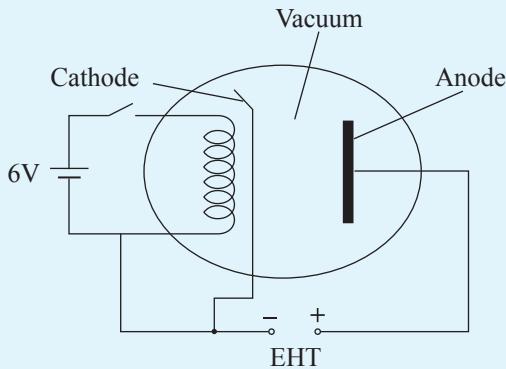
1. (a) Define the following terms as applied in mains electricity:
 - (i) The coulomb.
 - (ii) The watt.
 2. (a) An electric iron is marked 240 V, 1 100 W. What does this mean? What current does it consume when in normal operation? What is its resistance?
(b) A 240 V electric bulb has a filament of resistance 540Ω . Find the energy it converts to heat and light in 12 minutes.
 3. (a) Give an expression for the generation of heat energy in a coil of resistance R.
- (b) Explain why current flowing through a filament bulb gradually changes from the time the switch is turned on.
4. It takes 10 minutes for water in an electric jug connected to a 240V supply to reach boiling point. How long would the jug take to heat the same amount of water to boiling if the power supply was 220 V?
 5. An electric cooker operating on 240 V is designed with two elements of rating 1.2 kW and 1.5 kW connected in parallel. Calculate:
 - (a) the current consumed by each element, and the resistance of each, when both are in use.
 - (b) the power dissipated by the cooker if the voltage drops to 220V.

UNIT**35****Cathode Rays****Key Points**

- When a material is raised to sufficiently high temperature, the electrons in it acquire enough energy to overcome the attractive forces holding them and are therefore emitted. The emission of electrons from a hot surface is known as thermionic emission.
- Cathode rays are streams of fast-moving electrons.

Revision Questions 35

1. The figure below shows a glass bulb containing two electrodes in a vacuum:



- (a) Describe how cathode rays are produced.
(b) Why is the bulb evacuated?

Answer

- (a) When the heater circuit is turned on, the filament heats the cathode. Through thermionic emission, the cathode releases electrons which are attracted towards the high tension positive electrode (the anode). There is therefore continuous

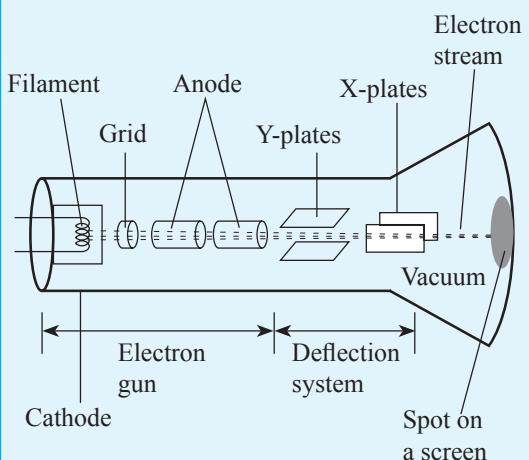
stream of fast-moving electrons from the cathode towards the anode. These are the cathode rays.

- (b) The bulb is evacuated to prevent the electrons from colliding with any particles, hence losing energy before reaching the screen.
2. State any three properties of cathode rays.

Answer

- (i) They travel in straight lines.
- (ii) Cause fluorescence on impact with certain materials, for example, zinc sulphide.
- (iii) They are charged, that is, they are deflected by both electric and magnetic fields.
- (iv) They possess kinetic energy.
- (v) They can produce X-rays when suddenly stopped by a metal target.

3. The figure shows the main features of a cathode ray oscilloscope (CRO).



- (a) State and explain the functions of the following parts:
- the grid.
 - the anode.
 - the deflection system.
 - the fluorescent screen.
- (b) State how the deflection system of a CRT (cathode ray tube) television differs from that of a CRO.
- (c) State what would be observed on the screen if a low frequency alternating signal is connected across the Y-plates.

Answer

- (a) (i) The grid – Controls the number of electrons reaching the anode, thus alters the brightness of the spot. It is slightly negative with respect to the anode. When it is made more negative, it limits the number of electrons reaching the screen.
- (ii) The anode – Attracts and accelerates the electrons and focuses the beam to a sharp point on the screen. The anodes are at different potentials. The greater the P.D between them, the greater the electric field intensity and therefore the greater the degree of focusing.
- (iii) The deflection system has two sets of parallel plates:
 Y-plates (placed horizontally) – Cause vertical deflection of the beam.
 X-plates (placed vertically) – Cause horizontal deflection of the beam.
- (iv) The screen is coated with phosphor material, for example, zinc sulphide, which fluoresces when struck by the electrons, producing a bright spot.
- (b) The deflection system of a CRT television

tube consists of magnetic coils which produce magnetic fields. A CRO consists of plates which produce electric fields. Magnetic deflection is preferred to electric deflection, as it gives a wider deflection of the beams.

- (c) The spot is a visual representation of concentration of electrons on the screen. It may move up and down such that a straight line may be observed (depending on the frequency).
4. (a) (i) Explain how CRO can be used as a voltmeter.
- (ii) What are the advantages of CRO as a voltmeter over moving -coil meters?
- (b) Apart from being used as a voltmeter, state three other uses of the CRO.

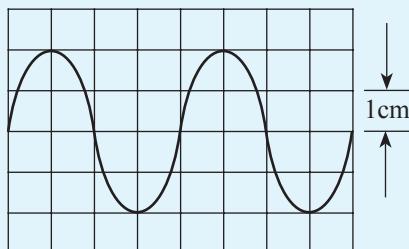
Answer

- (a) (i) With the time-base switched off and the X-plates earthed, the voltage to be measured is connected to the Y-plates. The voltage is then determined using the formula:
- $$\text{Voltage} = \text{displacement} \times \text{sensitivity}$$
- $$(\text{volts per division}),$$
- where the displacement is obtained by reading the screen and sensitivity is selected using Y-gain knob.
- (ii)
- Can measure both alternating and direct voltages.
 - Can measure large voltages without getting damaged and small voltages by adjusting the Y-gain knob.
 - Has infinite resistance and therefore does not interfere with the current in the circuit to which it is connected.

- Responds instantaneously unlike moving-coil meters whose pointers sway for sometime before settling.

- (b) Other uses of the CRO include:
- Measuring frequency of a.c signals.
 - Displaying and studying waveforms, for example, in hospitals to monitor the performance of the heart or brain.
 - Measurement of time interval in waveforms.

5. The figure below shows a waveform on a CRO screen:



Given that the Y-gain control is set at 20 V/cm and the time-base set to 10 ms/cm, calculate the:

- periodic time of the wave.
- frequency of the wave.
- peak voltage.

Answer

- (a) Time base setting = 10 ms/cm
Number of cycles shown = 2
Number of division covered by 1 cycle = 4 ms
Periodic time = 4×10

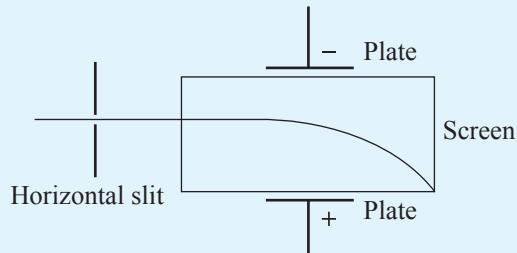
$$= 40 \text{ ms} (4.0 \times 10^{-2} \text{ s})$$

$$\begin{aligned}\text{(b) Frequency } &= \frac{1}{T} \\ &= \frac{1}{40 \times 10^{-3}} \\ &= 25 \text{ Hz}\end{aligned}$$

$$\begin{aligned}\text{(c) Y-gain} &= 20 \text{ V/cm} \\ \text{Deflection} &= 2 \text{ div from zero level} \\ \text{Peak voltage} &= 2 \times 20 \\ &= 40 \text{ V}\end{aligned}$$

Revision Exercise 35

- What is meant by thermionic emission?
- State any two properties of cathode rays.
- In the diagram below, a beam of electrons passes through a horizontal slit and strikes the screen:



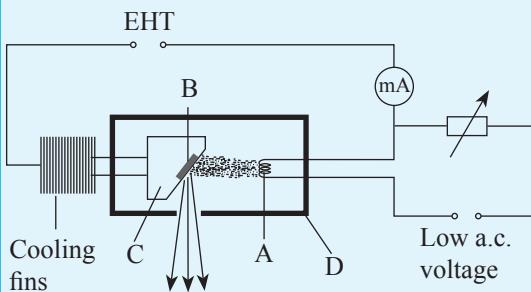
- Why does the beam bend downwards?
 - What change could be made to make the beam bend more?
 - What change could make the beam to bend upwards?
4. Explain how a CRO is used to display waveforms.

Key Points

- X-rays are a form of electromagnetic radiation produced when fast-moving electrons are brought to rest by matter. They are waves with strength lying between that of ultra-violet and gamma radiation.
- Very strong X-rays exhibit properties similar to gamma radiation, the difference only lying in the nature of their production.

Revision Questions 36

1. The figure below shows a modern X-ray tube:



- (a) Name the part labelled A and explain how it produces electrons.
- (b) Name the parts B, C and D. Of what materials are they made? Explain.
- (c) How are the electrons accelerated?
- (d) Explain what happens when the electrons hit part B.

Answer

- (a) A is the filament. The filament (cathode) is heated by an electric current and

thus produces electrons by thermionic emission.

- (b) Part B is the target and C the anode. The target is made of tungsten, which has very high melting point while the anode is made of copper because it is a very good conductor of heat and electricity. Part D is the lead shield. It is made of lead to block stray radiation from the tube.
 - (c) Electrons are accelerated towards the anode through application of high potential difference between the anode and the cathode. The higher the potential difference, the higher the frequency of the radiation produced, and the higher the resulting penetrating power.
 - (d) When the electrons hit the target at a very high speed, their kinetic energy is converted to heat and a small percentage transformed to electromagnetic waves in the form of X-rays.
- (a) What are hard and soft X-rays? Explain how they are produced.
 - (b) What is meant by intensity of X-rays? How is it varied?

Answer

- (a) Hard X-rays are very short wavelength X-rays with high penetrating power, while soft X-rays are longer wavelength X-rays with reduced penetrating power. The quality of X-rays produced is determined by the maximum speed acquired by the electrons. This is controlled by the

potential difference between the anode and cathode of the X-ray tube. Hard X-rays are generated by making the potential difference between the anode and cathode extremely high, while soft X-rays are produced by making the voltage relatively lower. Soft X-rays are useful in such cases as radiography (for example, detection of fractures), while hard X-rays are useful in heavy industries (for example, detection of weaknesses in metal joints).

- (b) Intensity of X-rays refers to the rate of flow of the X-rays energy through a unit area perpendicular to the direction of motion of the radiation. Intensity of the X-rays is varied by changing the potential difference across (and therefore current through) the filament – The higher the pd (or current), the higher the intensity.

3. State four properties of X-rays.

Answer

The properties of X-rays are as follows:

- (i) They are high-frequency electromagnetic waves.
- (ii) They travel in straight lines.
- (iii) They are not affected by electric or magnetic fields, that is, they carry no charge.
- (iv) They cause photoelectric emission.
- (v) They cause ionisation of gases. This is because they are capable of knocking off electrons from molecules in their path.
- (vi) They cause fluorescence in certain substances.

4. (a) Among the uses of X-rays in medicine is to locate fractures or foreign objects in the body. State how the sharpness of the images may be improved in this case.

- (b) State two other applications of X-rays.

- (c) Outline the dangers of X-rays.

Answer

- (a) The sharpness of image of X-ray photograph is enhanced by increasing the intensity of radiation. This is achieved by raising the filament current.

- (b) Other applications of X-rays:

(i) Medicine

- X-rayphotography(radiography) is used in detection of lung tuberculosis and location of cavities or other complications in the teeth.
- Treatment of cancer (radiotherapy). Here, hard X-rays are used to destroy cancerous cells.

(iii) Industry

- Inspection of welded joints to locate flaws or weaknesses. The same technology is used to inspect the quality (especially thickness) of such products as plastic.
- Used in airports for inspecting luggage (security).

(iv) X-ray crystallography

- Study of structure of crystals, more so the arrangement of atoms. This technology is applied in the examination of ancient objects contaminated with impurities or dirt.

(c) Dangers of X-rays

- Can cause damage to cell structure, causing mutation or abnormal changes in gene structure.

- Over-exposure to X-rays can cause cancer, for example, leukaemia. X-rays can also cause skin burns and reduction of blood supply to affected parts of the body.

Revision Exercise 36

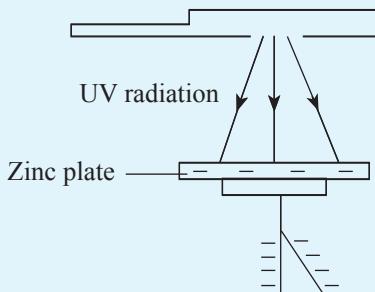
1. (a) (i) Draw a well-labelled diagram of a modern X-ray tube.
(ii) State the observation made on the radiation from an X-ray tube when the accelerating potential is raised.
(iii) Explain why the target of an X-ray tube gets extremely hot when the tube is in operation.
(b) State four main properties of X-rays.
(c) State the factors that govern:
(i) The wavelength of X-rays produced in an X-ray tube.
(ii) The intensity of the radiation.
(d) State the difference between X-rays and gamma radiation.
2. (a) State the difference between hard and soft X-rays.
(b) State two practical uses of X-rays.
(c) An X-ray camera is used to produce the image of a fractured thigh bone. State how the sharpness of the image may be improved.
3. The current flowing in an X-ray tube is 15 mA and the potential difference is 80 kV. Calculate the:
(a) rate at which energy is dissipated in the target of the tube.
(b) number of electrons hitting the target per second.
(c) maximum energy of the radiation generated.
4. Calculate the frequency of X-rays produced by an X-ray tube operating at 20 kV, assuming that no energy is dissipated as heat. (Planck's constant $h = 6.63 \times 10^{-34}$ Js, and the electronic charge is 1.6×10^{-19} C).

Key Points

- Photoelectric emission occurs when electromagnetic radiation causes the ejection of electrons from matter.
- During photoelectric emission, part of the radiation energy frees the electron from the hold of the nuclei while the rest becomes the kinetic energy of the emitted electron.
- The energy is absorbed in discrete energy packets called **quanta**. When dealing with the visible band of the spectrum (light), the quanta are referred to as photons.
- Experimental observation shows that for a given surface, there is a certain minimum frequency of radiation known as threshold or cut-off frequency below which no emission will occur.
- The intensity, I , of electromagnetic radiation is inversely proportional to the square of the distance d^2 , i.e., $I \propto d^{-2}$

Revision Questions

1. Radiation from a UV lamp is directed onto to a freshly cleaned zinc plate which is placed on the cap of a negatively charged electroscope as in the figure below.

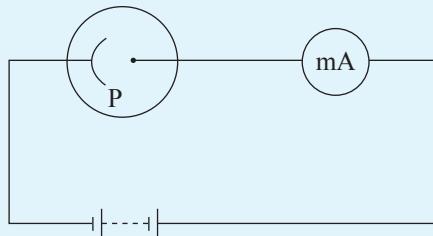


- (a) State and explain the observation made.
 (b) State and explain the observation made if a positively charged electroscope is used instead.

Answer

- (a) As the radiation falls on the plate, the leaf divergence decreases. The UV radiation causes emission of electrons from the zinc surface. The escaping electrons result in a decrease of a negative charge and hence decrease in the divergence of the leaf.
 (b) When a positively-charged electroscope is used, the leaf divergence is not affected. Any electrons ejected are quickly attracted back to the positively-charged plate.

2. The figure below shows a set-up used to study the photoelectric effect:



- (a) It is observed that when there is no radiation falling on the photocell, there is no deflection on the milliammeter. Explain.
 (b) When the radiation is allowed to fall on the cathode plate P, there is deflection on the milliammeter. Explain.

Answer

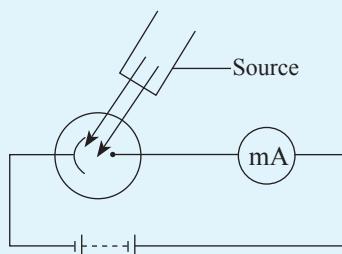
- (a) There is a gap between the cathode P and the anode, thus current cannot flow.
- (b) As the radiation falls on the cathode P, it causes emission of electrons from its surface. These are attracted to the anode, thus current flows.
3. Define the following terms:
- Threshold frequency.
 - Work function.
 - Electron-volt.

Answer

- (a) Threshold frequency, f_0 , is the minimum frequency of radiation that can cause photoemission from a given surface.
- (b) Work function, W_0 , is the minimum amount of energy required to liberate the electron from the nuclear hold of a given surface.
- (c) The electron-volt is energy required to transfer charge of an electron through a potential difference of 1 volt. It is equal to $1 \times 1.6 \times 10^{-19} \text{ J}$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

4. The set-up shown below can be used to investigate on how photoemission varies with the intensity of the radiation:



- State the measurements to be taken.
- Describe how the measurements taken in (a) above are used to show

that the rate of photoemission is directly proportional to the intensity of radiation.

Answer

- (a) • The distance d between the photocell and the source.
- The current I .
- (b) The source is placed at a specified distance d , and the corresponding value of current, I , noted. This is repeated for different values of d .

A graph of current I against the reciprocal of the square of distance (I/d^2) plotted. The graph is a straight line through the origin.

5. (a) State three factors that affect photoelectric emission.
- (b) Calculate the energy of photons associated with radiation of frequency $4.8 \times 10^{14} \text{ Hz}$, stating your answer in
- J
 - eV

Answer

- (a) The factors affecting photoelectric emission from a given surface are:
- The frequency or wavelength of radiation.
 - The intensity of the radiation.
 - The work function of the surface.

(b) (i) $E = hf$
 $= 6.63 \times 10^{-34} \times 4.8 \times 10^{14}$
 $= 3.18 \times 10^{-19} \text{ J}$

(ii) $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

$$\text{Work in electron-volts} = \frac{\text{work in joules}}{1.6 \times 10^{-19}}$$

$$= \frac{3.18 \times 10^{-19}}{1.6 \times 10^{-19}} \\ = 1.9875 \text{ eV}$$

6. The work function of a certain photo emissive surface is given as 1.8 eV.
- What is this value in joules?
 - What is the maximum wavelength of radiation that can cause photoemission from this material?

Answer

(a) Work in electron-volts = $\frac{\text{work in joules}}{1.6 \times 10^{-19}}$

$$1.8 = \frac{\text{work in joules}}{1.6 \times 10^{-19}}$$

$$\text{Work in joules} = 2.88 \times 10^{-19}$$

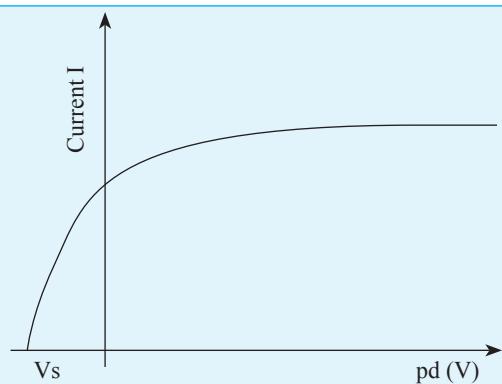
(b) $E = hf = \frac{hc}{\lambda}$

$$2.88 = \frac{3 \times 10^8 \times 6.63 \times 10^{-34}}{\lambda}$$

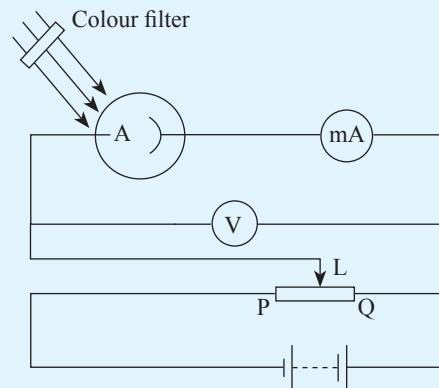
$$\lambda = 6.91 \times 10^{-7} \text{ m}$$

Revision Exercise 37

- In the making of photoelectric cell, why is a quartz window preferred to a glass one?
- Radiation at frequency $7.5 \times 10^{14} \text{ Hz}$ is directed onto a photo emissive surface whose work function is $3.56 \times 10^{-19} \text{ J}$. Determine the:
 - kinetic energy of the fastest moving ejected electron.
 - stopping potential for the surface.
- The following sketch shows the variation of photo-emissive current with potential for a given photo-emissive surface:



- (i) Explain the shape of the curve.
(ii) Draw a circuit that can be used to carry out the investigation.
- On the same axes, sketch a similar graph showing the variation when radiations:
 - I_1 of high intensity
 - I_2 of lower intensity are used.
- In an investigation to study how the kinetic energy of emitted electrons varies with the frequency of the radiation, the circuit shown in the figure below was used:



- What change occurs in the potential of point A as the floating connection L is moved from Q towards P?

(b) Describe how the experiment is carried out.

(c) In a similar experiment, the data in the table below was obtained:

| Frequency (f) ($\times 10^{14}$ Hz) | 5.2 | 5.6 | 6.0 | 6.4 | 6.8 |
|---|------|------|------|------|------|
| Stopping potential V _s (V) | 0.30 | 0.44 | 0.62 | 0.78 | 0.94 |

(i) Plot a graph of stopping potential V_s against frequency f.

(ii) Applying Einstein's equation of photoelectric emission.

$eV_s = hf - hf_0$, use the graph in (i) to determine the value of:

- the threshold frequency of the material used.
- the work function.

5. State and explain the application of photoelectric effect in the operation of:

- (a) a light-dependent resistor.
- (b) a photo-voltaic cell.

Key Points

- The nucleus of an atom contains protons (positively charged) and neutrons (with no charge). Around the nucleus are the electrons. In stable elements, the number of protons and neutrons for light nuclides are equal.
- For heavy elements, the neutron/proton ratio becomes greater than one and for achievement of stability, other factors like the pairing effect of protons and neutrons come into play.

Revision Questions 38

1. Explain what is meant by radioactive decay.

Answer

Radioactive decay is the spontaneous disintegration of a nucleus, resulting in increase of particles and energy from that nucleus.

2. (a) State the types of radioactive emissions, giving their properties and nature.
 (b) Radium-226 with atomic number 88 decays by emitting an alpha particle to become radon-222. Write down an equation for the process.

Answer

- (a) The three types of emission from radioactive sources are:

Alpha (α) $\left(\begin{smallmatrix} 4 \\ 2 \end{smallmatrix} \text{He} \right)$, beta (β) $\left(\begin{smallmatrix} 0 \\ -1 \end{smallmatrix} e \right)$
 and gamma rays (γ) (energy).

Properties and nature of emissions are:

Alpha particle

- Is a helium nuclide, 4 times heavier than hydrogen, positively charged.
- Has very strong ionisation effect.
- Can be stopped by thin paper or skin (low penetrating power).
- Is deflected by magnetic and electric field.

Beta particle

- Is an electron, hence negatively charged.
- Is stopped by metal foil (more penetrating power than alpha particle).
- Has weak ionisation effect.
- Is deflected by magnetic and electric fields.

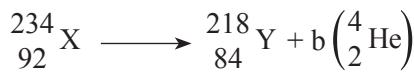
Gamma radiation

- Is an electromagnetic wave of high frequency.
- Has high penetrating power.
- Has minimal ionisation effect.
 It is not deflected by electric or magnetic field.



3. A nuclide X with mass number 234 and atomic number 92 decays to nuclide Y with mass number 218 and atomic number 84. Determine the number of alpha particles emitted.

Answer



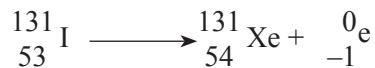
where b is the number of alpha particles.

Using mass number ; Using atomic number

$$\begin{array}{ll} 234 = 218 + 4b & 92 = 84 + 2b \\ 16 = 4b & 8 = 2b \\ b = 4 & b = 4 \end{array}$$

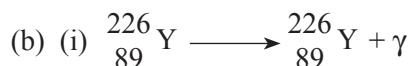
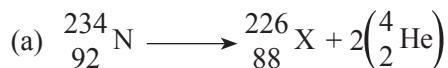
4. Radioactive iodine-131 with atomic number 53 decays by emitting a beta particle to become xenon-131. Write down the equation for the process.

Answer



5. A nuclide N with mass number 234 and atomic number 92 emits two alpha particles to become element X which then emits a beta particle to become element Y.
- (a) Write down the nuclear equation to illustrate the process.
- (b) If Y emits a gamma radiation;
- (i) write down the equation.
 - (ii) state the difference between Y and the new element.

Answer



- (ii) Initially Y is in a more excited state than the final state.

6. Define and explain half-life.

Answer

Half-life is the time taken for half of the number of nuclides initially present in a radioactive element to decay.

Or

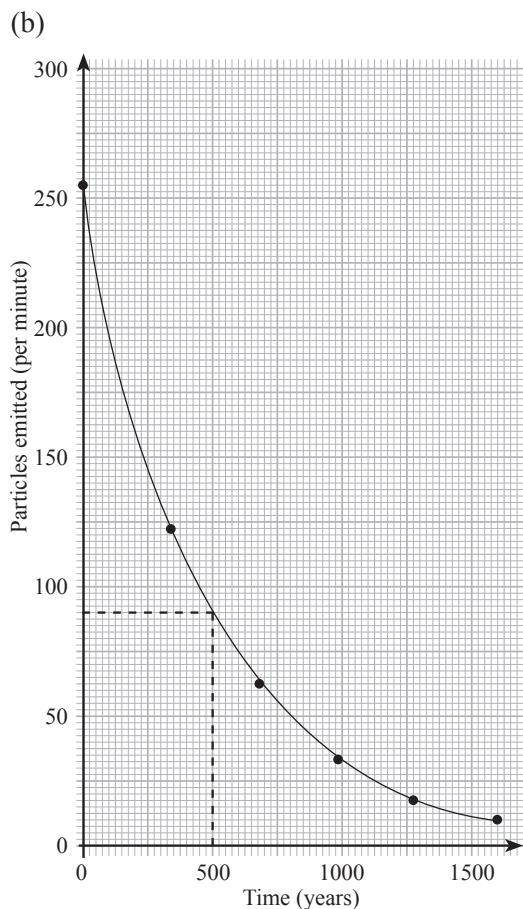
Half-life is the time taken for the rate of activity to reduce by half.

7. Consider a radioactive sample of mass 16 g, half-life of 320 years and that the sample emitted 256 particles per minute.
- (a) Draw a suitable table to depict the radioactive decay process.
 - (b) Plot a graph of particles emitted per minute against time.
 - (c) Estimate the fraction of the sample that remains unchanged after 500 years.

Answer

- (a) The rate of radioactive decay.

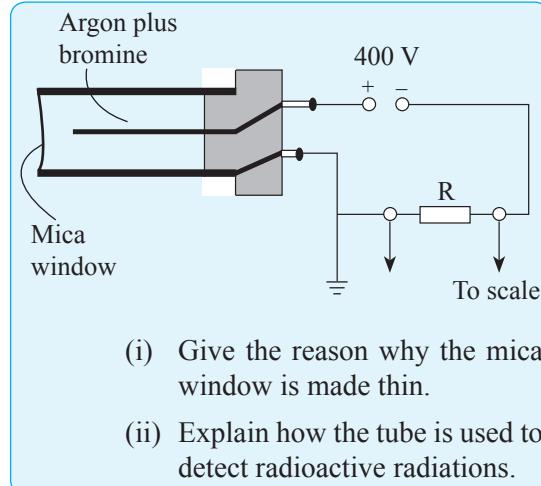
| No of half-lives | Particles per minute | No. of years | Mass undecayed (g) | Decayed mass (g) |
|------------------|----------------------|--------------|--------------------|------------------|
| 0 | 256 | 0 | 16 | 0 |
| 1 | 128 | 320 | 8 | 8 |
| 2 | 64 | 640 | 4 | 12 |
| 3 | 32 | 960 | 2 | 14 |
| 4 | 16 | 1280 | 1 | 15 |
| 5 | 8 | 1600 | 0.5 | 15.5 |



(c) After 500 years

$$\begin{aligned} \text{Fraction unchanged} &= \frac{\text{current activity}}{\text{original activity}} \\ &= \frac{90}{256} \\ &= 0.3516 \end{aligned}$$

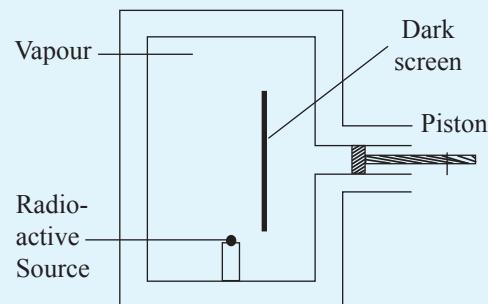
8. (a) State what is meant by the term ionisation.
 (b) The figure shows a Geiger-Muller tube.



Answer

- (a) Ionisation is the removal of an electron from an atom forming a positive ion. The electron may attach to a neighbouring molecule to become a negative ion.
- (b) (i) To allow all radiations to penetrate.
 (ii) Radiations ionise the argon vapour.
 (iii) Avalanche of ions flows between the terminals causing current to flow.
 (iv) Each pulse is registered as particle entry.

9. The figure below shows a cloud chamber that could be used to detect radioactive radiations:

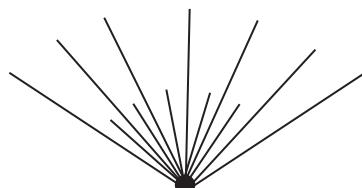


- (a) Explain how the cloud chamber is used to detect the radiations.
 (b) Sketch and explain the tracks made by the radiations.

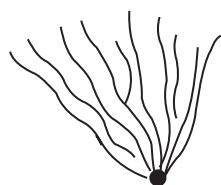
Answer

(a) The radiations ionise the gas inside the chamber. This results in the vapour condensing around the ions in their path. When illuminated, whitish lines show up as tracks.

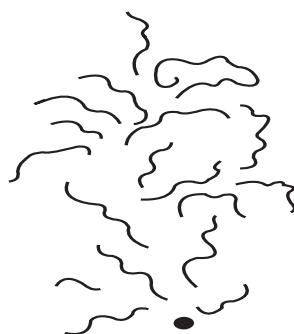
(b)



Alpha particles



Beta particles



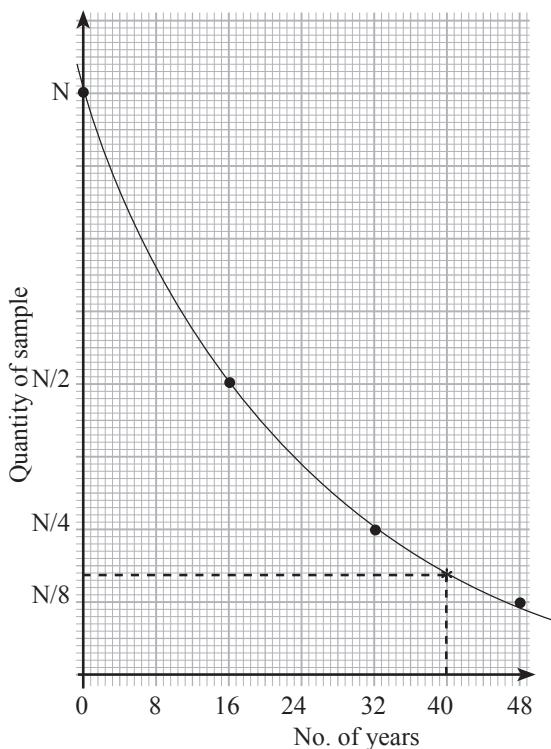
Gamma radiation

- Alpha particles generate thick short straight tracks. This is because they cause heavy ionisation due to their relatively larger mass.

- Beta particles form thin and irregular tracks. This is due to their much smaller mass and reduced ionisation of molecules in their path.
- Gamma radiation produces disjointed tracks. This is because gamma rays eject electrons from molecules in their paths and these in turn act as weak beta particles.

10. The half-life of a given radioactive element is 16 years. Determine the fraction of the element that will have decayed after 40 years.

Answer



$$\text{Fraction that will have decayed} = 1 - \frac{1}{10} \left(\frac{1}{8} \right)$$

$$= 1 - \frac{7}{40}$$

$$= \frac{33}{40}$$

11. State the applications of radioactivity.

Answer

- Detecting flaws in metal structures.
- Used in medicine and agriculture to trace movement of liquid in body organs and absorption of fertilisers by plant roots.
- Used as tracers to detect leakages in pipes.
- Malignant tissue is irradiated with gamma emissions to treat cancer.
- Determining the age of fossils through carbon dating.
- Detecting smoke.
- Thickness control in production of metal foils, iron sheets and plastic materials.
- Eliminate bacteria by sterilising.

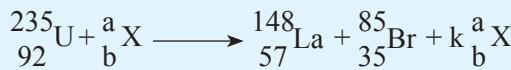
12. State the hazards of radioactive materials.

Answer

Exposure to the radiations may cause skin burns, cancer of the blood, sterility, fatal damages or harmful effect to body defense mechanism against diseases, change in genetic structure resulting in mutation.

13. (a) Define the term nuclear fission.

(b) The equation below represents nuclear fission reaction. State the values of a, b and k:



(c) What is X? Why is it useful in the reaction?

(d) Experiments show that there is some ‘lost mass’ after the reaction shown above. Explain.

Answer

- (a) Nuclear fission is the process whereby a heavy nuclide is bombarded with a neutron, splitting it into two smaller nuclides accompanied by release of large amounts of energy.
- (b) $235 + a = 148 + 85 + ka$
 $2 + a = ka$
 $a(k - 1) = 2$
 $92 + b = 92 + kb$; then, $b = 0$ and $a = 1$, so that $k = 3$
- (c) X is a neutron ^1_0n . It is useful since it has no charge, making it able to penetrate more deeply into the nucleus which has protons (positively charged).
- (d) The lost mass in a nuclear reaction is converted to energy.

14. The equation given below represents nuclear fission process:



- (a) Find the values of a, b and c .
- (b) Identify the two isotopes in the equation.
- (c) With reference to the equation above, explain the nuclear fission process.

Answer

- (a) $2 + a = c + 1$, so $c = a + 1$
 $1 + b = 2$, so $b = 1$
Since mass number of He is 4, then $a = 3$ and $c = 4$.
- (b) Two isotopes of hydrogen are ^2_1H and ^3_1H , i.e., deuterium and tritium.

- (c) Nuclear fission is a process whereby two light nuclides, combine to form a heavier nuclide, resulting in release of large energy. In the above situation, two isotopes of hydrogen, deuterium and tritium combine to form a heavier nuclide helium.

Revision Exercise 38

- (a) The nuclide of oxygen can be represented as $^{16}_8\text{O}$. Explain the significance of 16 and 8.
 (b) Complete the radioactive decay equation

$$^{234}_{92}\text{X} \longrightarrow \text{Y} + {}^0_{-1}\text{e} + \gamma$$

 (c) The half-life of a given radioactive substance is 3 hours. What percentage of the original substance will remain undecayed after 12 hours?
- The half-life of a certain radioactive element is 30 years. Determine what fraction of the element will remain undecayed after 70 years.
- (a) What are isotopes?
 (b) Write the equation to represent the bombardment of $^{34}_{16}\text{S}$ with a neutron to give an isotope of sulphur.
 (c) $^{235}_{92}\text{U}$ and $^{238}_{92}\text{U}$ are isotopes of uranium.

- (i) State the number of protons, neutrons, and electrons in each nuclide.
 (ii) The half-life of $^{235}_{92}\text{U}$ is 6.8×10^8 years and that of $^{238}_{92}\text{U}$ is 4.3×10^9 years.

Estimate the ratio;

$$R = \frac{\text{No. of U-238 decayed}}{\text{No. of U-235 decayed}}$$

at a time 4.3×10^9 years, if the isotopes had equal numbers of undecayed nuclides.

- In an experiment to determine the half-life of a radioactive element, the results were tabulated after accounting for background radiation.

| Time (s) | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|--------------------------------|----|----|----|----|----|----|----|
| Count rate (s^{-1}) | 30 | 25 | 22 | 19 | 17 | 14 | 13 |

- (a) Explain the presence of background radiation.
 (b) Describe how background radioactive can be determined.
 (c) Plot a graph of count rate against time and use it to determine the half-life of the radioactive element.
 (d) Calculate the percentage of the element remaining undecayed after 13 seconds.

Key Points

- In a solid structure, the individual energy levels in the atoms interact to produce ranges of energy referred to as energy band.
- An intrinsic semiconductor is a pure semiconductor while an extrinsic semiconductor is one to which traces of impurities have been added to enhance conductivity.

Revision Questions 39

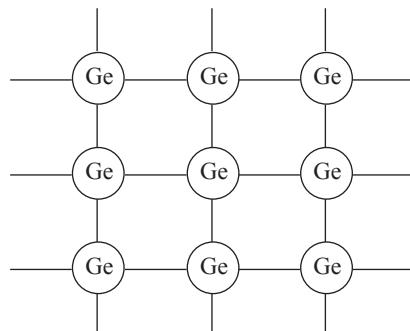
1. (a) The table below shows some examples and properties of conductors, semiconductors and insulators.

| Material | Conductors | Semi conductors | Insulators |
|--------------------------------|---|-----------------|------------|
| Examples | a | Germanium | Plastic |
| Effect of temp on conductivity | Increases in temperature reduces conductivity | b | No change |
| Charge carriers | c | d | None |

- (i) Replace the letter a, b, c, and d with suitable statement.
(ii) Using a diagram, explain the crystal structure of intrinsic semiconductor.
- (b) (i) What is doping?
(ii) Explain how p-type and n-type semi-conductors are formed.

Answer

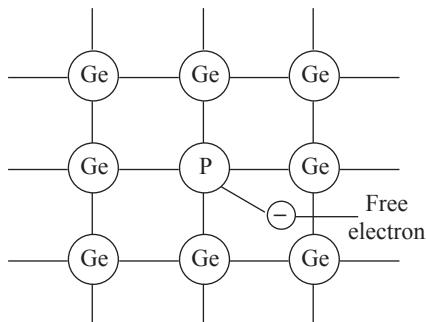
- (a) (i) a – Metals, for example, copper and silver.
b – Increase in temperature increases conductivity.
c – Electrons.
d – Holes and electrons.
(ii) The figure shows the crystal structure of germanium, an intrinsic semiconductor:



The atoms of such elements are linked by covalent bonds. Since the atoms are in Group 4 of the periodic table, they have four electrons in the outermost shell and form a maximum of four bonds.

- If temperature increases, it raptures some of the bonds, liberating electrons, thus increasing electrical conductivity.
- (b) (i) Doping is the controlled addition of certain impurities to an intrinsic semiconductor to enhance its conductivity.
(ii) To obtain n-type semi-conductor, the doping element (dopant) is a group five element, for example,

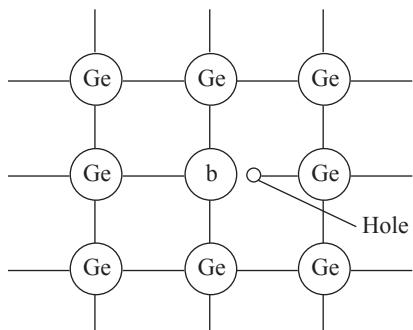
phosphorus. The dopant shares four of its outermost electrons with the four of the semi-conductor forming four covalent bonds, leaving one free electron as shown in the diagram. It is this electron that serves as a charge carrier in the material.



The dopant (phosphorus) is referred to as a donor atom.

For a p-type semi-conductor, the dopant is a Group 3 element, for example, boron. When say germanium is doped with boron, three covalent bonds are formed as a result of electron contribution from respective atoms.

A fourth bond is, however, considered to be made without boron contributing an electron. The absence of an electron in formation of this bond is called a hole, which is taken as being positive.

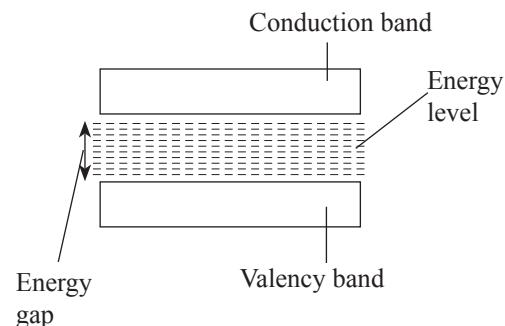


The dopant is referred to as an acceptor atom.

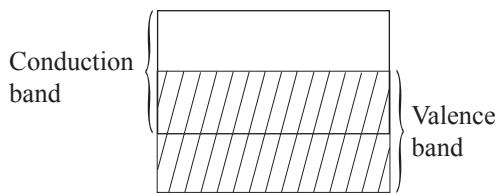
2. (a) (i) Explain why conductors, unlike intrinsic semiconductors, do not need doping to enhance conductivity.
- (ii) Explain how conduction occurs in the p-type and n-type semi-conductors.
- (b) Distinguish between:
- (i) a hole and a proton.
 - (ii) hole current and electron current.

Answer

- (a) (i) According to the energy band theory, materials have what is referred to as conduction band (which contains conduction electrons) and valence band (consisting of valence electrons). The two bands are separated by an energy gap.



For the intrinsic semiconductor, the energy gap between the valence band and conduction band cannot allow electrons in the valence to cross to the conduction band unless energy is injected into the material. Conductors of electricity like copper have overlapping conduction and valence bands, see the following figure. This enable electrons to freely move in the conduction band without the need for doping.



- (ii) In p-type semi-conductor, the holes are majority charge carriers. A shift in the hole created as a result of electron jump from an existing bond to a hole brings about conduction. In n-type semi-conductor, electrons are majority charge carriers. These electrons are easily excited to the conduction band and hence move under the influence of external potential difference.
- (b) (i) Hole is a vacant site in a bond which readily accepts an electron (i.e., can move under the influence of an electric field) and is only found in p-type semi-conductors. A proton is stable, immobile particle found in the nucleus of an atom.
- (ii) Hole current results from a perceived hole movement in p-type semiconductors, while electron current results from movement of electrons which could be in a semiconductor or electric wires. Hole current flows in the same direction as conventional current, that is, in the opposite direction to the flow of the electrons.

3. (a) Explain how p-n junction is formed.
- (b) (i) Sketch the symbol of a p-n junction diode.
- (ii) Explain what is meant by forward and reverse biasing of a diode. What is their effect on depletion layer and potential barrier?

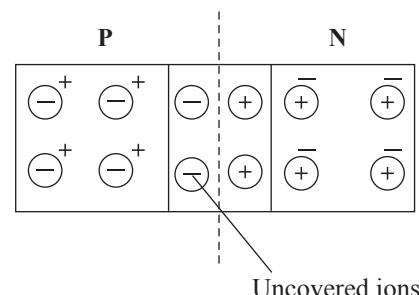
- (c) Sketch the graph of current-voltage characteristics of a diode and explain its shape.

Answer

- (a) A p-n junction is formed when an intrinsic semi-conductor is simultaneously doped with group three and five atoms. The result is a crystal structure with a p-type semi-conductor on one side separated by a junction (internal potential) with the n-type on the other.

It is the control of the thickness of this junction that enables the control of current flow in this semi-conductor.

The junction has fixed ions only after mobile charge carriers deplete themselves through neutralisation.

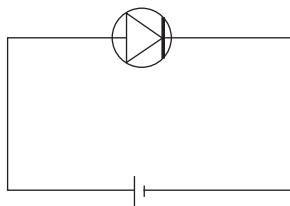


It is the uncovered ions which produce contact potential, otherwise called potential barrier (since it stops movement of charge carriers across the junction).

- (b) (i) The symbol of a p-n junction is as shown in the figure below.

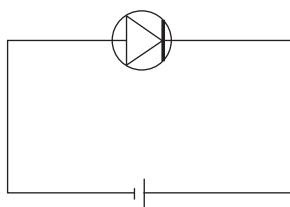


- (ii) When a diode is forward-biased, the p-type is connected to a positive terminal of the external power supply while n-type is connected to the negative terminal, see the following figure.

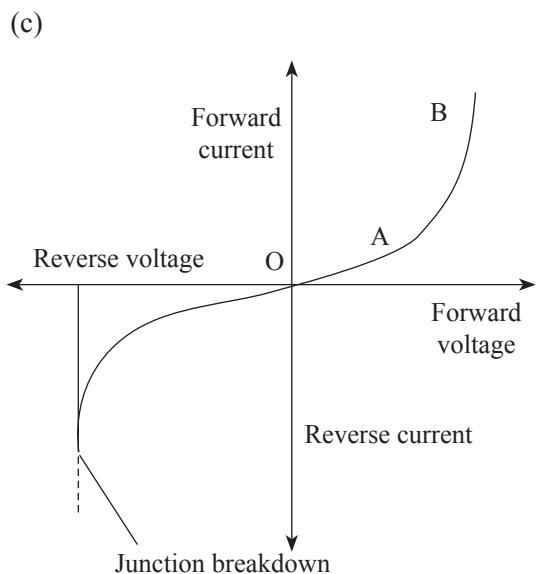


The effect of this is that the potential barrier is reduced as a result of holes from the p-type and electrons from the n-type being pushed towards the junction. This eventually narrows the depletion layer causing a big forward current to cross through the junction. The p-n junction when forward biased therefore has very low electrical resistance.

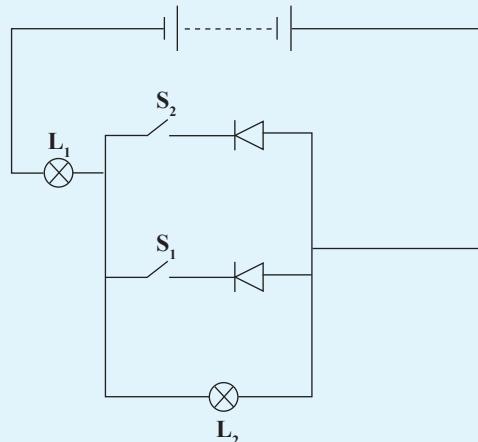
When a diode is reverse-biased, the p-type region is connected to the negative terminal of an external source while the n-type is connected to the positive, as below.



The potential barrier is not overcome and some free majority charge carriers can be attracted to the terminals of the external source leaving more fixed ions not covered by the mobile charge carriers. This increases the potential barriers and therefore the resistance to current flow across the junction. Thus, a diode reverse bias has high electrical resistance.



4. (a) (i) What is rectification?
(ii) Distinguish between half-wave and full-wave rectification.
(iii) Use diagrams to show the smoothed outputs obtained in half and full-wave rectification from an alternating source.
- (b) In the figure below, bulbs L_1 and L_2 are identical:



Explain what is observed when:

- (i) S_1 and S_2 are open.
(ii) S_2 is closed and S_1 is open.

Answer

- (a) (i) Rectification is the process of converting alternating current to direct current.
- (ii) In half-wave rectification, one half of the voltage cycle is not transmitted to the output since there is no conduction in that cycle.



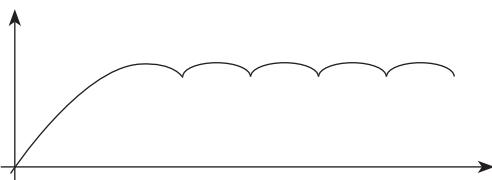
In full-wave rectification, both the half cycles of the alternating sources are transmitted to the output after rectification process.



(iii) Smoothened half-wave rectification.



Smoothened full-wave rectification.



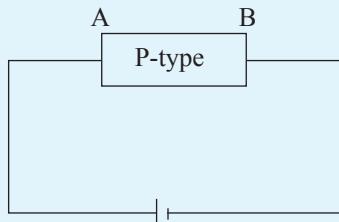
- (b) (i) The bulbs L_1 and L_2 have the same amount of current flowing through them, hence give out light of same brightness.
- (ii) Light L_2 is shorted, all the current flows through L_1 , the brightness increases since overall resistance in the circuit is reduced.

Revision Exercise 39

1. (a) (i) Explain why temperature increases the conductivity of a semi-conductor but decreases that of a conductor.

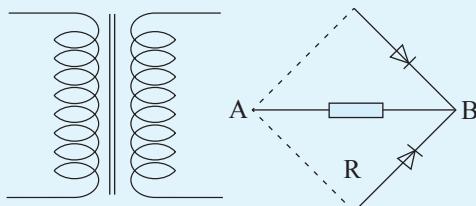
- (ii) Describe how arsenic (Group 5) and indium (Group 3) doping agents are used in making extrinsic semi-conductors.

- (b) A cell is connected across the P-type semi-conductor as shown in the diagram below.



What effect will this have on fixed ions, majority and minority charge carries.

2. (a) P-N junction is forward biased.
- (i) Sketch a graph of bias voltage against current and state the significance of the gradient.
 - (ii) Explain the effect of forward biasing to the depletion layer and resistance to flow of current.
- (b) Given a torch bulb and a cell, briefly describe how you would identify whether a diode is in good working condition or not.
3. The diagram shows a rectifier circuit for producing a full rectified output.



- (i) Complete the circuit diagram in such a way that the output across AB is smoothened.
- (ii) Sketch the display that will be seen on the CRO when connected across AB.

SAMPLE PAPER 1 (1)

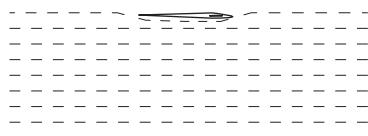
TIME: 2 HOURS

SECTION A (25 marks)

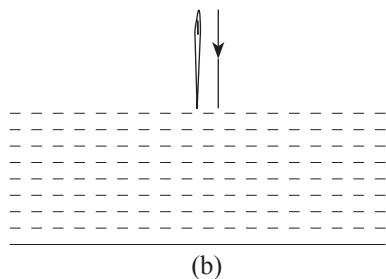
1. The mass of a bucket containing sand was found to be 12 kg. If the volume of the sand was $2\ 900\ \text{cm}^3$ and that the mass of empty bucket was 0.3 kg, find the density of sand.

(2 marks)

2. Figure (a) shows a steel needle resting on water surface:



(a)



(b)

- (i) What makes the needle to float in (a)?

- (ii) Explain what would happen if the needle was placed vertically on the water surface as in figure (b).

(2 marks)

3. The pressure at the top of a mountain is found to be 700 mmHg. Calculate the height of the mountain given that the density of mercury is $13\ 600\ \text{kg/m}^3$, density of air $1.25\ \text{kg/m}^3$ and the pressure at sea level is 760 mmHg.

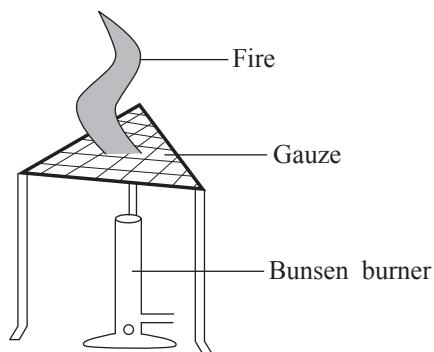
(2 marks)

4. Two samples of bromine vapour are allowed to diffuse separately under different conditions: one in a vacuum and

the other in air. In which of the conditions will bromine diffuse faster?

(1 mark)

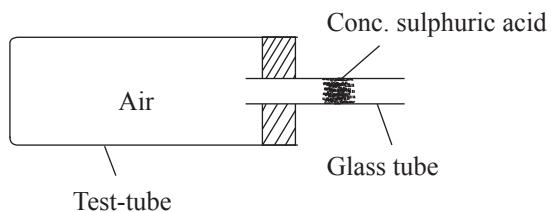
5. The figure below shows the flame of bunsen burner immediately after being lit from above the gauze:



Explain why it takes some time before the flame crosses to the region below.

(2 marks)

6. The figure below represents a simple gas thermometer set-up by a student.



- (a) State any one adjustment to increase the sensitivity of the apparatus.

(1 mark)

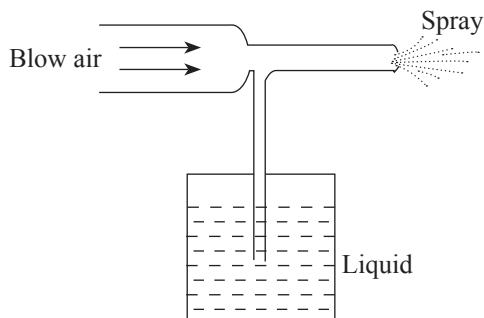
- (b) State one advantage of gas thermometer over mercury in glass thermometer.

(1 mark)

7. A non-uniform metre rule weighing 0.9 N is balanced horizontally on a sharp pivot placed at the 40 cm mark, when a load of 1.26 N is placed at the 32 cm mark.

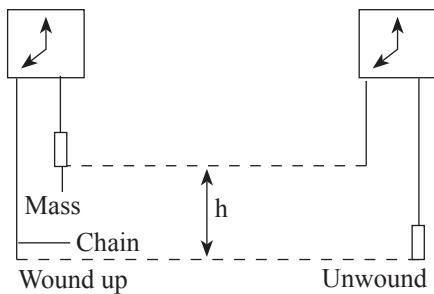
Determine the position of the centre of gravity of the metre rule. (3 marks)

8. The figure below illustrates the working of a simple paint sprayer:



Explain why the liquid rises to form a spray. (2 marks)

A manual clock in which the energy needed to provide movement of the hands comes from the falling mass is shown below:

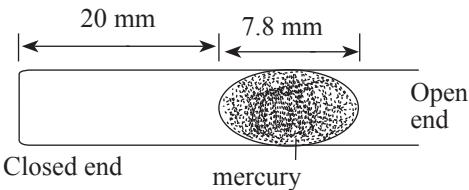


To power the clock, the chain is wound up to raise a mass of 4 kg to a certain maximum level. The winding is done once per week. Use the information to answer questions 9 and 10.

9. If the mass falls through a distance of 1.5 m, **calculate** the change in its gravitational potential energy. (2 marks)

10. **Calculate** the average power output of the falling mass. (2 marks)

The figure below shows a 20 mm column of air trapped in a long tube closed at one end by mercury of length 7.8 mm. The prevailing atmospheric pressure is 760 mmHg.



Use the diagram to answer questions 11 and 12.

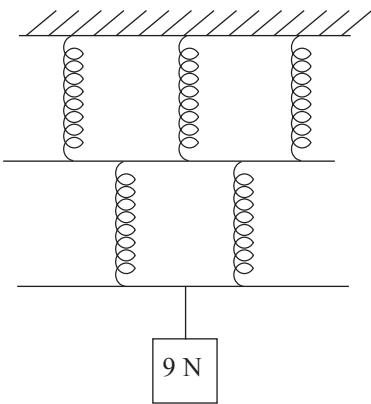
11. **Determine** the pressure of the trapped air column when the tube is held vertically with the open end facing up. (1 mark)

12. **Determine** the height of the trapped air column when the tube is held as described in 11 above. (3 marks)

SECTION B (55 marks)

13. (a) (i) **State** Hooke's law. (1 mark)
- (ii) A student is given the following apparatus: metre rule, clamp stand, spiral spring, set of hooked masses. **Draw** the diagram of the set-up of apparatus to verify the law. (1 mark)
- (iii) **List** the measurements to be taken. (2 marks)
- (iv) **Explain** how the measurements taken are used to verify the law. (4 marks)

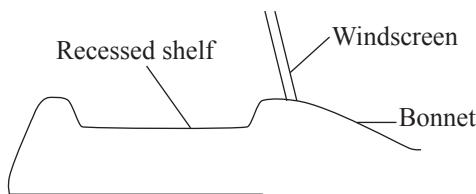
- (b) The following figure shows a network of identical springs of spring constant 2.1 N/cm supporting a load of 9 N.



Determine the total extension for the network. *(3 marks)*

14. (a) **State** Newton's law of motion. *(1 mark)*

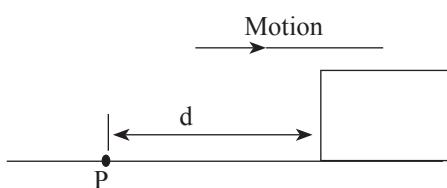
(b) Behind the windscreen of some cars there is a shelf, which is horizontal but recessed to stop objects from falling off.



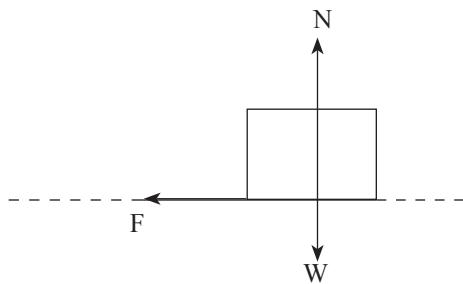
A pencil has been left on the shelf. Whenever the car accelerates forward, the pencil is against the rear edge of the shelf. Whenever the car is braking, the pencil is against the front edge.

Explain these observations. *(3 marks)*

- (c) A block is projected from a point P across a rough horizontal surface, as below.

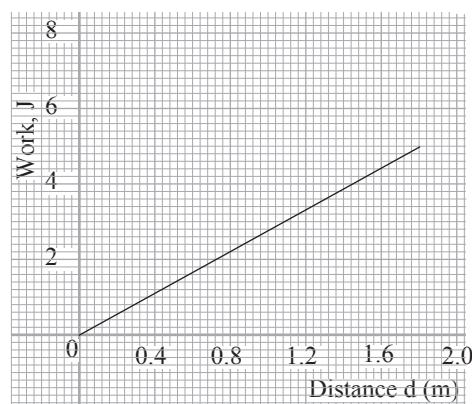


The block slows down under the influence of a constant frictional force and eventually comes to rest. Below is a force diagram for the block while it is moving:



- (i) **State**, with a reason, the amount of work done by each of the forces W and N as the block moves across the surface. *(2 marks)*

- (ii) The sliding block does work against friction. The graph shows how the total work done varies with the distance d which the block has travelled from the projection point P.



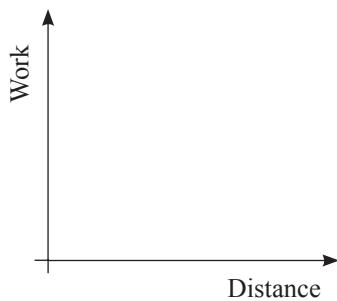
Use the graph to **determine** the force F. *(2 marks)*

- (iii) The block comes to rest 1.8 m from P. Add a line to the graph above to **show** how the kinetic

energy of the block varies during the motion. (1 mark)

- (iv) The mass of the block was 0.82 kg. **Calculate** the speed with which it was projected. (2 marks)

- (d) Suppose that instead of a constant friction force, the block had been brought to rest by a drag force (air resistance) which depends on speed. On the axes below, sketch a graph to show qualitatively how you would expect the total work done against air resistance to vary with the distance d .



Explain the shape of your graph. (1 mark)

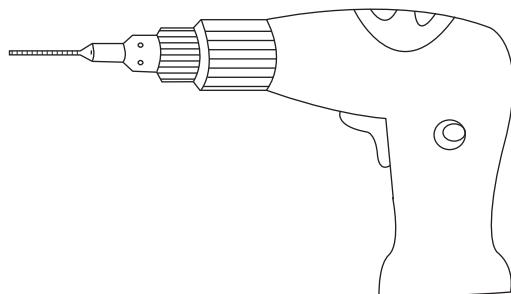
15. (a) You are to measure the specific heat capacity of aluminium using a cylindrical block of aluminium that has been drilled out to hold an electrical heater and a thermometer.

- (i) **Draw** a diagram of the apparatus, including the electrical circuit, which you would use. (2 marks)

- (ii) **List** the measurements you would take. (2 marks)

- (iii) **Explain** how you would use these measurements to find the specific heat capacity of aluminium. **State** any assumptions you have made. (2 marks)

- (b) The electric drill shown below is labelled 230 V, 200 W. It has a removable steel drill bit that is used to drill into a wall for 30 seconds.



- (i) **Calculate** how much electrical energy is used by the drill during the period. (1 mark)

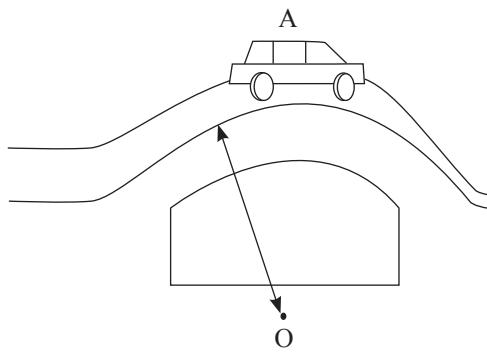
- (ii) After use, the steel drill bit is very hot. If the mass of the drill is 15 g and the room temperature is 20 °C, **calculate** the maximum possible temperature of the drill (specific heat capacity of steel is $510\text{Jkg}^{-1}\text{K}^{-1}$) (3 marks)

- (iii) **State** an assumption you have made in (ii) above. (1 mark)

- (iv) The actual temperature of the drill bit will be less than the figure obtained in (ii). **Suggest** a reason why. (1 mark)

16. (a) A body of mass m travelling at a constant speed v around a circular path of radius r must have a resultant force F acting upon it. **Write** down a formula for the magnitude of F and **state** the direction in which it acts. (1 mark)

- (b) The following diagram shows a car at the highest point A of hump-backed bridge:



When the car is driven over the bridge, it follows the path of a vertical circle of radius 25.0 m with centre at point O below the bridge. If the mass of the car is 925 kg, **calculate** the normal reaction force R when:

- the car is parked at rest at A.
(1 mark)
 - the car is passing point A at a speed of 10.0 m/s. (3 marks)
- (c) If the car is driven across the bridge repeatedly at gradually increasing speeds, it is found that above a certain critical speed, the car loses contact with the road at A, and 'takes off'.
- Explain** why this happens.
(1 mark)
 - Calculate** the critical speed for this particular bridge. (2 marks)
- (d) An object in free fall is said to be 'apparently weightless'. **Explain** what this means, illustrating your answer with reference to the situation described in this question. (2 marks)
17. (a) (i) **Define** relative density of a substance.
(1 mark)
- (ii) With the aid of a labelled diagram, **describe** an experiment to determine the relative density of a liquid using the principle of moments.
- (b) The figure below shows a hot air balloon of mass 400 kg anchored to the ground. Density of air is 1.2 kg/m^3 and density of hot air is 0.18 kg/m^3 .
-
- Hot air balloon
- Find** the tension in the string.
(3 marks)
 - Calculate** the acceleration with which the balloon begins to rise when the string is cut.
(3 marks)

SAMPLE PAPER 1(2) SECTION A (25 marks)

- Write down** the vernier calliper's reading shown in the figure below:
(1 mark)

0 5 10
5 6 7

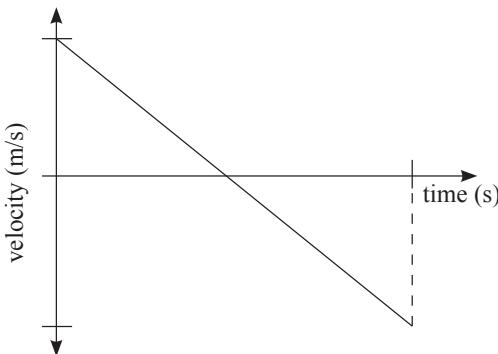
- In the figure below, **state** the resultant force on the body:
(2 marks)

5.3 N ← 2.7 N ← 10 N → 3.6 N

- An object of mass 750 g weighs 6.9 N when fully immersed in glycerine of

density $1\ 250\ \text{kg/m}^3$. What is the volume of the object? (3 marks)

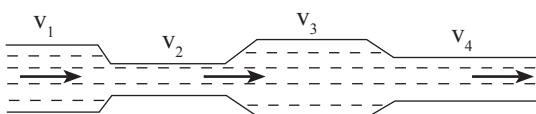
4. The figure below shows velocity-time graph for a body:



Sketch the corresponding displacement-time graph. (2 marks)

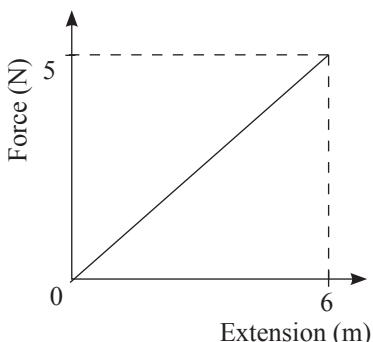
5. (a) State Bernoulli's principle. (1 mark)

(b) A tube of varying cross-section area has water flowing steadily with speeds v_1 , v_2 , v_3 and v_4 through its sections as shown in the diagram.



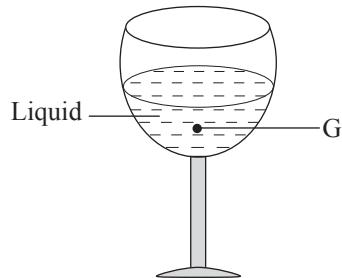
Arrange the speeds v_1 , v_2 , v_3 and v_4 in order, starting with the lowest. (1 mark)

6. The figure below shows a graph of Force (N) against extension for a spring with elastic limit not exceeded:



Determine the work done in stretching the spring. (3 marks)

7. The figure below shows a liquid in a container:



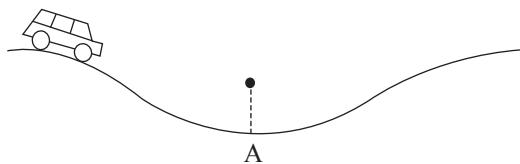
(a) Explain what happens to the stability of glass when more liquid is added. (2 marks)

(b) If the glass is empty, what is its state of equilibrium? (1 mark)

8. A 20 g marble moving at 40 m/s bounces off a hard wall at 25 m/s. Given that the impact lasts for 0.2 seconds, determine the force of impact. (3 marks)

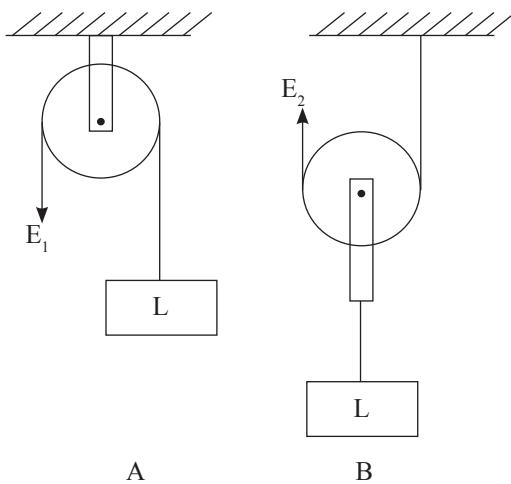
9. In a smoke cell experiment, bright specks moving randomly were observed. Explain the observation. (2 marks)

10. A car speeding downhill at 72 km/h as shown below.



If the radius of curvature of the road is 20 m, calculate the apparent weight of the driver of mass 70 kg at point A. (Take $g = 10\ \text{m/s}^2$) (3 marks)

11. A student using two identical pulleys set up pulley systems to lift a load L as shown.



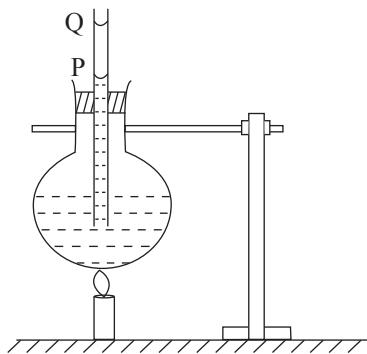
Compare:

- (a) Efforts E_1 and E_2 . (1 mark)
 (b) Efficiencies of systems A and B. (1 mark)

SECTION B (55 marks)

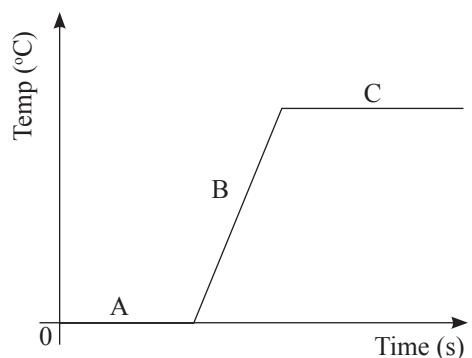
12. (a) State two factors considered when choosing a thermometric liquid. (2 marks)

- (b) The figure below shows a set-up for investigating the thermal expansion of water:



The level of water in the tube initially falls slightly before it rises from P to Q. Explain. (2 marks)

- (c) The figure below shows variation of temperature against time when frozen water is heated for some time.



- (i) Name the process occurring at:

A: _____

C: _____ (2 marks)

- (ii) In the boxes below, sketch the spacing of the particles as they would appear. (3 marks)

Under 0°C Region B After region C



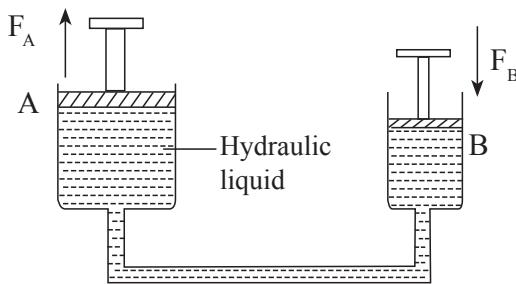
- (d) In another experiment, the volume of a fixed mass of water was measured at various temperatures between 0°C and 100 °C.

- (i) Sketch a graph of volume against temperature that would be obtained. (2 marks)

- (ii) On the graph, mark using letter X the point where water has the highest density. (1 mark)

- (iii) State one advantage of the property of water illustrated in the diagram in (ii) above. (1 mark)

13. The figure shows a hydraulic lift. The area of the smaller piston B is 8 cm^2 while that of piston A is 440 cm^2 .



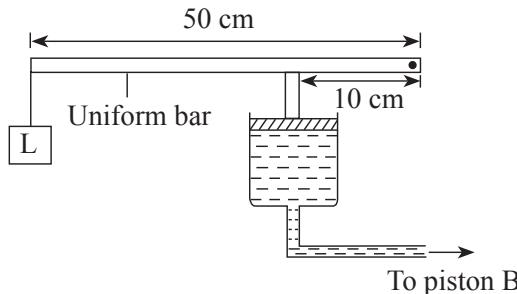
A force F_B is applied on piston B and this generates an upward thrust on piston A.

- (a) **State** why a gas cannot be used in place of the hydraulic liquid. (2 marks)

- (b) **Express** the force F_A in terms of F_B . (3 marks)

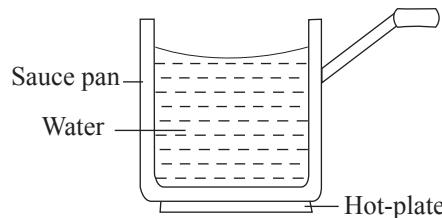
- (c) **Calculate** the maximum load that can be lifted by piston A when a force of 120 N is applied on B. (2 marks)

- (d) Piston A is now connected to a lever system as shown below.



Calculate the load L that is required to ensure the bar remains horizontal when a force of 40 N is applied in B. (3 marks)

14. (a) The figure shows an electric hot plate being used to heat a sauce pan containing water.



- (i) By **what** method is the heat transferred through the pan? (1 mark)

- (ii) **Explain** why plastic is used as material for the handle. (1 mark)

- (iii) **Explain** how water gets heated to the point of boiling. (2 marks)

- (b) In an experiment to **determine** the specific latent heat of fusion of water, ice at 0°C is melted into water contained in a well-lagged copper calorimeter. The following measurements were made:

- Mass of calorimeter: 250 g
- Initial mass of water: 200 g
- Initial temperature of water: 21°C
- Final mass of calorimeter + Water + melting ice: 475 g
- Final temperature of mixture: 11°C

(Specific heat capacity of water is $4.2 \text{ J kg}^{-1}\text{K}^{-1}$ and specific heat capacity for copper is $400 \text{ J kg}^{-1}\text{K}^{-1}$).

- (i) **Determine** the mass of melted ice. (1 mark)

- (ii) **Find** the heat lost by the calorimeter and water. (3 marks)

(Given that L_f is the Specific Latent heat of Fusion of ice.)

(iii) **Write** an expression for the heat gained by melting ice. (1 mark)

(iv) **Calculate** heat gained by melted ice. (1 mark)

(v) **Determine** the value of L_f (2 marks)

15. (a) (i) **Explain** how temperature affects the density of a fixed mass of a gas at constant pressure. (2 marks)

(ii) **Explain** what is meant by absolute zero temperature. (2 marks)

(b) A gas at room temperature (27°C) and atmospheric pressure 100 kPa is compressed to one eighth its original volume and an absolute pressure of 2 000 kPa. **Determine** the:

(i) new temperature of the gas. (3 marks)

(ii) ratio of the new density to original density. (3 marks)

16. (a) **Define** the term power and **State** its SI unit. (2 marks)

(b) A student of mass 75 kg climbs up a set of stairs 6.0 m high in 54 seconds, **determine** the:

(i) work done by the student. (2 marks)

(ii) student's power output during the climb. (2 marks)

(c) (i) If the student in (b) above used a lift with a motor

rated 300 W, **determine** her average speed upwards.

(2 marks)

(ii) **Determine** the efficiency of the motor used by the lift.

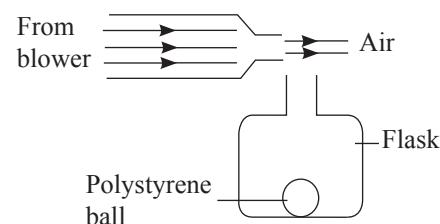
(2 marks)

SAMPLE PAPER 1(3)

SECTION A (25 marks)

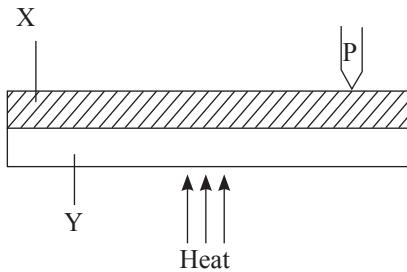
- The weight of a 16 kg object is 80 N on a certain planet.
(a) Find the gravitational field strength on the planet. (2 marks)
(b) If an object weighs 140 N on the planet, find its mass. (1 mark)
- State** two factors that **determine** pressure in a liquid at a particular place. (2 marks)
- A 300 kg block of aluminium 200°C is put in 200 g of water in a well-lagged calorimeter of heat capacity 800 J/kgK. Given that the initial temperature of the water is 23°C , **determine** the final temperature. (Specific heat capacity of Aluminium = $900 \text{ Jkg}^{-1}\text{K}^{-1}$, Specific heat capacity of water = $4200 \text{ JJkg}^{-1}\text{K}^{-1}$). (3 marks)

- The figure below shows a very light polystyrene ball placed in a flask. When a jet of air is violently blown over the mouth of the flask, the ball is observed to rise from the bottom.



Explain the observation. (2 marks)

5. Two metals X and Y welded together are heated so that they break the contact shown at P in the figure.



Explain how the contact is broken.
(2 marks)

6. A uniform metre rule of mass 200 g is pivoted at the 20 cm mark. **Determine** the mark on the ruler at which a mass of 500 g should be placed in order to obtain balance. (3 marks)

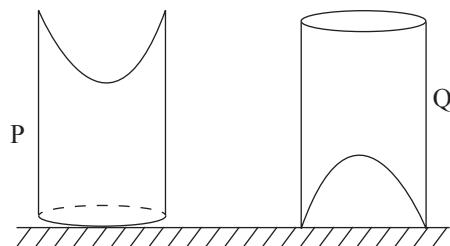
7. A gas enclosed in a strong vessel is heated to a temperature of 58 °C. During the process, the pressure rises from 1.03 Atmospheres to 2.15 Atmospheres. **What** was the initial temperature of the gas?
(3 marks)

8. The speed of a body in circular motion remains constant even though it is continually acted upon by a force. **Explain.** (1 mark)

9. **Distinguish** between thermal conduction and radiation. (1 mark)

10. A student puts a drop of methylated spirit and a drop of water at room temperature on her hand. **Explain** why the methylated spirit feels much colder than the water.
(2 marks)

11. A cylindrical block of metal with a curved section is placed to rest in two different positions as shown in the following figure.

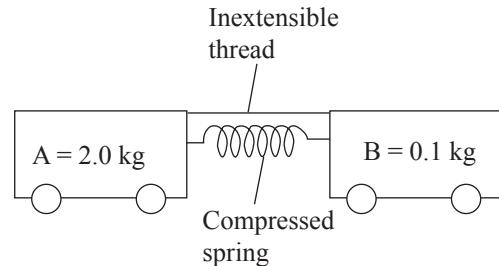


State and explain which of the positions is more stable. (2 marks)

12. **Define** the term velocity ratio of a machine. (1 mark)

SECTION B (55 marks)

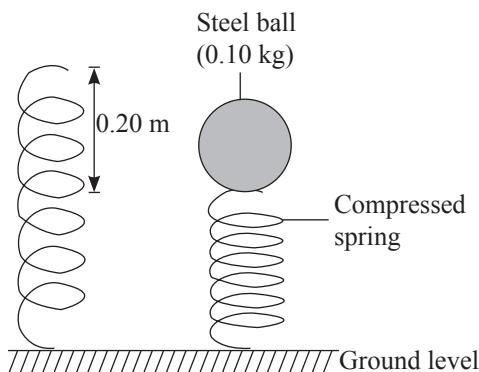
13. (a) The diagram shows two stationary trolleys A and B separated by a compressed spring and held together by an inextensible thread. The mass of trolley A is 2.0 kg and that of trolley B 0.1 kg. When the thread is cut, the trolleys move rapidly apart.



- (i) **State** the energy changes that occur when the string is cut. (1 mark)

- (ii) If trolley A moves off with a speed of 0.25 m/s, **calculate** the speed with which trolley B moves off. (3 marks)

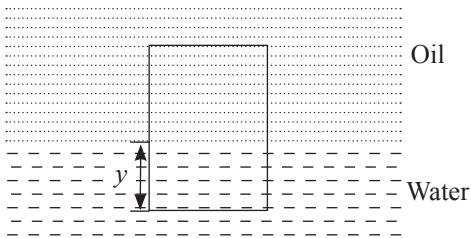
- (b) A steel ball of mass 0.10 kg was placed on top of a level ground. The spring was then compressed by 0.20 m with an average force of 1.0 N as shown.



- (i) **State** the energy changes that take place from when the compressed spring is released to when the steel ball attains maximum height. (2 marks)
- (ii) **Determine** the spring constant. (2 marks)
- (iii) **Calculate** the maximum height the ball attains. (Take $g = 10 \text{ N/kg}$) (3 marks)
14. (a) In an experiment to **determine** the diameter of a cylindrical pencil, a student was provided with a string and a metre rule.
- (i) **Write down** the procedure that can be used to determine the diameter of the pencil. (3 marks)
- (ii) **Explain** how parallax error is reduced during measurement with a metre rule. (1 mark)
- (b) In an experiment to **determine** the density of a material of paper, a student is provided with a pile of papers, a ruler, a micrometer screw gauge and a beam balance.
- (i) **Describe** how the student can proceed to obtain the density of the material making up the paper. (5 marks)

(ii) **State and explain** the assumptions made by the student. (4 marks)

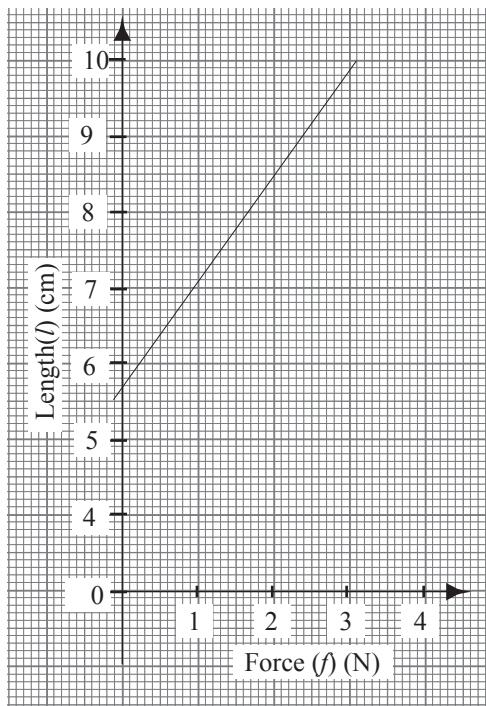
15. Oil of density 800 kg/m^3 rests on the surface of water. A cubic iron block of side 50 mm and density 950 kg/m^3 floats by a distance y in the fresh water as shown in the figure below.



Given that the density of water is 1000 kg/m^3 , **determine**:

- (a) the weight of the iron. (3 marks)
- (b) an expression for the upthrust on iron due to water. (2 marks)
- (c) an expression for the upthrust on the iron cube due to oil. (2 marks)
- (d) the value of y . (3 marks)

16. (a) Two springs are made from identical pieces of wire of same material. **State** any two factors that **determine** their springs' constants. (2 marks)
- (b) A spring when loaded with a stone of mass m extends by 1.2 cm. When the same spring is loaded with the mass and an additional 150 g mass, the extension is 1.6 cm. **Find** the value of mass m . (2 marks)
- (c) The graph shows the variation of length l , of a spring as it is subjected to a varying stretching force, f .

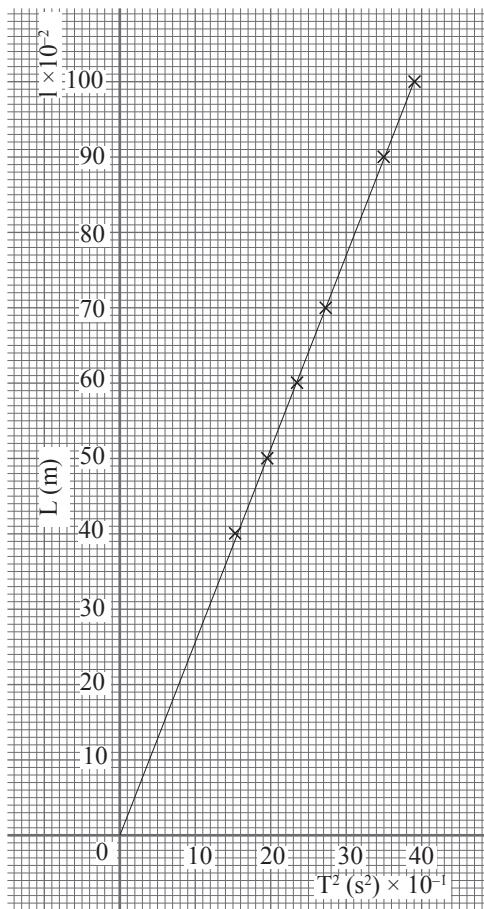


From the graph:

- (i) **determine** the original length of the spring before stretching. (1 mark)
 - (ii) **find** the spring's constant. (3 marks)
 - (iii) **show** a sketch for a spring of the same unstretched length but smaller diameter. (1 mark)
17. (a) A cyclist C and sprinter P are 100 m opposite each other. If the cyclist is moving at 12 m/s and the sprinter at 8 m/s.
- (i) **Determine** the time (t) after which they meet each other. (2 marks)
 - (ii) **Find** the distance (S) travelled by the sprinter in the time (t) above. (2 marks)
 - (iii) **Sketch** the distance-time graph

to represent the motion of the cyclist. (2 marks)

- (b) The graph below shows how the square of the periodic time (T^2) varies with the length l of a simple pendulum in an experiment to **determine** the gravitational acceleration, g .



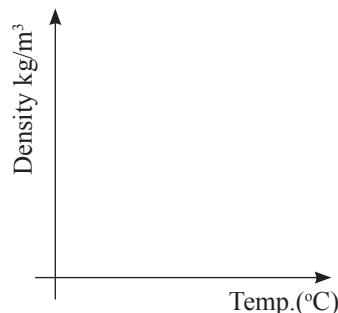
Determine:

- (i) time for 10 oscillations when the length of the spring is 65 cm. (2 marks)
- (ii) gravitational acceleration, given that $T = 2\pi \sqrt{\frac{l}{g}}$ (3 marks)

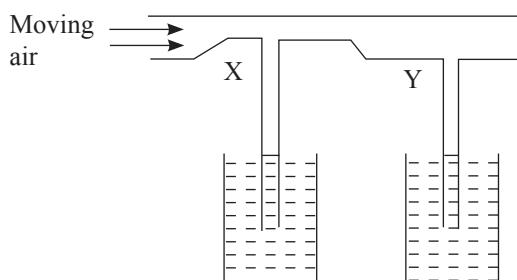
SAMPLE PAPER 1(4)

SECTION A (25 marks)

- A metal ball displaces a volume of 30 ml of water in a measuring cylinder. The ball is attached to a cork using a light string to help sink the cork. The combination when totally immersed displaces 170 ml of water. If the density of the cork is 0.5 g/cm^3 , **determine** the mass of the cork. *(3 marks)*
- On the axes provided below, **sketch** a graph to show how the density of water varies with temperature between 0°C and 10°C . *(1 mark)*

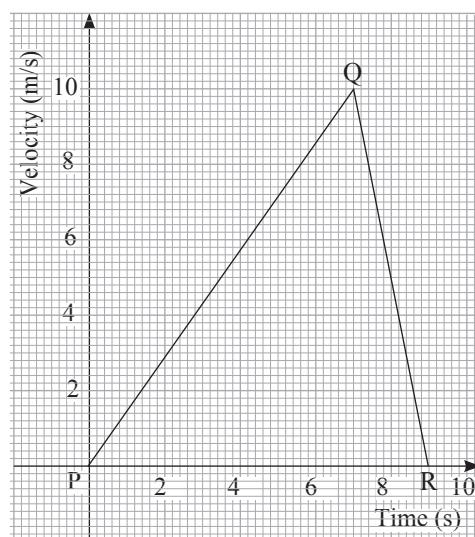


- Explain** why water on surface of glass smeared with oil forms droplets while on a clean glass surface it spreads. *(2 marks)*
- (a) **Indicate** the levels of water in X and Y in the diagram below when air is blown in the direction shown. *(1 mark)*

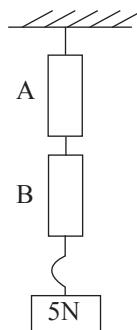


(b) **Explain** your answer in (a) above. *(2 marks)*

- Describe** the energy changes that take place when a windmill is used to generate electricity. *(2 marks)*
- The velocity-time graph below depicts the motion of a lift climbing from the ground floor.



- (i) **At what** point is the lift at the highest point? *(1 mark)*
- (ii) **Determine** the maximum height attained by the lift. *(2 marks)*
- The figure below shows an assembly of two identical spring balances, A and B each of mass 70 g and supporting a weight of 5 N:

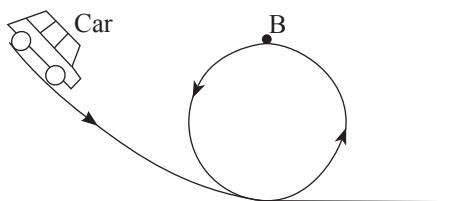


Determine the reading on spring balance:

(i) A _____

(ii) B _____ (2 marks)

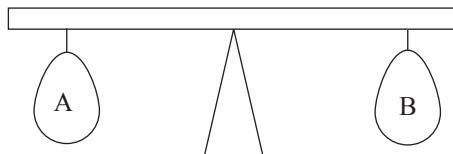
8. The figure shows a looped track for a stunt car.



At some instance, the vehicle passes at position B on a loop of radius 3.0 m.

Find the minimum speed of the car at position B, below which the car will fall off the track. (3 marks)

9. Two identical balloons A and B containing equal masses of gas at the same temperature are balanced on the lever system as shown in the figure below.



Explain why the lever tips to the right

if the temperature of the gas in A is increased. (2 marks)

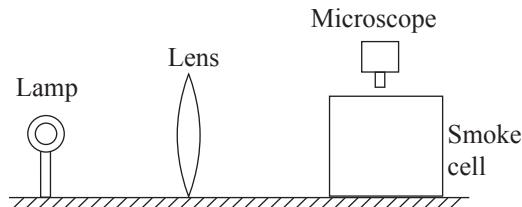
10. **State** two factors that can speed up evaporation in a given liquid. (2 marks)

11. (a) Sketch a graph of acceleration against mass for a force acting on various masses. (1 mark)

- (b) **Explain** the shape of the graph. (1 mark)

SECTION B (55 marks)

12. The motion of smoke particles enclosed in a smoke cell can be studied using the set-up shown below:



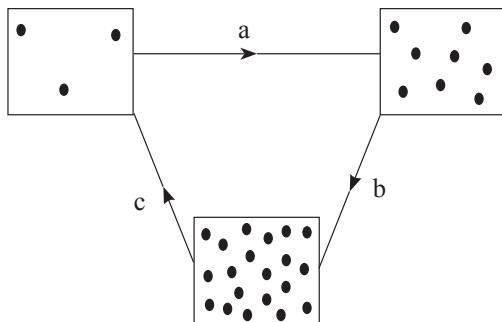
- (a) **Draw** a ray diagram to show how the smoke particles illuminated. (2 marks)

- (b) (i) **Explain** what happens in the smoke cell. (2 marks)

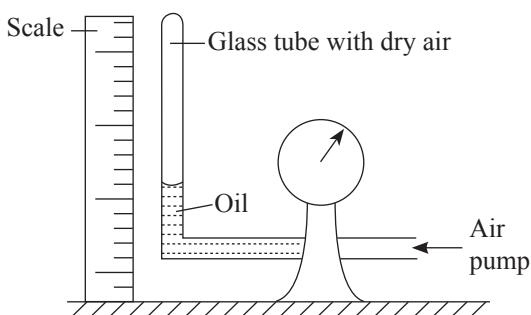
- (ii) **What** is the purpose of the microscope? (1 mark)

- (c) **State** two factors that affect the motion of the particles in the smoke cell. (2 marks)

- (d) The diagram shows different **states** of matter:



13. The figure below shows a set-up to investigate how the pressure of a gas varies with its volume:
- (i) **Name** the processes a, b and c. (1 mark)
- (ii) **Explain** why solids have a definite shape but liquids take the shape of the container in which they are put. (2 marks)

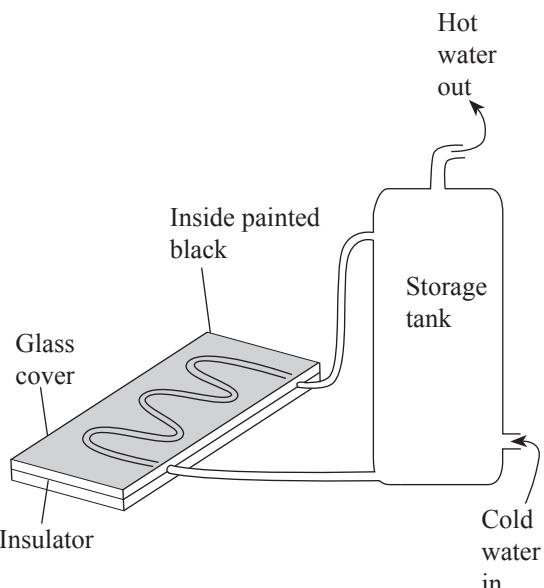


- (a) **Describe** how the apparatus may be used to verify Boyle's law. (4 marks)
- (b) Using the set-up, the following results were obtained:

| | | | | |
|---------------------------------|----|----|----|----|
| Pressure N/m² | 27 | 54 | 60 | 90 |
| Volume cm³ | 80 | 40 | 36 | 24 |

- (i) **Plot** a suitable graph used to confirm that Boyle's law is obeyed. (6 marks)
- (ii) **Determine** the slope of the graph. (2 marks)

14. A simple design of solar heater is shown in the figure below:



- (a) (i) **Why** is the inside surface painted black? (1 mark)

- (ii) The top surface is covered with glass while the bottom is an insulating material. **Explain** the choice of these materials. (2 marks)

- (iii) **Why** is the coiled pipe inside the box made of copper? (1 mark)

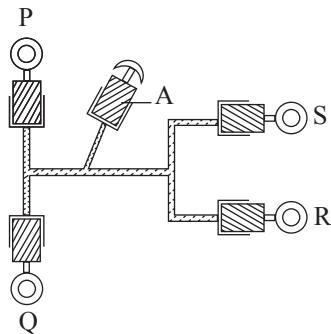
- (b) On a particular day, the temperature of 200 kg of water in the tank increases from 24 °C to 35 °C in 5 hours.

- (i) **Determine** the amount of heat energy delivered by the solar heater. (3 marks)

- (ii) **Calculate** the average power dissipated by the heater. (2 marks)

- (c) **Suggest** ways of minimising heat losses in the storage tank. (2 marks)

15. The figure below shows a hydraulic brake system for a car. The area of the master piston A is 0.75 cm^2 while the slave pistons attached to the tyres P, Q, R and S are of area 3 cm^2 each. A force of 500 N is applied on the master cylinder.



(a) **Define** pressure and give its SI units. (2 marks)

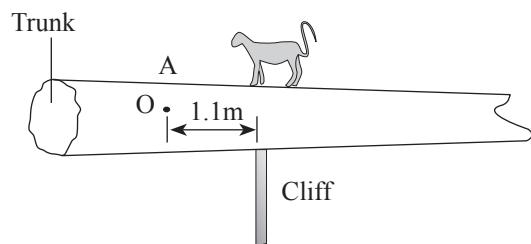
- (b) (i) **State** the principle of transmission of pressure in liquids. (1 mark)
(ii) **State** two important properties of the fluid used in the system. (2 marks)

(iii) **Explain** why the slave cylinders are of the same size. (1 mark)

(c) **Calculate:**

- (i) The pressure generated in the master cylinder. (2 marks)
(ii) Braking force on each tyre. (3 marks)

16. (a) In the following figure, a 25 kg monkey walks on a fallen tree trunk partly overhanging the edge of a cliff. The mass of the trunk is 75 kg and its centre of gravity O is at a distance of 1.1 m.

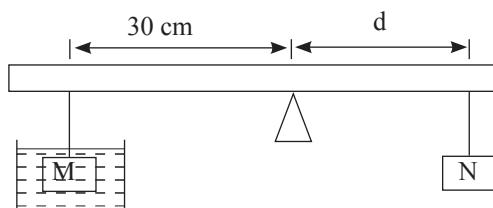


(i) **Explain** why the trunk does not tip over when the monkey is at the position marked A. (1 mark)

(ii) **What** is the reaction force from the ground? (2 marks)

(iii) **How** far beyond the cliff edge can the monkey walk before the trunk tips over? (3 marks)

- (b) Two identical blocks M and N of volume V of the same material are balanced on the lever arrangement shown below:

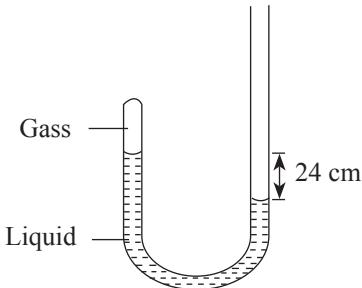


(i) Given that the densities of the liquid and the blocks are 0.8 g/cm^3 and 2.7 cm^3 respectively, **write** expressions for clockwise and anti-clockwise moments about the pivot. (3 marks)

(ii) Hence or otherwise, **determine** the distance d. (2 marks)

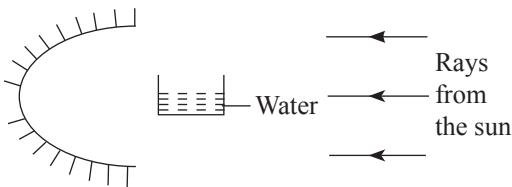
SAMPLE PAPER 1(5)
SECTION A (25 marks)

1. The figure below shows a U-tube with gas trapped at one end by a liquid of density 1400 kg/m^3 :



Given that atmospheric pressure is $1.03 \times 10^5 \text{ N/m}^2$, **determine** the gas pressure. (3 marks)

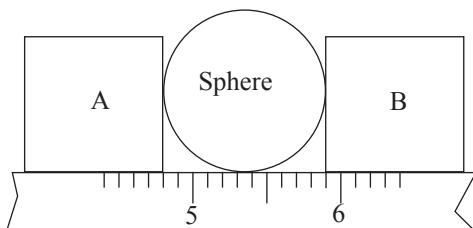
2. The diagram below shows a solar concentrator.



Explain with the aid of a ray diagram how the water in the container is heated. (2 marks)

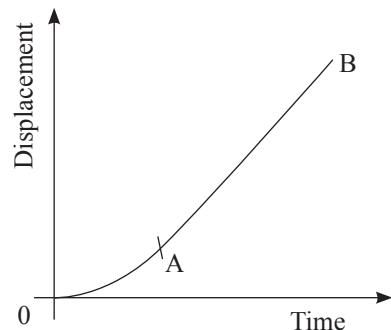
3. A body weighs 20 N and has a volume of 200 cm^3 . **Find** its weight when fully immersed in a liquid of density 8 g/cm^3 . (3 marks)

4. The figure below shows two blocks A and B placed against a sphere on a metre rule:



Determine the radius of the sphere. (2 marks)

5. The figure below is a sketch of displacement-time graph for a metal ball falling through a highly viscous liquid:



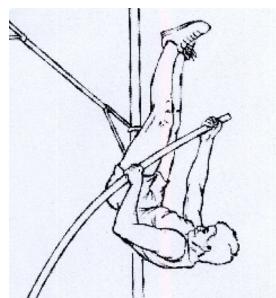
Explain the shape of the graph along:

(a) section OA. (1 mark)

(b) section AB. (2 marks)

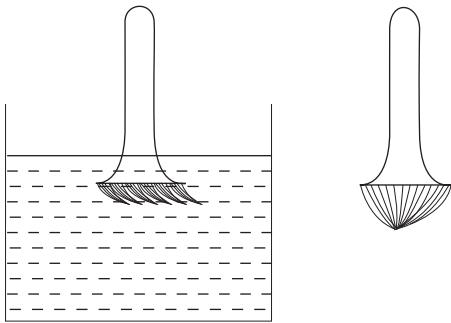
6. A pipe has cross-section area of 49 cm^2 at one end and 16 cm^2 at the other. If water gets into the pipe through the wider end with a velocity of 8 m/s, **calculate** the velocity of water at the narrower end. (2 marks)

7. The figure below shows a pole-vaulter on the verge of clearing a height:



(a) Modern poles are capable of bending to very extreme level. **Explain** why this is advantageous to the athlete. (1 mark)

- (b) **Explain** why it is more comfortable for the pole-vaulter to land on thick cushion rather than sand or dust. (2 marks)
8. A gas cylinder contains gas at a pressure of 3.05×10^6 Pa and temperature 32°C . **Determine** the pressure of the gas if the temperature falls to 10°C . (3 marks)
9. The figure below shows a paint brush dipped in a clear paint and when removed from the paint.

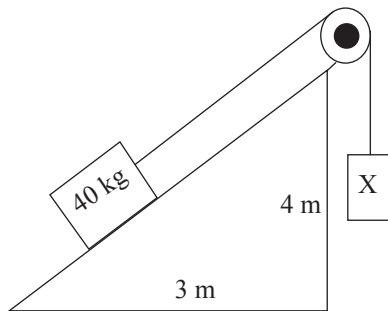


Explain the shape of the bristles. (2 marks)

10. **State** the advantage of using a density bottle instead of a measuring cylinder in determining density. (1 mark)
11. **What** is meant by Brownian motion? (1 mark)

SECTION B (55 marks)

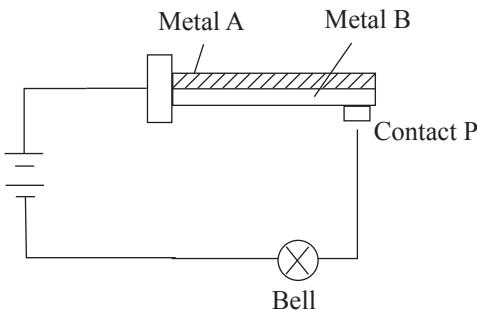
12. (a) In a machine combining gears and wheel and axle, the number of teeth on the driving wheel is 20 while the driven wheel has 60 teeth. The handle moving the driving wheel is of radius $R_1 = 40$ cm, while the radius R_2 of the axle is 8 cm.
- Determine:**
- (i) the velocity ratio of the gear and that of wheel-axle. (4 marks)
- (ii) Overall VR of the combination. (1 mark)
- (iii) If a force $F = 30$ N is applied, **determine** the maximum load that can be raised assuming that the efficiency is 100%. (3 marks)
- (b) A mass of a 40 kg is moved up a rough inclined plane at uniform speed by the pull from the overhanging mass X as shown in the figure.



Determine the mass X if the system is 80% efficient. (3 marks)

13. In an experiment to calibrate a mercury thermometer, a student dipped the bulb in melting ice and recorded the length of the mercury column as 3.6 cm from the bulb. The student then placed the bulb in boiling water and recorded the new length as 19.2 cm.
- (a) (i) **State** what the two points represent. (2 marks)
- (ii) **Describe** how the points are marked. (4 marks)
- (b) **Determine** the temperature at which the length of mercury column is recorded as 13.2 cm. (3 marks)

- (c) The figure below shows a fire alarm circuit consisting of a bimetallic strip, bell and a battery:



Explain how the system works.
(2 marks)

14. A 150 g mass is held at the centre of a rotating turntable by an elastic cord.

- (a) Given that the table covers 6 revolutions per second and the mass is at a radius of 0.45 m, **determine**:

- (i) the angular velocity of the mass.
(2 marks)
- (ii) the tension in the cord.
(2 marks)

- (b) If the cord stretches at 12 N/mm, **determine**:

- (i) the resulting extension.
(2 marks)
- (ii) the unstretched length of the cord.
(2 marks)

- (c) Given that the breaking tension of the cord is 130 N, **determine** the maximum linear velocity at which the mass can be rotated.
(4 marks)

15. (a) A motorist driving at a speed of 90 m/hr notices a donkey-cart 40 m ahead and applies brakes. If the reaction time of the motorist was

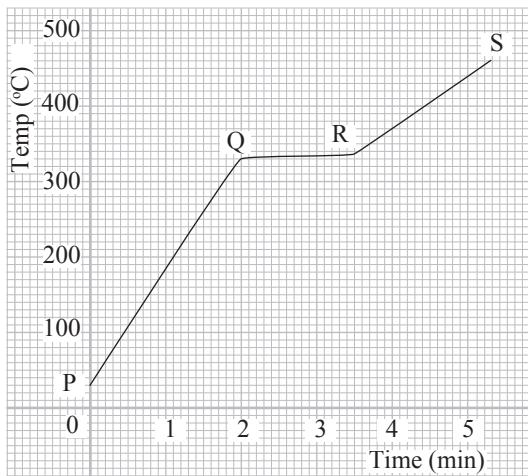
0.6 s and that the mass of the car is 1 500 kg, **determine**:

- (i) the distance covered before application of brakes. (2 marks)
- (ii) the acceleration, if the motorist just stops short of hitting the cart. (3 marks)
- (iii) the magnitude of the braking force. (2 marks)

- (b) If the motorist had negligible reaction time, **determine** the acceleration.
(2 marks)

- (c) On the same axes, **sketch** the velocity-time graphs for (a) and (b) above.
(2 marks)

16. (a) The figure below is a graph of temperature against time for 250 g of substance which is solid at room temperature:



Throughout the time of the experiment, a 75W heating element is used to supply heat to the substance at a steady rate. From the graph, **determine** the:

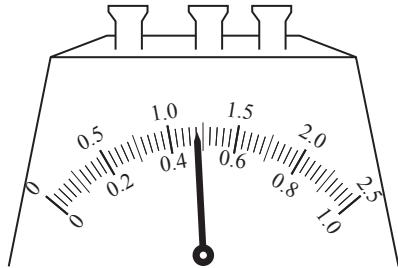
- (i) room temperature. (1 mark)

- (ii) melting point of the substance. (1 mark)
- (iii) specific heat capacity of the solid. (3 marks)
- (iv) specific latent heat of fusion of the solid. (2 marks)
- (b) Using the kinetic theory, **explain** the shape of the graph at:
- (i) PQ
 (ii) QR
 (iii) RS (3 marks)

SAMPLE PAPER 2 (1)

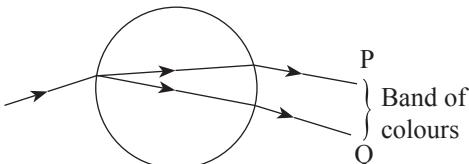
SECTION A (25 marks)

1. The figure below shows an ammeter reading when a student used the instrument to measure current through a conductor:



Determine the reading if the lower scale was used. (1 mark)

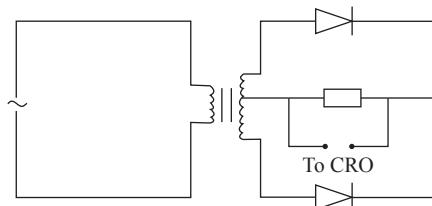
2. The figure below shows the formation of a band of colours when white light traverses a drop of water:



(i) **Explain** why it is split into different colours between P and Q. (2 marks)

(ii) **What** natural phenomenon is associated with the above? (1 mark)

3. An electric iron is rated at 1.5 KW, 240 V. **Calculate** the resistance of the element. (2 marks)
4. The figure below shows an arrangement of diodes for rectification of a.c.

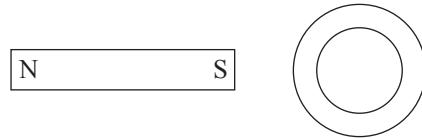


(a) **What** is a diode? (1 mark)

(b) On the axes provided, **sketch** the wave form for the output voltage. (1 mark)

5. A model preparing for beauty contest stands 70 cm away from a concave mirror of focal length 90 cm. **State** two characteristics of the image observed. (2 marks)

6. The diagram below shows a soft iron ring lying next to the south-pole of a magnet.



(a) **Complete** the diagram to show the magnetic field patterns between the magnet and the ring. (2 marks)

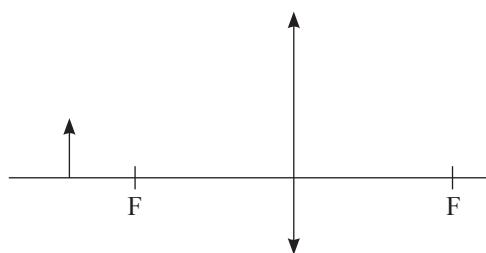
(b) **State** a practical application of the above effect. (1 mark)

7. **Define** the term **threshold frequency** as applied to photoelectricity. (1 mark)

8. An X-ray tube has an accelerating potential of 25 kV. Assuming all the energy goes into producing the X-rays, **calculate** the shortest wavelength of the X-ray beam. (Take Planck's constant = 6.63×10^{-34} Js and charge on an electron = 1.6×10^{-19} C). **(3 marks)**

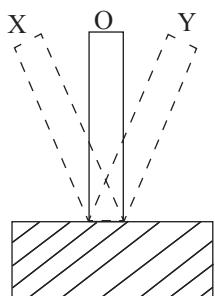
9. A boy standing in front of a high wall claps his hands once and hears an echo after 0.64 seconds. If he moves 20 m farther away from the wall and claps again, he hears the echo after 0.76 seconds. **Calculate** the speed of sound. **(3 marks)**

10. The incomplete diagram below shows an object placed in front of a converging lens.



Complete the diagram to show the position of the image produced. **(2 marks)**

11. The diagram below shows a blade fixed on a wooden base and plucked to vibrate about the rest position.



If the movement from O to X and back

to O takes 0.4 seconds, **calculate** the frequency of vibration of the blade.

(2 marks)

12. The half-life of a radioactive substance is 4 years. **Determine** the fraction decayed after 20 years. **(2 marks)**

SECTION B (55 marks)

13. (a) The table below shows values of current and voltage for a junction diode.

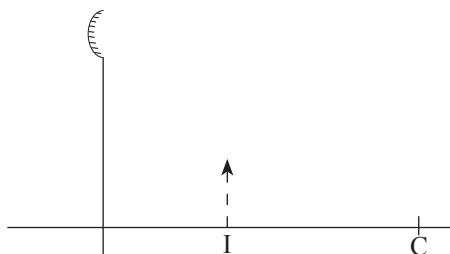
| Voltage (V) | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 |
|--------------|---|-----|-----|-----|-----|-----|-----|-----|-----|
| Current (mA) | 0 | 0 | 0 | 0 | 0.5 | 1.4 | 5 | 17 | 50 |

- (i) Plot a graph of current against voltage. **(5 marks)**

- (ii) **Explain** the nature of the graph. **(2 marks)**

- (iii) **Determine** the resistance of the diode when the voltage is 0.65 V. **(3 marks)**

14. (a) The figure below shows an image I of an object in a convex mirror of curvature C.



By ray diagram construction, **locate** the object. **(4 marks)**

- (b) An object is placed at a distance of 16 cm from a convex mirror of focal length 10 cm. **Calculate**:

- (i) the value for image distance. **(3 marks)**

(ii) the magnification. (2 marks)

- (c) The figure below shows a satellite dish used to receive television signals.

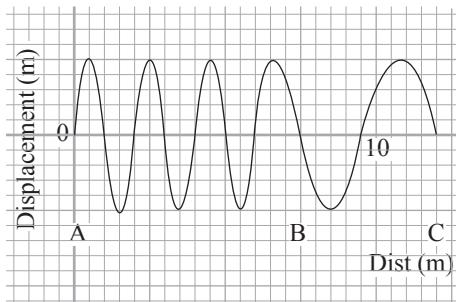


(i) **What** type of reflector is the dish? (1 mark)

(ii) At **what** point of the reflector is the signal detector? (1 mark)

(iii) If this dish was part of a perfect sphere, **what** effect would it have on the detected signal? (2 marks)

15. (a) The diagram shows a displacement-distance graph of a water wave of frequency 100 Hz travelling from A to C.



(i) **State** and **explain** the change that occurs at point B. (3 marks)

(ii) **Determine** the average velocity of the wave as it travels from B to C. (3 marks)

(iii) **State** characteristics of the wave

form that remain unchanged as passes. (2 marks)

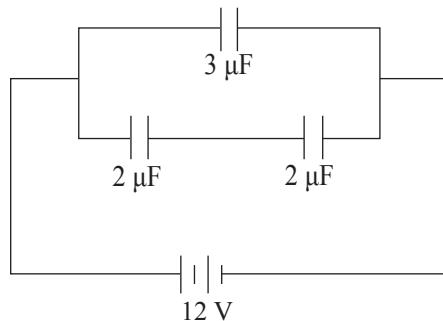
- (b) (i) **Distinguish** between soft X-rays and hard X-rays. (1 mark)

(ii) **State** two factors which may affect the sharpness of an image produced by an X-ray beam. (2 marks)

16. (a) **Define** the term capacitance of a capacitor. (1 mark)

(b) **State** three factors that affect the capacitance of a parallel plate capacitor. (3 marks)

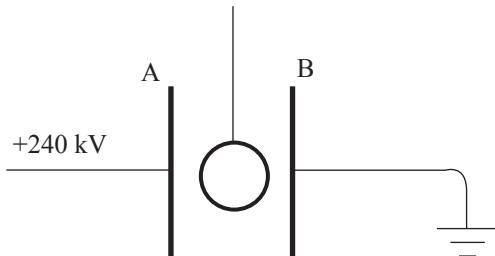
- (c) The figure below shows an arrangement of capacitors connected to a 12 V d.c. supply.



(i) **Determine** the effective capacitance. (2 marks)

(ii) **Calculate** the charge through the 3 μF capacitor. (2 marks)

- (d) The figure below shows two parallel metal plates A and B placed some distance apart, with plate B earthed.



If plate A is maintained at higher positive potential and a light ball coated with conducting paint is suspended between the plates, **explain** why the ball will oscillate touching the plates A and B alternately. **(3 marks)**

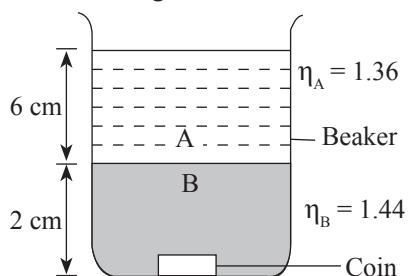
17. (a) **Draw** a labelled ray diagram to illustrate how a pinhole camera forms a magnified image of an object.

(3 marks)

(b) A tree of height 7.5 m is focused on the screen of pinhole camera made using a box of length 15 cm. If the height of the image is 10 cm, **determine** the distance of the tree from the camera. **(3 marks)**

- (c) (i) **State** Snell's law. **(1 mark)**

(ii) A coin is placed at the bottom of a beaker containing two immiscible liquids A and B of refractive indices $\eta_A = 1.36$ and $\eta_B = 1.44$ respectively as in the diagram below.



Calculate the apparent depth of the coin as seen by an observer from the top.

(4 marks)

SAMPLE PAPER 2 (2)

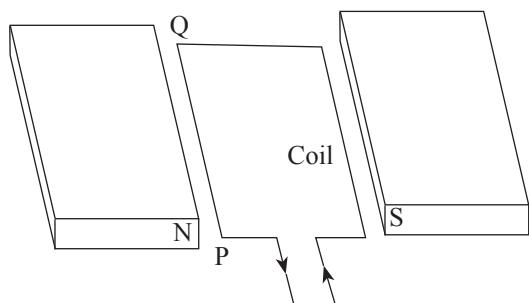
SECTION A (25 marks)

1. A student rubbed a plastic rod with a piece of material and found that the rod attracted light pieces of paper. In terms

of charge, **explain** what happens to the rod and the material. **(2 marks)**

2. When a cell is connected to an external resistance of value R_1 , the terminal voltage is 1.1 V and the current flowing is recorded as 0.8 A. When connected to a different resistor R_2 the terminal voltage is 0.9 V and the current is 0.5 A. Use the values to **determine** the EMF and internal resistance of the cell. **(3 marks)**

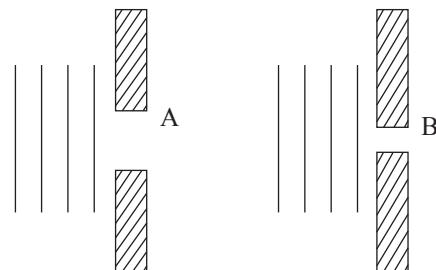
3. The figure below shows current flowing in coil placed in a magnetic field.



(a) **Show** on the diagram the direction of the force acting on the coil labelled P and Q. **(1 mark)**

(b) **State** two ways of increasing the force on the coil. **(2 marks)**

4. Water waves of same wavelength are incident on different apertures A and B as shown below.



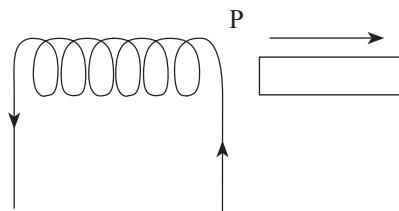
Complete the diagrams to show the

pattern of the waves beyond the apertures in each case. *(1 mark)*

5. When a current I flows through a resistance wire of 12.5Ω , heat is developed in the wire at the rate of 50 joules per second. **Determine** the value of I . *(3 marks)*

6. **Arrange** the following radiations in ascending order of frequencies: Infra-red, Microwaves, Red light, X-rays and Green light. *(1 mark)*

7. The figure below shows a bar magnet being pulled away from one end of a solenoid, with current induced in the direction shown.



Show in the diagram the polarity of the magnet. *(2 marks)*

8. The speed of a wave is 3×10^8 m/s. If the wave has a wavelength of 180 m, **determine** its periodic time. *(3 marks)*

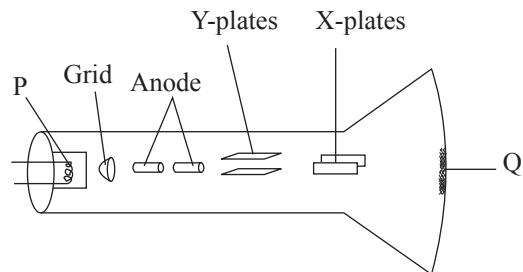
9. **State** the two functions of the earth-pin on the three-pin plug. *(2 marks)*

10. The distance between an object and its image in a convex mirror is 21 cm. Given that the image distance is 6 cm, **determine** the focal length of the mirror. *(3 marks)*

11. A special sea-vessel is used for determining the sea-depth through echo-sounding. If the echo is received after $3\frac{1}{2}$ seconds, **determine** the depth of the sea given that the speed of sound in water is 1500 m/s. *(2 marks)*

SECTION B (55 marks)

12. The figure below is a cathode ray tube.



- (a) (i) **Name** the parts labelled P and Q. *(2 marks)*

- (ii) The electron gun emits electrons through thermionic emission. **Explain** how this occurs in the tube. *(2 marks)*

- (b) (i) **State** the purpose of X and Y-plates. *(2 marks)*

- (ii) **State** two functions of the anode. *(2 marks)*

- (iii) **Explain** why the inside of the tube is essentially vacuum. *(1 mark)*

- (c) Television tubes use deflection coils instead of X and Y plates. **State** two advantages of these. *(2 marks)*

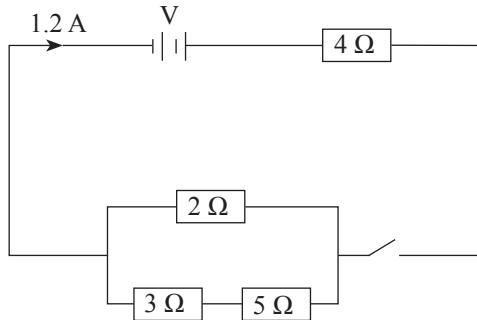
13. (a) (i) **Explain** the meaning of the term 'polarisation' as applied to a dry cell. *(2 marks)*

- (ii) How is polarisation overcome? *(1 mark)*

- (iii) A current of 120 mA flows through a point in a circuit for 5.3 minutes. Calculate the charge transferred. *(2 marks)*

- (b) The following figure shows an

electrical circuit with a network of resistors connected to a battery.



A current of 1.2 A flows through the $4\ \Omega$ resistor when the switch is closed.

Determine:

(i) the total resistance in the circuit. *(2 marks)*

(ii) the voltmeter reading. *(2 marks)*

(iii) the voltage across the $5\ \Omega$ resistor. *(4 marks)*

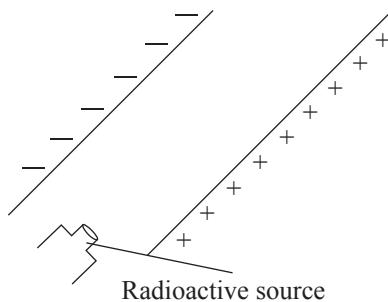
14. (a) Using a ray diagram, illustrate the use of a lens as a magnifying glass. *(3 marks)*

- (b) A lit candle is placed 68 cm from a screen. A convex lens is then positioned so that an image three times as large as object is formed on the screen. **Determine:**

(i) the distance between the lens and the candle. *(3 marks)*

(ii) the position and nature of an object placed 10 cm from the lens. *(5 marks)*

15. (a) A radioactive source emitting alpha, beta and gamma radiations is directed into an electric field as shown.



Show the paths for the three emissions inside the electric field. **Explain.** *(4 marks)*

- (b) A sample of radioactive material has a half-life of 3 days.

(i) **Explain** the term half-life.

(ii) If the sample originally had 128 particles, **fill** in the table below:

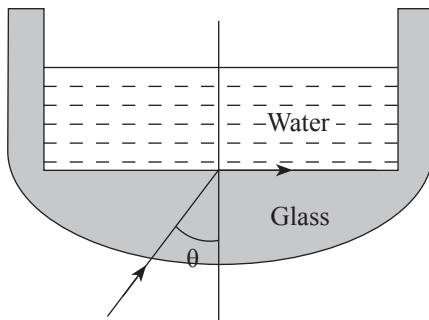
| Particles emitted per minute | Time (days) | Fraction decayed |
|------------------------------|-------------|------------------|
| 128 | 0 | 1 |
| | 3 | |
| | 6 | |
| | 9 | |
| | 12 | |

(iii) Fill the table and **illustrate** the process graphically.

(iv) **State** the fraction remaining undecayed after 7 days. *(7 marks)*

16. (a) **State** two conditions necessary for total internal reflection to occur. *(2 marks)*

- (b) The diagram below shows a ray incident on a glass container with a hemispherical solid base carrying some water.

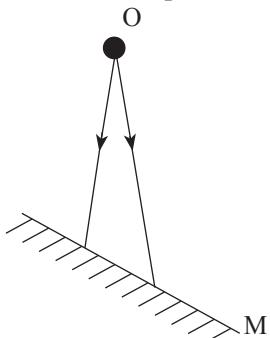


Given that the refractive index of water is 1.33 and that of glass is 1.5,

- calculate** the value of angle θ if the ray is to take the path shown. (4 marks)
- sketch** the path the ray will take if the angle θ is maintained and the water removed. (3 marks)

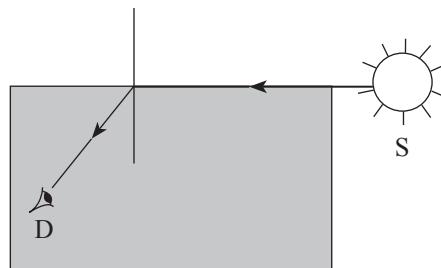
**SAMPLE PAPER 2(3)
SECTION A (25 marks)**

- The figure below represents an object O placed in front of a plane mirror M.



Complete the ray diagram to locate the position of the image. (2 marks)

- Explain** how a positively charged electroscope can be used to **determine** the charge on charged rod. (2 marks)
- The figure shows a diver positioned at point D below the water surface, and a setting sun S.

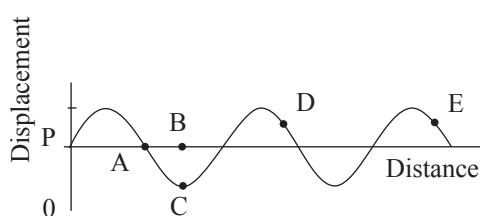


In what direction above the horizontal surface of the water will the diver see the setting sun? (Refractive index of water = 1.33). (3 marks)

- Distinguish** between X-rays and gamma radiation. (1 mark)
- Given three resistors of $2\ \Omega$, $6\ \Omega$ and $9\ \Omega$, **draw** a diagram to show how they can give an effective resistance of $5.6\ \Omega$. (2 marks)
- The figure below shows a conductor carrying current in a magnetic field:



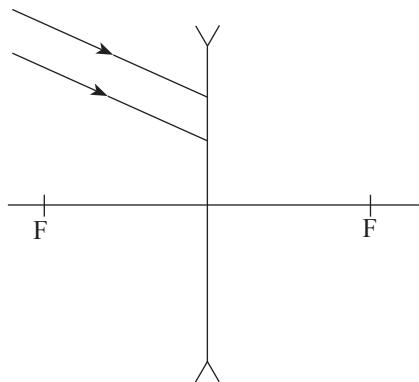
- (a) **Indicate** on the diagram, the direction of force on the conductor. (1 mark)
- (b) **State** two changes that can be made to alter the direction of the force. (2 marks)
- The figure below shows a transverse wave profile.



Identify any two marked points whose separation is equivalent to:

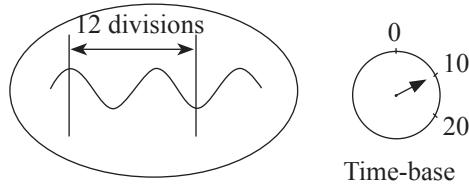
- wavelength (1 mark)
- amplitude (1 mark)

8. State two advantages of the lead-acid accumulator over the dry cell. (2 marks)
9. The figure below shows a pair of parallel rays from infinity incident on a concave lens.



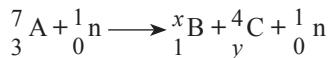
Complete the diagram to show the position of the image formed. (2 marks)

10. The figure below shows an output on a CRO screen with the time-base set as indicated.



Determine the frequency of the wave. (3 marks)

11. The equation below represents a nucleus fission reaction where a nuclear A is bombarded by a neutron to produce two nuclides B and C.



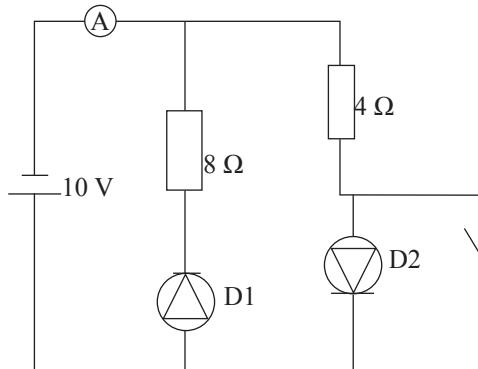
- (a) **Determine** the values of x and y. (2 marks)

- (b) **State** the role of neutron on the right hand side of the equation. (1 mark)

SECTION B (55 marks)

12. (a) (i) Given phosphorus and germanium, **explain** how an n-type semi-conductor is formed. (3 marks)
- (ii) **What** is the charge of a p-type semi-conductor? **Explain.** (2 marks)

- (b) The figure below shows an electric circuit with two diodes and two resistors.

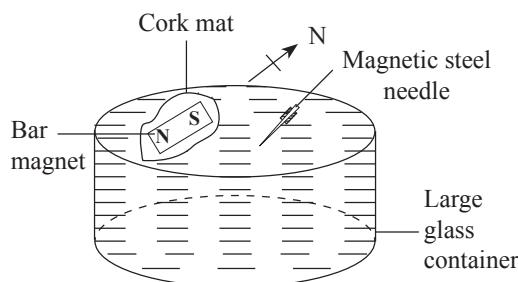


Determine the reading of the ammeter when:

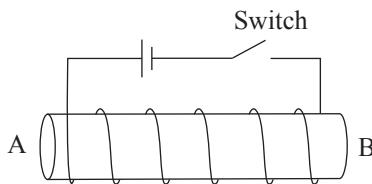
- (i) the switch is open. (3 marks)
- (ii) the switch is closed. (3 marks)

13. (a) A student is provided with the following apparatus: a basin with water, a bar magnet, a steel needle and a cork-mat.
- (i) **Explain** how the student can magnetise the needle using the bar magnet. (1 mark).
- (ii) **Explain** what happens if the bar magnet is made to float on water in the basin. (1 mark)
- (iii) **State** what happens if the needle is pushed through a small piece of cork to float on water and placed near the floating magnet as shown in the diagram.

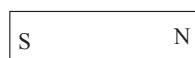
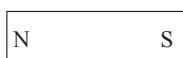
(2 marks)



- (b) A soft iron rod and a steel bar are placed in turns in a solenoid connected as in figure below.



- (i) Show the polarity of end B of the coil when the switch is closed. (1 mark)
- (ii) Describe what happens to the two rods when current is switched on for some time, then turned off. (2 marks)
- (c) Show the magnetic field pattern for the two bar magnets arranged side by side as shown in the figure. (2 marks)



- (i) Which of the above arrangements would be suitable for storing magnets in pairs? (1 mark)
- (ii) Explain, using a sketch, why soft iron keepers are placed at the end of arrangement chosen (use a sketch). (2 marks)

14. (a) Explain how the intensity and frequency of radiation affects photoemission of a given surface.

(2 marks)

- (b) The data below shows the results obtained from an experiment to determine the maximum kinetic energy of electrons emitted from a metal surface when irradiated with radiations of varying frequency.

| Frequency ($\times 10^{14}$ Hz) | Energy (10^{-19} J) |
|-------------------------------------|---------------------------|
| 5.5 | 0.62 |
| 6.0 | 0.96 |
| 7.3 | 1.80 |
| 8.0 | 2.28 |
| 8.8 | 2.80 |

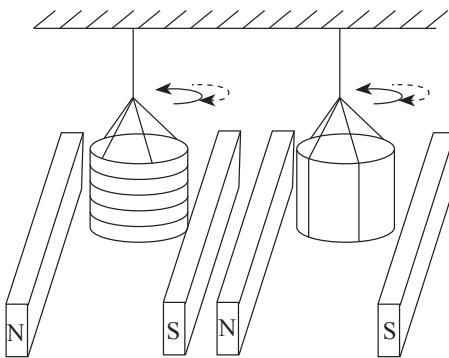
Draw a graph of kinetic energy (y-axis) against frequency of radiation.

(5 marks)

Given the equation $k.e_{\max} = hf - hf_0$

- (c) Use your graph to determine the:
- (i) Planck's constant (3 marks)
 - (ii) Threshold frequency. (1 mark)
 - (iii) Work function of the surface. (2 marks)

15. (a) The following figure shows two cylindrical blocks, one comprising copper discs insulated from one another and the other a single copper block placed between magnetic poles of the same strength. The two are simultaneously set in a horizontal oscillation as indicated.



Which of the blocks will come to rest earlier? **Explain.** (2 marks)

- (b) A step-down transformer with turns ratio 12:1 and efficiency 95% has 2 000 turns in the primary coil. When the primary circuit is connected to a 240 V a.c. source, the power delivered to a load is found to be 500 W. **Determine:**

- (i) the number of turns in the secondary coil. (2 marks)
- (ii) the input power. (2 marks)
- (iii) The secondary voltage. (2 marks)
- (iv) the secondary current. (2 marks)

16. (a) A consumer uses the following electrical appliances daily: four 60 W bulbs working for $3\frac{1}{2}$ hours, two 75 W bulbs working for 3 hours 45 minutes, an electric blender rated 500 W working for 15 minutes, and a television set rated 100 W working for 12 hours.

- (i) **Calculate** the total number of units consumed in a day. (3 marks)
- (ii) If the appliances are used for 30

days, **determine** the total cost if the cost per unit is 4.80 cents.

(2 marks)

- (b) A sub-station transmits 1.1 MW of power through cables of total resistance 1.8Ω at a voltage of 11 kV.

- (i) **State** two ways of minimising power loss during transmission. (2 marks)
- (ii) **Determine** power loss during the transmission. (3 marks)

SAMPLE PAPER 2(4) SECTION A (25 marks)

1. A hollow conductor resting on an uncharged electroscope is charged by either of the two methods:
- Carefully lowering the charged metal sphere without touching the sides until it is well inside the can.
 - Allowing the metal sphere to transfer the charge by simply touching the can from the outer surface.

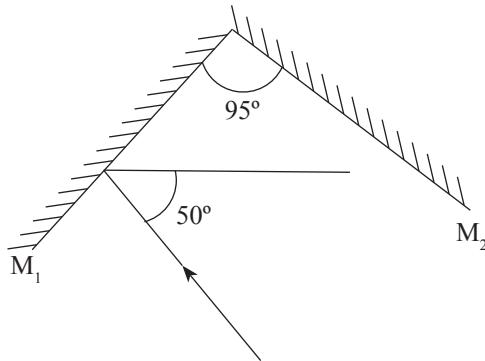
State and explain the difference observed in the leaf divergence for the two cases.

(3 marks)

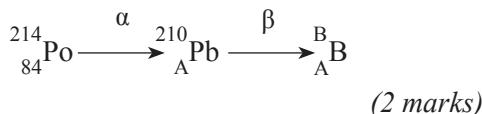
2. A student holds a convex mirror of focal length 20 cm at a distance of 25 cm from her face. **State** three characteristics of the image she observes. (3 marks)
3. An electric blender is rated 240 V, 400 W.
- (a) What current flows through the blender when it is in operation? (1 mark)
 - (b) Suppose the blender is connected

in series with a resistance of $136\ \Omega$, **what** will be the potential drop across its ends? (2 marks)

4. **Distinguish** between X-rays and cathode rays. (2 marks)
5. **Explain** why boron atom is referred to as acceptor atom during doping. (1 mark)
6. (a) **Distinguish** between a photon and proton. (1 mark)
 (b) **Sketch** a graph of energy of a photon and wavelength. (2 marks)
7. The figure shows a ray incident on a plane mirror M_1 at an angle of 50° . Mirror M_1 is inclined at an angle of 95° to a second mirror M_2 :



- (i) **Complete** the diagram to show how the ray will finally be reflected from mirror M_2 . (1 mark)
- (ii) **State** the angle of reflection in M_2 . (1 mark)
8. In the nuclear reaction below, **find** A and B.



(2 marks)

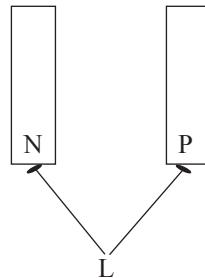
9. The table shows part of the electromagnetic spectrum.

| Gamma | X-rays | UV | Visible Light | Infra red | Radio waves |
|-------|--------|----|---------------|-----------|-------------|
|-------|--------|----|---------------|-----------|-------------|

- (a) **Explain** what happens to photo energy as one moves across the spectrum from gamma to radiowaves. (2 marks)
- (b) **What** part of the electromagnetic spectrum does a TV remote control gadget make use of? (1 mark)
10. **Explain** why sound from a distance source is heard more clearly at night than during the day. (2 marks)
11. **Explain** why the resistance of a metal conductor increases with increase in temperature. (1 mark)

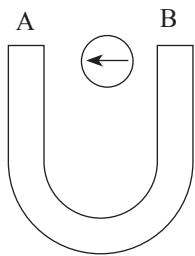
SECTION B (55 marks)

12. The diagram below shows two steel pins held at the poles of two magnets.

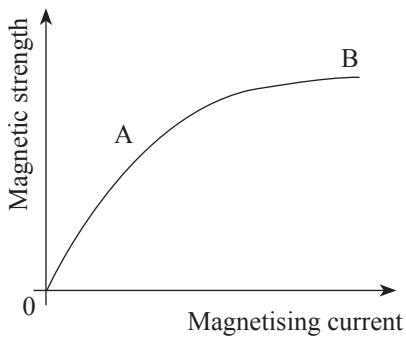


- (a) **State** the polarity at :
 - (i) P _____
 - (ii) L _____
- (b) (i) By **what** process are the pins magnetised? (1 mark)

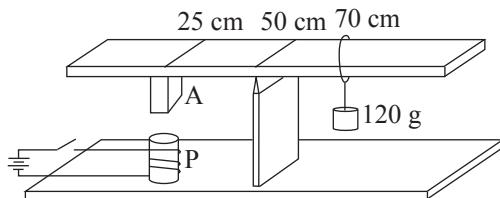
 (ii) **State** the law illustrated by the two pins. (1 mark)
- (c) The figure shows a U-shaped magnet with a plotting compass placed between its poles. The arrow at the compass represents its north pole.



- (i) **State** the polarities at A and B. (1 mark)
- (ii) **Draw** a diagram to indicate the magnetic field pattern around the U-shaped magnet. (1 mark)
- (d) The graph below shows the variation of magnetic strength against magnetising current.

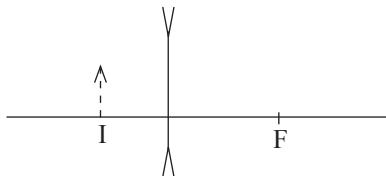


- (i) **Explain** the sections OA and AB. (2 marks)
- (ii) On the same axes, **sketch** the graph of a harder magnetic material. **Explain** your answer. (2 marks)
13. The figure shows a uniform metre rule with a bar magnet fixed to it at the 25 cm mark. The metre rule balances by the knife-edge at the 50 cm mark when a 120 g mass is suspended at the 70 cm mark. An electromagnet P is positioned just below the magnet as shown:



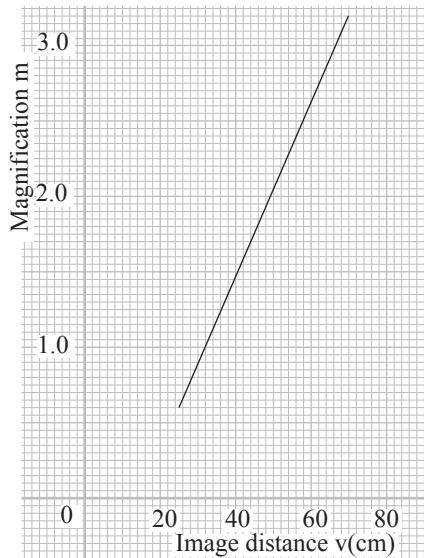
- (a) **Determine** the weight of the magnet. (3 marks)
- (b) When the circuit is switched on, it is observed that the position of the 120 g mass has to be adjusted by 5 cm towards the pivot to balance the metre rule.
- (i) **Determine** the new clockwise moment on the ruler. (2 marks)
- (ii) **State** the type of force (attractive or repulsive) and **determine** its magnitude. (4 marks)
- (iii) **State** the polarity of A. (2 marks)
14. The figure below shows a graph of displacement against time for a particular point in a wave.
- | Time (ms) | Displacement (mm) |
|-----------|-------------------|
| 0.0 | 0.0 |
| 0.125 | 1.5 |
| 0.25 | 0.0 |
| 0.375 | -1.5 |
| 0.5 | 0.0 |
| 0.625 | 1.5 |
| 0.75 | 0.0 |
| 0.875 | -1.5 |
| 1.0 | 0.0 |
- (a) **Explain** what is meant by displacement in a wave. (1 mark)
- (b) From the graph, **determine** the:
- (i) amplitude. (1 mark)
 - (ii) period. (2 marks)
 - (iii) frequency. (2 marks)
- (c) Given that the velocity of the wave is 320 m/s, **calculate** the wavelength of the wave profile shown. (2 marks)

- (d) On the same axes, **sketch** a wave profile with the same frequency but lower loudness if the given wave was a sound wave. *(1 mark)*
- (e) In a countryside where homesteads are situated in valleys surrounded by hills, radio reception from a distant transmitter is better than the TV reception. **Explain** this. *(2 marks)*
15. (a) The figure below shows the image in a concave lens of principal focus F as shown.



Locate the object by ray diagram construction. *(3 marks)*

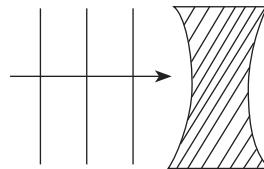
- (b) The figure below is a graph of magnification m against image distance v for a convex lens.



- (i) Given the equation $m = \frac{v}{f} - 1$,

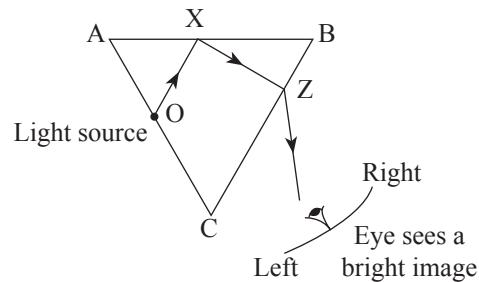
use the graph to **determine** the value of the focal length f .
(4 marks)

- (ii) What is the significance of the x-intercept? *(2 marks)*
- (c) The distance between an object and its virtual image in a convex lens is 36 cm. Given that the image is magnified 3 times, **determine** the focal length of the lens. *(4 marks)*
16. (a) A concave metallic block is placed at the base of a basin containing water such that it is just submerged. A straight wave is generated on the surface of the water, as shown.



Complete the diagram to show how the wave progresses over and beyond the block as viewed from the top. **Explain** your answer. *(3 marks)*

- (b) A light source is placed at a point on AC of an equilateral prism, as below.

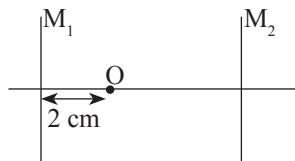


When the eye is moved from left to right, the image of the source as viewed through side BC suddenly becomes very bright.

- (i) **Explain** the difference in what is observed when the eye is further right and further left from the position shown. (3 marks)
- (ii) **State** the conditions necessary for the formation of the bright image. (1 mark)
- (iii) If the angle $OXZ = 84^\circ$, **determine** the refractive index of the glass prism. (3 marks)

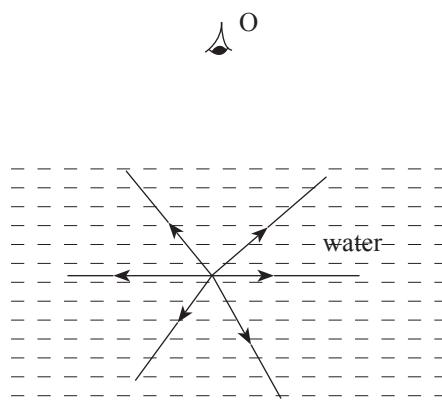
SAMPLE PAPER 2(5)
SECTION A (25 marks)

1. The figure below shows two parallel mirrors placed some distance apart. An O object is placed 2 cm from M_1 .



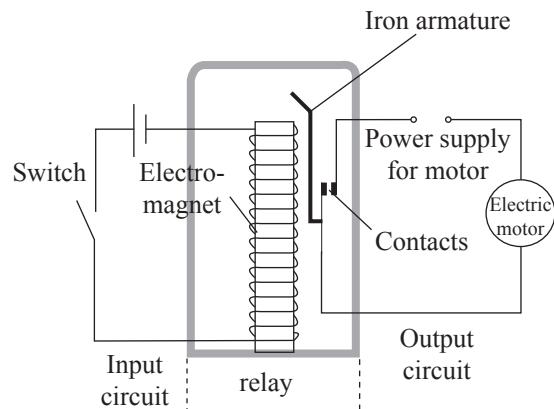
Determine:

- (i) the number of images the arrangement is capable of producing. (1 mark)
- (ii) **how** far the second image formed by M_2 is from M_1 . (1 mark)
2. **Draw** the combined magnetic field pattern of a magnet placed in the earth's magnetic field with the south pole of the magnet pointing towards the earth's north-pole and show the position of the neutral points. (2 marks)
3. The figure shows a point source of light in water and an observer O viewing from the above surface.



Given that water has a refractive index of $\frac{4}{3}$, **determine** the maximum angle for the cone of rays that will reach the observer. (2 marks)

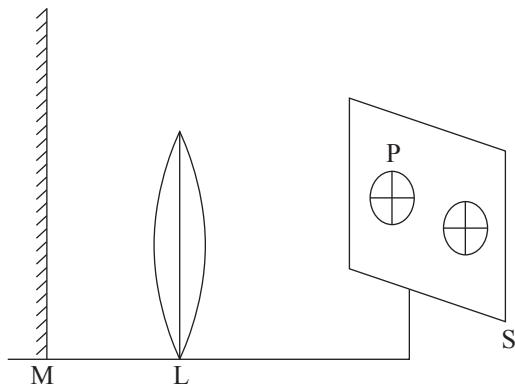
4. The figure below shows an electromagnet relay switch.



Explain its operation. (2 marks)

5. **Calculate** the speed of green colour of light in air, given that its wavelength is $6.14 \times 10^{-7} \text{ m}$ and frequency $4.88 \times 10^{14} \text{ Hz}$ (2 marks)
6. Briefly **explain** how you would use a positively charged electroscope to test the electrical conductivity of a material. (2 marks)

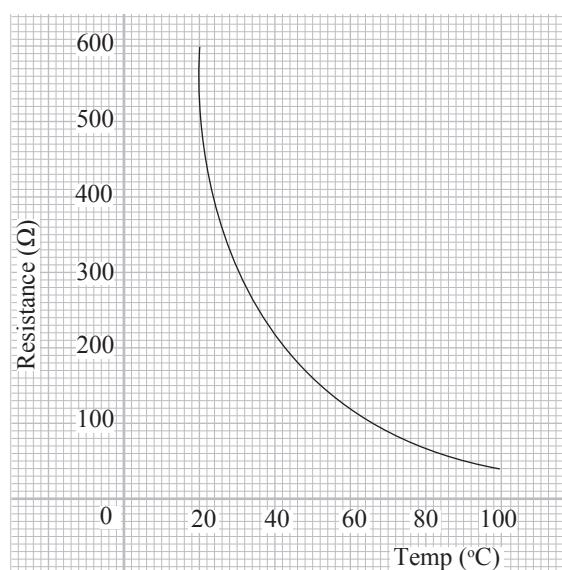
7. The figure below shows a set-up for determining the focal length of a convex lens L. The lens is placed between the plane mirror M and the object cross-wires is adjusted until the image of the illuminated cross wires appears on the screen S.



On the same figure, sketch a ray diagram to **illustrate** how the image of the cross point P of the wires forms on the screen. (2 marks)

8. **Describe** an experimental observation which shows that cathode rays move in straight lines. (1 mark)
9. A lead plate is used to shield a worker from X-ray radiation. **Give** the reason. (1 mark)
10. Potassium in a photocell emits electrons when illuminated with orange light. Tungsten emits electrons only when illuminated with ultra-violet light. **State** and **explain** which metal has a larger work function. (2 marks)

The following graph represents the variation of resistance of a certain semiconductor material with temperature. Use the graph to answer questions 11 and 12.

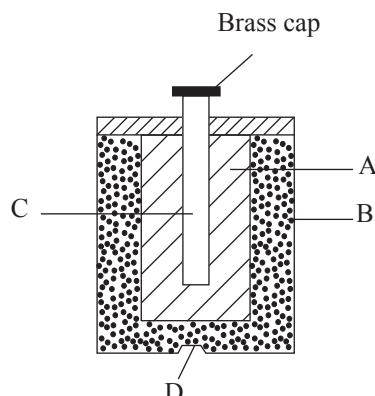


11. **Explain** the shape of the graph. (1 mark)

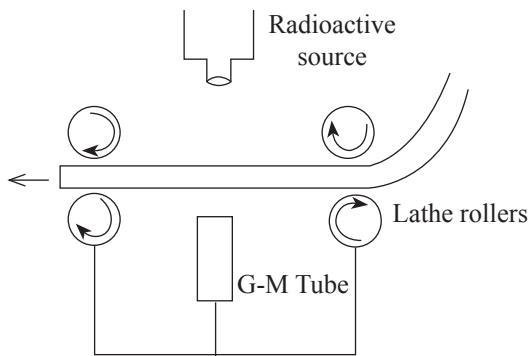
12. If a current of 17 mA flows through the material, **what** is the corresponding potential difference at the temperature of 67 °C? (2 marks)
13. **List** two different ways of changing the direction of a wave. (2 marks)
14. If the charge on a capacitor is kept constant, **explain** the effect on the potential difference when a dielectric is introduced between the plates. (1 mark)

SECTION B (55 marks)

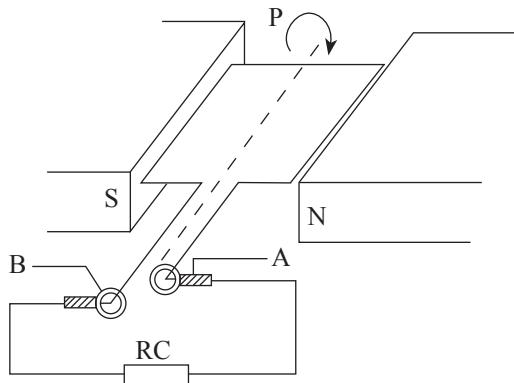
15. (a) The figure below shows a dry cell.



- (i) **Name** the parts labelled A, B and C. (3 marks)
- (ii) **Explain** the purpose of parts A, C and D in the cell. (3 marks)
- (iii) **State** the polarity of end marked D. (1 mark)
- (iv) **Explain** why the terminal voltage of the cell is likely to be less than its EMF when in use. (1 mark)
- (b) (i) A lead-acid cell is rated 50 Ah and supplies a steady current of 2 A. **What** does the term '50 Ah' mean? (2 marks)
- (ii) **State** two advantages of lead acid cell over a dry cell. (2 marks)
16. (a) **Describe** using a diagram what you understand by a ring circuit and why it is preferred in domestic wiring. (5 marks)
- (b) **Identify and explain** the faults in the light circuit shown. (3 marks)
-
- (c) A bulb is rated 1.2 kW, 240 V.
- (i) **Explain** the meaning of the statement. (1 mark)
- (ii) **What** is the resistance of the heater element? (2 marks)
- (iii) How long will the heater take to raise the temperature of $1\frac{1}{2}$ litres of water from 21°C to 75°C? (Specific heat capacity of water is $4\ 200\ \text{Jkg}^{-1}\text{K}^{-1}$). (3 marks)
17. (a) The figure below shows a metal plate and a metal grid connected to a high voltage potential. When an alpha source is directed towards the plate and the grid, a spark is registered by a scale. **Explain** what happens between the plate and the grid. (3 marks)
-
- (b) The equation below represents a nuclear fission process.
- $$^{235}_{92}\text{X} + {}^1_0\text{n} \rightarrow {}^{148}_a\text{Y} + {}^b_{35}\text{Z} + 3 {}^1_0\text{n}$$
- (i) **Determine** the values of a and b. (2 marks)
- (ii) **State** two characteristics of nuclear fission process. (2 marks)
- (c) The diagram shows one application of radioactive particles.



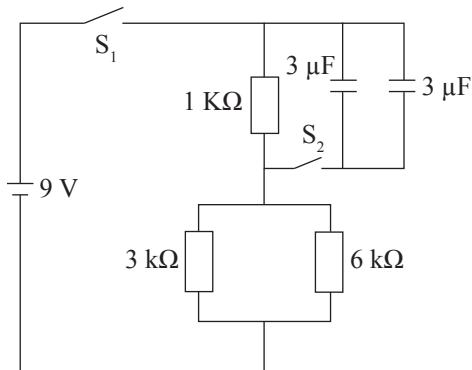
- (a) With reason, **state** the most suitable radioactive emission to be used. (2 marks)
- (b) **Explain** how the thickness control is effected. (3 marks)
18. (a) The figure below illustrates the working of a simple a.c. generator.



- (i) **Name** the parts labelled A and B. (2 marks)
- (ii) **Indicate** the direction of the current flow in the coil at point P as it passes the position shown. (1 mark)
- (iii) **State** three factors that **determine** the value of emf induced in the coil. (3 marks)
- (b) With the aid of simple diagrams, **describe** two methods, one which involves high loss of energy and the

other minimal loss, which can be employed to operate a 12 V lamp with voltage from a 240 V a.c. mains supply. In each case, **explain** how the energy losses occur. (4 marks)

19. The figure below shows a combination of resistors and capacitors in a d.c. circuit.



- (a) If switch S_1 is closed and S_2 is open, **determine**:
- the current through the $6\text{ k}\Omega$ resistor. (3 marks)
 - voltage across the $1\text{ k}\Omega$ resistor. (3 marks)
- (b) With the two switches closed:
- on the same axis, sketch the charge against time graphs. (2 marks)
 - determine** the total charge stored by the $3\text{ }\mu\text{F}$ capacitor. (2 marks)

MARKING SCHEME

SAMPLE PAPER 1 (1)

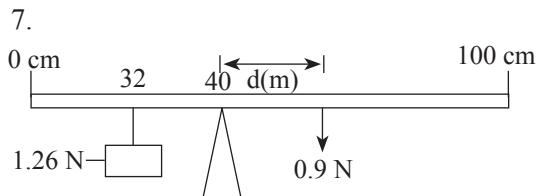
1. Mass of sand = $7 - 0.3 = 6.7\text{ kg}$

Density = $6\ 700 \div 2\ 900$

= 2.310 g/cm^3

2. (a) Surface tension.
 (b) The needle breaks the water surface hence sinks.
3. Pressure difference = $(760 - 700)\text{mmHg}$
 $= 60 \text{ mmHg}$
- $$h \times 1.25 \times 10 = \frac{60}{1000} \times 13600 \times 10$$
- $$h = \frac{0.06 \times 13600}{1.25}$$
- $$h = 652.8 \text{ m}$$
4. Bromine diffuses faster in vacuum than in air.
5. Wire gauze, being a good conductor, promptly conducts away the heat thus delaying the temperature of the gas from reaching the ignition level.
6. (i) • Using a narrower glass tube.
 • Using a bigger test-tube. (**Any one**)

(ii) Gas thermometer will detect a small change in temperature unlike the mercury thermometer.



At equilibrium,

Clockwise moment = Anticlockwise moment

$$0.9 \times d = 1.26 \times 8$$

$$d = \frac{1.26 \times 8}{0.9}$$

$$= 11.2$$

Centre of gravity should be at

$$40 + 11.2 = 51.2 \text{ cm}$$

8. The speed of air increases in the narrow section, thus lowering the pressure.

Atmospheric pressure acting on the surface pushes the liquid up the tube. The liquid on collision with air is broken into droplets forming the spray.

9. Change in PE = mgh
 $= 4 \times 10 \times 1.5$
 $= 60 \text{ J}$

10. Power = $\frac{\text{energy}}{\text{time}}$
 $= \frac{60}{7 \times 24 \times 3600}$
 $= 9.92 \times 10^{-5} \text{ W}$

11. Pressure = $(760 + 7.8) \text{ mm}$
 $= 767.8 \text{ mm.}$

12. The gas laws,

$$p_1 V_1 = p_2 V_2$$

$$p_1 = 760 \text{ mmHg}, p_2 = 767.8 \text{ mmHg},$$

$$V_1 = 20 \text{ mm}$$

$$V_2 = \frac{p_1 V_1}{p_2}$$

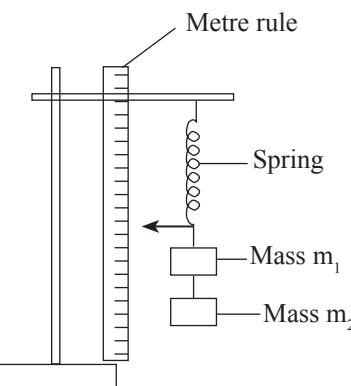
$$= \frac{760 \times 20}{767.8}$$

$$h_2 = 19.8 \text{ mm}$$

SECTION B

13. (a) (i) The extension is directly proportional to the applied force provided the spring's elastic limit is not exceeded.

(ii)



(iii) • Mass supported.

- Total length of the spring under the load.

(iv) • From the masses, force applied is calculated.

- From the length of the spring, extension is obtained from the difference between the lengths.
- A graph of force against extension is plotted.
- A straight line through the origin implies Hooke's law is obeyed.

(b) 3 springs sharing the load of 9 N, load per spring = $\frac{9}{3} = 3 \text{ N}$

$$\text{Extension} = \frac{3}{2.1} = 1.43 \text{ cm}$$

2 springs sharing a load of 9 N, load per spring = $\frac{9}{2}$

$$= 4.5 \text{ N}$$

$$\text{Extension} = \frac{4.5}{2.1}$$

$$= 2.14 \text{ cm}$$

$$\text{Total extension} = 1.43 + 2.14$$

$$= 3.57 \text{ cm}$$

14. (a) The rate of change of momentum is directly proportional to the applied force and it takes place in the direction of force.

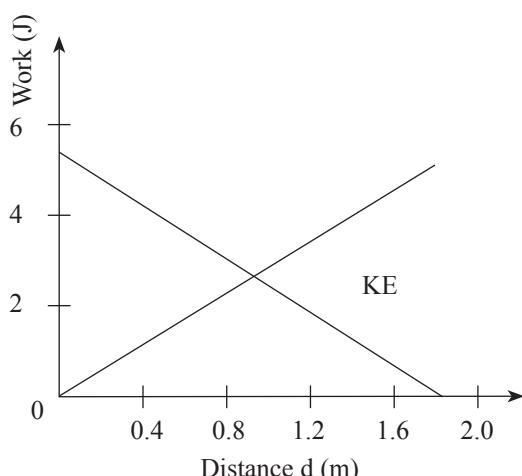
(b) When the car accelerates, the pencil exhibits the tendency to remain at rest, hence remains behind. When the car brakes, the moving pencil retains inertia in motion, hence moves forward.

(c) (i) Amount of work done by force F is the product of F and distance d. No work is done by forces marked either N or W because there is no vertical displacement.

(ii) The gradient = F

$$\begin{aligned} F &= \frac{\Delta w}{\Delta d} \\ &= \frac{5 - 0}{1.8 - 0} \\ &= \frac{5}{1.8} \\ &= 2.778 \text{ N} \end{aligned}$$

(iii)



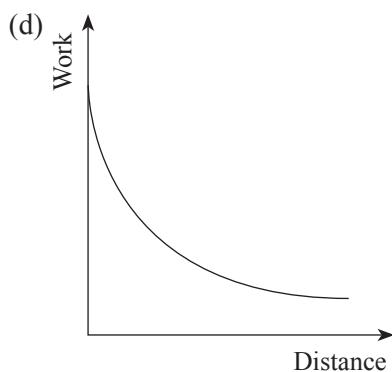
(iv) $KE = \frac{1}{2}mv^2$

$$= 5\text{J}$$

$$5 = \frac{1}{2} \times 0.82 \times v^2$$

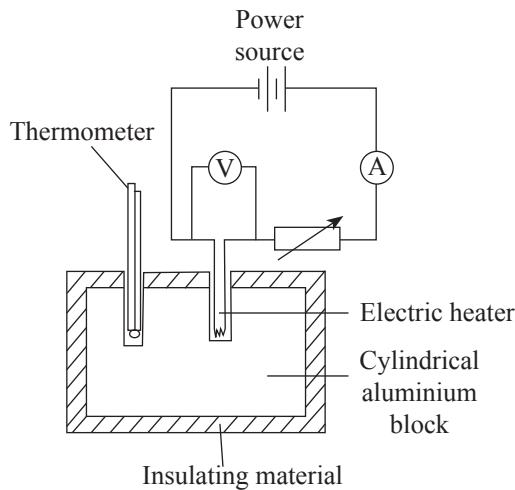
$$v^2 = 12.19$$

$$v = 3.49 \text{ m/s}$$



Initially, there will be deceleration before terminal velocity is attained.

15. (i)



(ii) Voltage across the heater,
Current, time interval

The mass of aluminium, change
in temperature

Heat lost heat gained by
(iii) by the, = the aluminium,
heater, VIt block, $mc\Delta\theta$

$$c = \frac{VIt}{mc\Delta\theta}$$

Assumptions:

- No heat loss to the environment.
- All electrical energy is converted to heat energy.

(b) (i) Energy = power \times time

$$= 200 \times 30$$

$$= 6\ 000 \text{ J}$$

(ii) (I) $Q = mc\Delta\theta$

$$6\ 000 = 0.15 \times 510 \times (t - 20)$$

$$(t - 20) = 784.31$$

$$t = 804.31 \text{ }^\circ\text{C}$$

(II) All the electrical energy is converted to mechanical energy and finally into heat energy.

(iii) Because some mechanical energy is used to overcome the frictional force between the moving parts of the drill.

16. (a) $F = \frac{mv^2}{r}$

It acts towards the centre of the circular path.

(i) $R = mg$

$$= 925 \times 10$$

$$= 9\ 250 \text{ N.}$$

(ii) $F_r = \frac{mv^2}{r}$

$$= \frac{925 \times 10^2}{25}$$

$$= 3\ 700 \text{ N}$$

$$R = mg - F_r$$

$$= 9250 - 3700$$

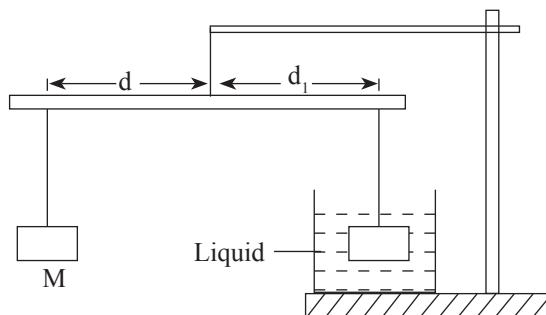
$$= 5550 \text{ N}$$

- (c) (i) With the increasing linear velocity, it increases the centripetal force which exceeds the reaction force hence the car takes off.

$$\begin{aligned} \text{(ii)} \quad v &= \sqrt{rg} \\ &= \sqrt{25 \times 10} \\ &= 15.81 \text{ m/s} \end{aligned}$$

- (d) Weightlessness means reaction force equals to weight hence F_r is also zero, the body therefore falls freely.

17. (a) Relative density of a substance is the ratio of density of a substance to the density of water.



- Measure the length d when the mass is suspended in air.
- Suspend the mass in liquid until it balances, then measure d_1 .

$$\text{Relative density} = \frac{d}{d - d_1}$$

- (b) (i) Volume of balloon

$$= \frac{\text{mass}}{\text{density}}$$

$$= \frac{400}{6.18}$$

$$= 2222.2 \text{ m}^3$$

Mass of air displaced

$$= 2222.2 \times 1.2$$

$$= 2667 \text{ kg}$$

$$\text{Weight} = \text{Upthrust} = 26667 \times 10$$

$$= 26667 \text{ N}$$

$$\text{Tension} = 26667 - 4000$$

$$= 22667 \text{ N}$$

$$\text{(ii)} \quad F = ma$$

$$22667 = 400 \times a$$

$$a = 56.67 \text{ m/s}^2$$

Sample Paper 1(2)

$$1. \quad 6.0 + 0.03 = 6.03 \text{ cm}$$

$$2. \quad \text{Resultant} = (8.4 + 3.6) - (5.3 + 2.7) \\ = 12 - 8 = 4 \text{ N, to the right}$$

$$3. \quad \text{Weight in air} = \frac{750}{1000} \times 10 \\ = 7.5 \text{ N}$$

$$\text{Apparent loss in weight} = 7.5 - 6.9$$

$$= 0.6 \text{ N}$$

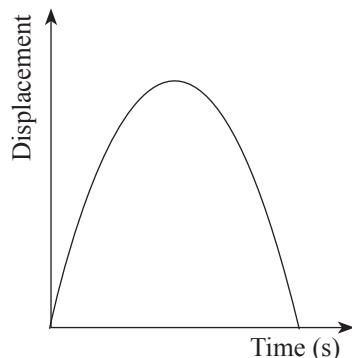
Volume displaced = volume of object

$$V \times 1250 \times 10 = 0.6$$

$$V = 4.8 \times 10^{-5}$$

$$= 48 \text{ cm}^3$$

4.



5. (a) Increase in pressure of a fluid results in decrease in velocity and vice versa.

(b) $v_3 > v_1 > v_4 > v_2$

6. Work done is area under the graph

$$\begin{aligned} \text{Work done} &= \frac{1}{2} \times 0.06 \times 5 \\ &= 0.15 \text{ J} \end{aligned}$$

7. The stability reduces because of the rise in the point of centre of gravity.

8. Initial momentum = 0.02×40

$$= 0.8 \text{ kgm/s}$$

$$\text{Final momentum} = 0.02 \times -25$$

$$= -0.5 \text{ kgm/s}$$

$$\text{Change in momentum} = -0.5 - 0.8$$

$$= -1.3 \text{ kgm/s}$$

Force = rate of change in momentum

$$= \frac{-1.3}{0.2}$$

$$= -6.5 \text{ N}$$

9. Bright specks are as a result of scattering of light by smoke particles which move randomly due to the bombardment by the invisible air molecules.

10. Weight = $mg + \frac{mv^2}{r}$

$$= m(g + \frac{v^2}{r})$$

$$= 70(10 + \frac{20^2}{20})$$

$$= 2100 \text{ N}$$

11. (i) E_1 is greater than E_2 .

- (ii) Efficiency of system A is greater than that of B.

SECTION B (55 marks)

12. (a) • Wide temperature range between freezing point and boiling point.

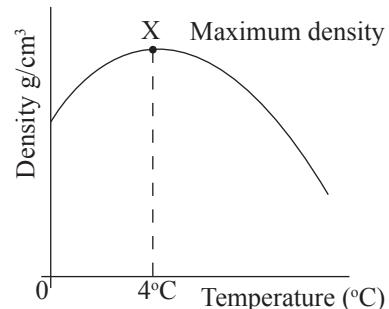
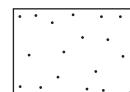
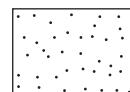
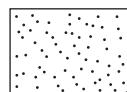
- Uniform thermal expansion.

- (b) The material of the tube expands resulting to fall in level.

- (c) (i) A: Melting process.

- C: Boiling process.

(ii)



- (iii) Sustaining aquatic life during cold seasons.

13. (a) Gas is compressible, therefore will not transmit pressure equally.

$$(b) \text{Pressure from piston B} = \frac{F_B}{8 \times 10^{-4}} \text{ N/m}^2$$

$$\therefore \text{Pressure at A} = \frac{F_B}{8 \times 10^{-4}} \text{ N/m}^2$$

$\therefore \text{Force at A} = \text{Pressure} \times \text{Area}$

$$= \frac{F_B}{8 \times 10^{-4}} \times 440 \times 10^{-4}$$

$$F_A = 55 F_B$$

$$(c) F_A = 55 F_B$$

$$= 55 \times 120$$

$$= 6600 \text{ N}$$

$$(d) \text{ Upward force on piston A} = 55 \times 25 \\ = 1375 \text{ N}$$

By the principle of moments,
clockwise = anticlockwise
moments moments

$$1375 \times 0.1 = L \times 0.5$$

$$L = 275 \text{ N}$$

14. (a) (i) Conduction.

(ii) Plastic is an insulator (hence does not conduct heat).

(iii) The hot molecules at the bottom rise up and are replaced by the cold and dense molecules from the top. This sets up convectional currents until water boils.

$$(b) (i) \text{ Mass of melted ice} = 475 - 450 \\ = 25 \text{ g.}$$

$$(ii) \text{ Heat lost by calorimeter} = 0.25 \times 400 \times 10 \\ = 1000 \text{ J}$$

$$\text{Heat lost by water} = 0.2 \times 4200 \times 10 \\ = 8400 \text{ J}$$

$$\text{Total heat lost} = 9400 \text{ J}$$

$$(iii) \text{ Heat gained by melting ice} = 0.025 L_f$$

$$(iv) \text{ Heat gained by melted ice} = 0.025 \times 4200 \times 11 \\ = 1155 \text{ J}$$

$$\text{Total heat gained} = 0.025 L_f + 1155$$

(v) Total heat = Total heat gained - lost

$$0.025 L_f + 1155 = 9400$$

$$0.025 L_f = 9400 - 1155$$

$$L_f = \frac{8245}{0.025}$$

$$= 329800 \text{ J kg}^{-1}$$

15. (a) (i) Increase in temperature increases the volume, thus reducing the density and vice versa.

(ii) This is the temperature when the molecules of the gas have zero kinetic energy thus the molecules are assumed to have zero volume or pressure.

$$(b) (i) \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \\ = \frac{1 \times 10^5 \times v}{300} \\ = \frac{2 \times 10^6 \times v}{8 \times T_2}$$

$$T_2 = 750 \text{ K}$$

$$(ii) \frac{m}{T_1 P_1} = \frac{m}{T_2 P_2} \\ \frac{P_2}{P_1} = \frac{T_1}{T_2} \\ = \frac{300}{750} \\ = \frac{2}{5}$$

16. (a) Power is the rate of doing work or energy expended per unit time. Unit is Watt.

(i) Work done = force \times distance

$$= 6 \times 750$$

$$= 4500 \text{ J}$$

$$\begin{aligned} \text{(ii) Power} &= \frac{\text{work done}}{\text{time taken}} \\ &= \frac{4500}{54} \\ &= 83.3 \text{ W} \end{aligned}$$

$$\begin{aligned} \text{(iii) Average speed} &= \frac{\text{power}}{\text{force}} \\ &= \frac{300}{750} \\ &= 0.4 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \text{(iv) Efficiency} &= \frac{\text{Work output}}{\text{Work input}} \times 100 \\ &= \frac{\text{Power output}}{\text{Power input}} \times 100 \\ &= \frac{83.3}{300} \times 100 \\ &= 27.8\% \end{aligned}$$

Marking Scheme 1(3)

1. (a) $W = mg$

$$\begin{aligned} g &= \frac{W}{m} \\ &= \frac{80}{16} \\ &= 5 \text{ N/kg} \end{aligned}$$

$$(b) x = \frac{140}{5} = 28 \text{ kg}$$

2. • Density.

• height /depth.

$$\begin{aligned} \text{3. Heat loss by hot block} &= 900 \times (200 - T) \times 0.3 \\ &= 54000 - 270 T \end{aligned}$$

$$\begin{aligned} \text{Heat gained by water and calorimeter} &= 4200 \times 0.2 \times (T - 23) + 800 \times (T - 230) \end{aligned}$$

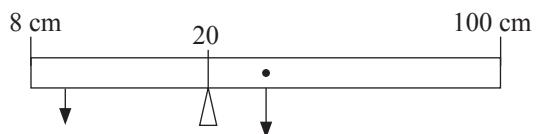
$$1640 T - 28060 = 54000 - 270 T$$

$$T = 42.96$$

4. Air leaves the jet at high speed, lowering the pressure in that region. High atmospheric pressure lifts the ball upwards.

5. Metal X expands more than Y, causing the strip to bend downwards thus breaking contact.

6.



$$0.3 \times 2 = 5x$$

$$\begin{aligned} x &= \frac{0.6}{5} \\ &= 0.12 \text{ m} \end{aligned}$$

$$\text{The mark} = 20 - 12$$

$$= 8 \text{ cm}$$

$$\begin{aligned} \text{7. Using } \frac{P_1}{T_1} &= \frac{P_2}{T_2} \\ \frac{1.03}{T_1} &= \frac{2.15}{331} \\ &= 158 \text{ K} \end{aligned}$$

8. The body is continually changing direction, hence accelerating.

9. Thermal conduction is the heat transfer as a result of vibration of atoms while radiation is as a result of electromagnetic waves.

10. Methylated spirit evaporates away faster thus drawing latent heat from the body.

11. Position P because of low COG.

12. The ratio of distance moved by effort to the distance moved by the load.

SECTION B

13. (a) (i) Elastic potential (compressional) energy changed to kinetic energy.

$$(ii) m_1 u_1 = m_2 u_2$$

$$2 \times 0.25 = 0.1 \times u_2$$

$$u_2 = 5 \text{ m/s}$$

- (b) (i) Elastic potential energy, to gravitational potential energy.

$$(ii) F = \frac{1}{2} kx^2$$

$$k = \frac{2}{0.2^2}$$

$$= 50 \text{ N/m}^2$$

$$(iii) \frac{1}{2} kx^2 = mgh$$

$$h = \frac{1.0}{0.1 \times 10}$$

$$= 1.0 \text{ m}$$

14. (a) (i) Make a knot at one end of the string. Wrap the string tightly and closely round the pencil, say 20 times. Make a second knot after 20 wraps.

Open the thread and determine the length between the knots. Divide the reading by 20 to get the circumference of the pencil.

Use the formula;

$$\text{Diameter} = \frac{\text{circumference}}{\pi}$$

$$D = \frac{C}{3.142}$$

- (ii) Place the eye directly above the reading being taken.

- (b) (i) Obtain the thickness (d) of the pile using the micrometer screw gauge.

Use the ruler to determine the length (l) and width (w) of the pile of paper.

Obtain the volume V, of the pile using the formula $V = lwd$.

Use beam balance to measure mass m of the pile.

Determine the density ρ of paper using the formula $\rho = \frac{m}{V}$.

- (ii)
- No zero error –Thimble scale zero coincides with the centre line of the sleeve scale when the instrument is closed.
 - Papers are of same material hence same density.

$$15. (i) \text{Weight} = \rho vg$$

$$= 950 \times (50)^3 \times 10$$

$$= 1.1875 \text{ N}$$

$$(ii) \text{Upthrust} = 50 \times 50 \times y \times 10^{-9} \times 1000 \times 10$$

$$= 0.025 y$$

$$(iii) \text{Upthrust}$$

$$= 50 \times 50 \times (50 - y) \times 10^{-9} \times 800 \times 10$$

$$= 1 - 0.02 y$$

$$(iv) 0.025 y + 1 - 0.02 y = 1 - 1875$$

$$y = \frac{0.1875}{0.005}$$

$$y = 37.5 \text{ mm}$$

$$16. (a) \text{Diameter}$$

$$\text{Length}$$

$$(b) \frac{m}{1.2} = \frac{m + 150}{1.6}$$

$$1.6m = 1.2m + 180$$

$$m = 450 \text{ g}$$

$$(c) (i) 5.4 \text{ cm}$$

(ii) Taking points (0.3, 5.8) and (1.4, 7.4)

$$\text{Spring constant} = \frac{\text{change in force}}{\text{change in extension}}$$

$$= \frac{1.4 - 0.3}{7.4 - 5.8}$$

$$= 0.675 \text{ N/cm}$$

$$\text{or } 68.75 \text{ N/m}$$

$$17. (a) (i) \text{ Distance} = 100 \text{ m},$$

$$\text{Relative speed} = (12+8)$$

$$= 20 \text{ m/s}$$

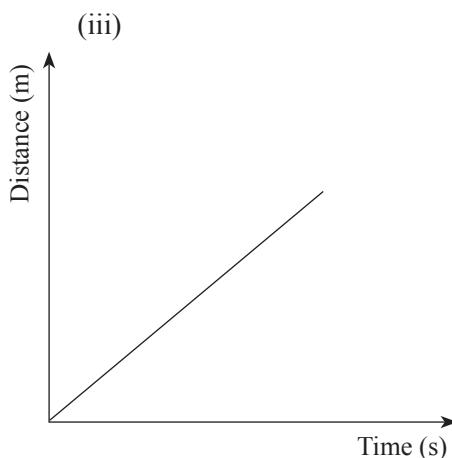
$$\text{Time} = \frac{100}{20}$$

$$= 5 \text{ sec}$$

$$(ii) \text{ Distance} = \text{speed} \times \text{time}$$

$$= 8 \times 5$$

$$= 40 \text{ m}$$



(b) (i) From the graph, for length = 65 cm

$$T^2 = 2.5 \text{ sec}$$

$$T = 1.58 \text{ sec}$$

$$\text{For 10 oscillations} = 1.58 \times 10$$

$$= 15.8 \text{ sec}$$

$$(ii) T^2 = 4\pi^2 \frac{1}{g}$$

$$\text{gradient} = \frac{g}{4\pi^2}$$

$$= \frac{(90 - 40) \times 10^{-2}}{(35 - 15) \times 10^{-1}}$$

$$= 9.85 \text{ m/s}^2$$

Marking Scheme 1(4)

$$1. \text{ Volume of cork} = (170 - 30) \text{ cm}^3$$

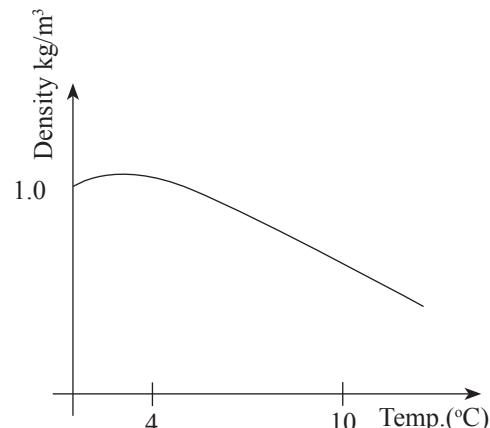
$$= 140 \text{ cm}^3$$

$$\text{Mass} = \text{density} \times \text{volume}$$

$$= 0.5 \times 140$$

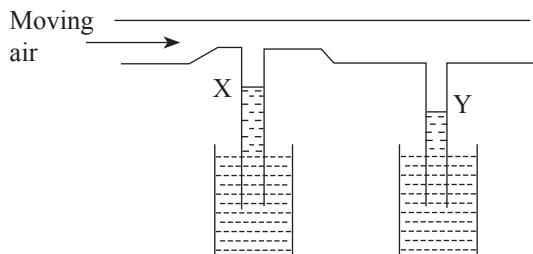
$$= 70 \text{ g}$$

2.



3. On an oily surface, there are weak adhesive forces between water molecules and molecules of the surface, hence droplets form. On a clean glass surface, the adhesive forces between water and glass molecules are greater.

4. (a)



- (b) High speed of air in the narrow section creates a region of low pressure hence the liquid in part X rises more than in part Y.
5. Kinetic energy of the wind is converted to mechanical energy to rotate the turbine. Mechanical energy is then converted to electrical energy as the turbines cut the magnetic field.
6. (a) Point R.
 (b) Distance = Area under the graph

$$= \frac{1}{2} \times 8 \times 9$$

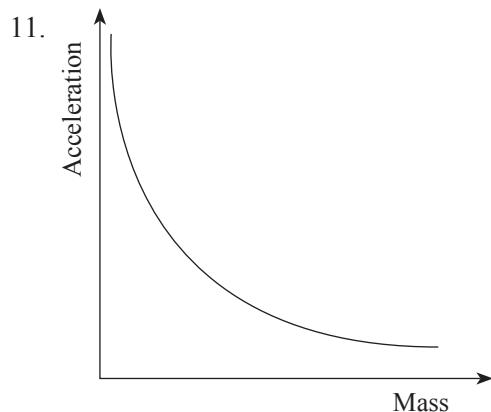
$$= 36 \text{ m}$$

7. A – 5.7 N
 B – 5 N

8. $v^2 = rg$
 $v = \sqrt{10 \times 3}$
 $= 5.48 \text{ m/s}$

9. The volume increases thus reducing the apparent weight. The moment of force on side A reduces and the lever tips.

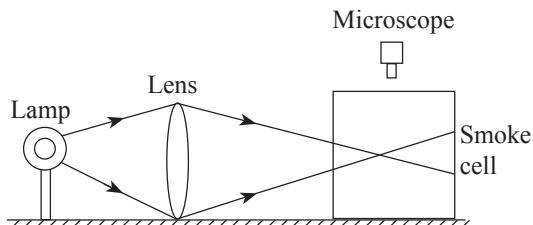
10. • Large area of the liquid exposed.
 • Draught.
 • Presence of moving air. **(Any two)**



For the same force acting on a body, the mass is inversely proportional to the acceleration.

SECTION B

12. (a)



(b) (i) Smoke particles are seen moving haphazardly when bombarded by the air particles.

(ii) To magnify the bright specks.

- (c) • Temperature of the environment.
 • Density of the particles.

- (d) (i) a – Condensation
 b – Freezing
 c – Sublimation

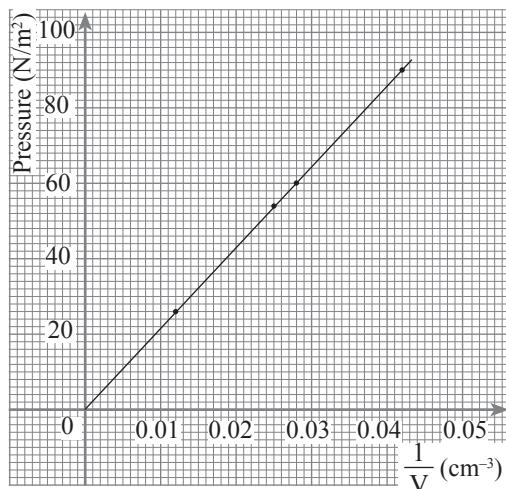
(ii) Solids have a stronger force of attraction between the particles than liquids hence the intermolecular distance in solids is smaller than that of liquids.

13. (a) Initial reading of pressure and volume are recorded.

- Keep temperature constant.
- Vary the pressure of the gas and record the corresponding volume readings.
- Graph of pressure against $\frac{1}{V} \text{ cm}^{-3}$ is obtained.

(b)

| | | | | |
|---|--------|-------|-------|-------|
| Pressure N/m² | 27 | 54 | 60 | 90 |
| Volume (cm³) | 80 | 40 | 36 | 24 |
| $\frac{1}{V}$ (cm⁻³) | 0.0125 | 0.025 | 0.028 | 0.042 |



$$\begin{aligned}\text{Slope} &= \frac{\text{change in } P}{\text{change in } \frac{1}{V}} \\ &= \frac{83.4 - 40.3}{0.04 - 0.02} \\ &= \frac{43.2}{0.02} \\ &= 2160\end{aligned}$$

14. (a) (i) To absorb radiant heat from the sun.

- (ii) Glass surface traps heat while insulating material reduces heat loss by conduction.
- (iii) Copper is a good conductor of heat.

$$\begin{aligned}(\text{b}) \quad (\text{i}) \quad \text{Quantity of heat} &= mc\theta \\ &= 200 \times 4200 \times 11 \\ &= 9240 \text{ kJ}\end{aligned}$$

$$\begin{aligned}(\text{ii}) \quad \text{Power} &= \frac{Q}{T} \\ &= \frac{9240000}{5 \times 3600} \\ &= 513.3 \text{ W}\end{aligned}$$

- (c) – Lagging the outside of the tank.
– Making the inside surfaces of the tank shiny.

15. (a) Pressure is the force normally acting per unit area. The SI unit is N/m².

- (b) Pressure applied to an enclosed liquid is transmitted equally to every part of the liquid.

- (c)
- Non-compressibility
 - Non-viscous
 - Non-corrosiveness (**Any two**)

- (d) For equal distribution of braking force.

$$\begin{aligned}(\text{e}) \quad (\text{i}) \quad P &= \frac{F}{A} \\ &= \frac{500}{0.75 \times 10^{-4}} \\ &= 6.667 \times 10^6 \text{ N/m}^2\end{aligned}$$

$$(\text{ii}) \quad \text{Force} = P \times A$$

$$= 6.667 \times 10^6 \times 3 \times 10^{-4}$$

$$(iii) 27\ 000 Vd = 5\ 700 V$$

$$= 2.001 \times 10^3 N$$

$$d = 0.21 m$$

16. (a) (i) The centre of gravity is within the base of support.

$$(ii) \text{Total mass} = (75 + 25) kg$$

$$\text{Weight} = 100 \times 10$$

$$= 1\ 000 N$$

- (iii) At equilibrium;

Clockwise moments = anticlockwise moments

Let the distance be d

$$250 \times d = 1.1 \times 750$$

$$d = 3.3 m$$

$$(b) (i) \text{Force from } N = \rho_s v_v g$$

$$= 2700 \times V \times 10$$

$$= 27\ 000 V$$

Clockwise moment = Force \times distance

$$= 27\ 000 Vd$$

$$(ii) \text{Upthrust} = \rho_s v_v g$$

$$= 800 V \times 10$$

$$= 8\ 000 V$$

Apparent weight = Actual weight - upthrust weight

$$= 27\ 000 V - 8\ 000 V$$

$$= 19\ 000 V$$

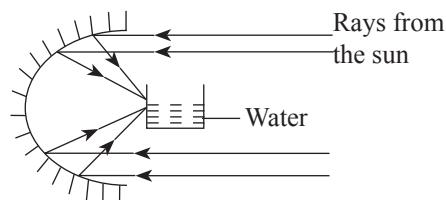
Anticlockwise moment = $19\ 000 V \times 0.3$

$$= 5\ 700 V$$

Marking Scheme 1(5)

$$\begin{aligned} 1. \text{ Gas pressure} &= \text{Atmospheric pressure} - h \rho g \\ &= 1.03 \times 10^5 - (0.24 \times 1400 \times 10) \\ &= 9.964 \times 10^4 Pa \end{aligned}$$

2.



The rays converge at the principal focus of the concentrator heating the container.

$$3. \text{Weight of the liquid displaced} = \frac{200 \times 0.8 \times 10}{1000}$$

$$= 1.6 N$$

$$\text{Apparent weight} = 20 - 1.6$$

$$= 18.4 N$$

$$4. \text{Diameter} = 5.9 - 4.8 cm$$

$$= 1.1 cm$$

$$\text{Radius} = 0.55 cm$$

5. (i) The body accelerates because the weight is greater than the sum of upthrust and viscous drag.

- (ii) The body attains terminal velocity the resultant force equals to zero.

$$6. A_1 v_1 = A_2 v_2$$

$$49 \times 7 = 16 v_2$$

$$v_2 = 24.5 m/s$$

7. (i) The pole has a stored elastic potential energy, which is useful for propelling the athlete.

- (ii) The cushion increases the time of impact, hence reducing the rate of change in momentum.

$$8. \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = \frac{3.05 \times 10^6 \times 283}{305} \\ = 2.83 \times 10^6 \text{ Pa}$$

9. Inside: Molecules of the paint attract the bristles evenly all round, hence spread apart.

Outside: Surface tension of the paint draws the bristles together.

10. Reading of volume is not taken, hence minimising on error.

11. The continual random motion of molecules within a fluid.

SECTION B

12. (i) VR of gear = $\frac{\text{no. of teeth of the driven gear}}{\text{no. of teeth of driving gear}}$

$$= \frac{60}{20} \\ = 3$$

$$\text{VR of the wheel and axle} = \frac{\text{radius of wheel}}{\text{radius of axle}}$$

$$= \frac{40}{8} \\ = 5$$

$$(ii) \text{ Combined VR} = 3 \times 5$$

$$= 15$$

$$(iii) \text{ Efficiency} = \frac{MV}{VR} \times 100\%$$

$$\Rightarrow \frac{L/30}{15} \times 100 = 100$$

$$\frac{L}{30} = 15$$

$$= 450 \text{ N}$$

$$(b) \text{ Efficiency} = \frac{\text{work input}}{\text{work output}} \times 100$$

$$\frac{40 \times 5}{x \times 4} = 0.8$$

$$x = 62.5 \text{ N}$$

13. (a) (i) Lower fixed point.

Upper fixed point.

- (ii) The temperature reduces up to a constant value which is recorded as 0°C .

The temperature rises up to a constant value recorded as 100°C .

$$(b) \frac{100}{19.2 - 3.6} \times (13.2 - 3.6)$$

$$= \frac{100}{15.6} \times 9.6$$

$$= 61.5^\circ\text{C}$$

- (c) When there is fire outbreak, the bimetallic strip gets heated and bends to make contact with P. The complete circuit sets the bell to ring.

14. (a) (i) $\omega = 2\pi f$

$$= 2\pi \times 6$$

$$= 37.70 \text{ rad/s}$$

- (ii) Tension = centripetal force

$$= m\pi \omega^2$$

$$= 0.15 \times 0.45 \times (37.70)^2$$

$$= 95.93 \text{ N}$$

$$(b) (i) \text{ Extension} = \frac{F}{k}$$

$$= \frac{95.93}{12}$$

$$= 7.99 \text{ mm}$$

$$(ii) \text{ Unstretched length} = \text{Total length} - \text{extension}$$

$$= 0.45 - 0.00799$$

$$= 0.442 \text{ cm}$$

$$(c) \text{ Extension} = \frac{130}{12}$$

$$= 10.833 \text{ mm}$$

$$\text{New } r = \text{unstretched length} + \text{extension}$$

$$= 0.442 + 0.010833 = 0.453 \text{ m}$$

$$\frac{mv^2}{r} = 130$$

$$\frac{0.15v^2}{0.453} = 130$$

$$v = 19.8 \text{ m/s}$$

15. (a) (i) The distance covered

$$= 25 \times 0.6$$

$$= 15 \text{ m}$$

(ii) From $v^2 = u^2 + 2as$

$$0 = (25)^2 + 2a \times 25$$

$$a = -12.5 \text{ m/s}^2$$

(iii) Braking Force = ma

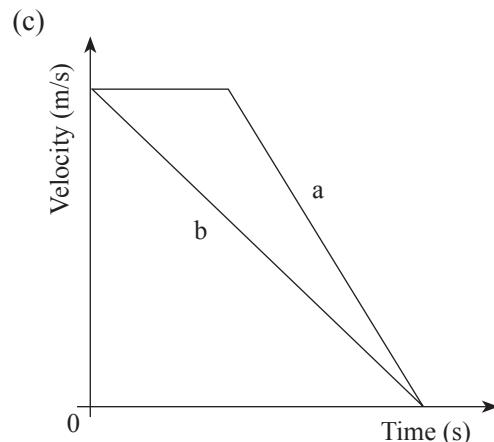
$$= 1500 \times 12.5$$

$$= 18750 \text{ N}$$

(b) $v^2 = u^2 + 2as$

$$0 = (25)^2 + 2a \times 40$$

$$a = -7.8125 \text{ m/s}^2$$



16. (a) (i) Room temperature = 24°C

(ii) Melting point = 328°C

(iii) Time of heating = $2.2 - 0$

= 2.2 minutes.

Heat energy dissipated is:

power \times time

$$= 75 \times 2.2 \times 60$$

$$= 9900 \text{ J}$$

Quantity of heat absorbed by substance = $mc\theta$

$$= 0.25 \times (328 - 24) c$$

$$= 76 c$$

$$\therefore 9900 = 76 c$$

$$c = 130.5 \text{ J kg}^{-1} \text{ K}^{-1}$$

(iv) Time over which melting takes place = $3.6 - 2.2$

= 1.4 minutes

Heat energy dissipated = $75 \times 1.4 \times 60$

$$= 6300 \text{ J}$$

$$\therefore mL_f = 6\ 300$$

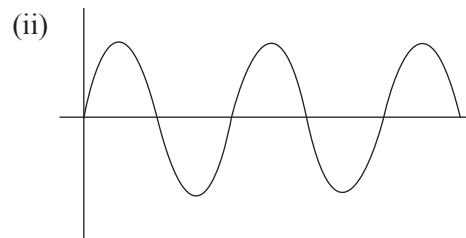
$$L_f = \frac{6\ 300}{0.25}$$

$$= 25\ 200 \text{ J kg}$$

- (b) (i) PQ – Temperature rising in solid state. Molecules are gaining kinetic energy thus vibrating more violently.
- (ii) QR – Change of state from solid to liquid. Energy absorbed is used to break the intermolecular bonds.
- (iii) RS – Temperature rising in the liquid state. Molecules are gaining KE and move faster.

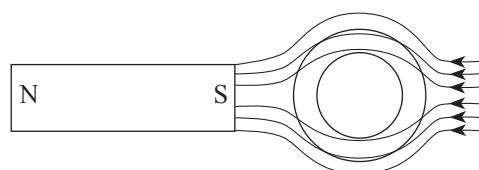
Marking Scheme 2(1)

1. Ammeter reading = 0.48 A
2. (i) Dispersion occurs because different colours have different wavelength (different indices of refraction), hence they travel with different velocity in water.
 (ii) Formation of rainbow.
3. $R = \frac{V^2}{P}$
 $= \frac{(240)^2}{1500}$
 $= 38.4 \Omega$
4. (i) A device which allows current to flow in one direction only.



5. The image is virtual, erect and magnified.
(Any two)

6.



(b) Magnetic shielding.

7. The minimum frequency required to remove an electron from a metal surface.

8. Total electrical energy = eV

$$= 1.6 \times 10^{-19} \times 25\ 000$$

$$= 4 \times 10^{-15} \text{ J}$$

$$\begin{aligned} \text{Energy of X-rays} &= \frac{hc}{\lambda} \\ &= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{\lambda_{\min}} \\ &= 4 \times 10^{-15} \end{aligned}$$

$$\lambda_{\min} = 4.9725 \times 10^{-11} \text{ m}$$

9. Let the distance be d from the wall.

$$\begin{aligned} \text{Speed} &= \frac{2d}{t} \\ &= \frac{2d}{0.64} \end{aligned}$$

Final distance from the wall = d + 20

$$\text{Speed} = \frac{2(d+40)}{0.76}$$

Speed remains constant hence,

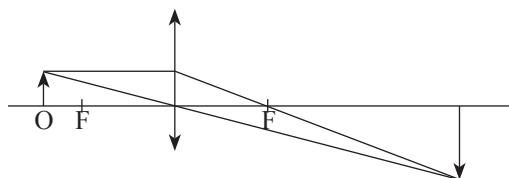
$$\frac{2d}{0.64} = \frac{2(d+40)}{0.76}$$

$$d = 106.67 \text{ m}$$

$$\begin{aligned}\text{Speed} &= \frac{2 \times 106.67}{0.64} \\ &= 333 \text{ m/s}\end{aligned}$$

10. Two rays drawn

Image



11. Half oscillation = 0.4 seconds

1 complete oscillation = 0.8 s

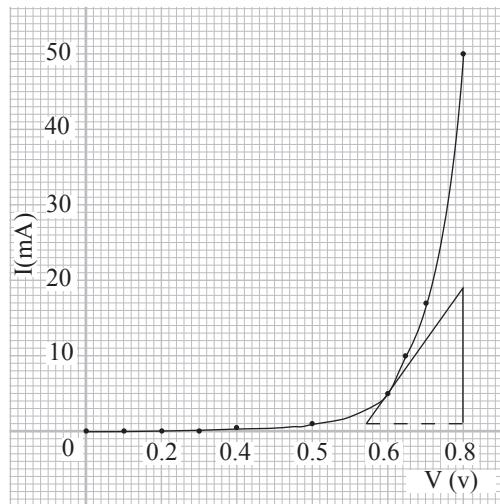
$$\begin{aligned}\text{Frequency} &= \frac{1}{T} \\ &= \frac{1}{0.8} \\ &= 1.25 \text{ Hz}\end{aligned}$$

$$12. \text{ No of half lives} = \frac{20}{4} = 5$$

$$\begin{aligned}\text{Fraction undecayed} &= \frac{1}{2^5} \\ &= \frac{1}{32} \\ &= 0.03125\end{aligned}$$

$$\begin{aligned}\text{Fraction decayed} &= 1 - \frac{1}{32} \\ &= \frac{31}{32} \\ &= 0.969\end{aligned}$$

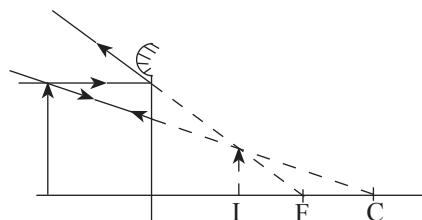
13. (a) (i)



(ii) Initially minimal current flows with the increase in voltage up to the junction voltage. At this point the junction p.d. is overcome and small increase in voltage results to large increase in current.

$$\begin{aligned}\text{(iii) Gradient} &= \frac{30 - 0.1}{0.8 - 0.22} \\ &= \frac{29.9}{0.22} \\ &= 135.9 \Omega\end{aligned}$$

14. (a)



$$(b) \text{ (i)} \quad \frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{-1}{10} = \frac{1}{16} + \frac{1}{v} = \frac{-13}{80}$$

$$v = -6.15 \text{ cm}$$

$$\begin{aligned}\text{(ii) magnification} &= \frac{v}{u} \\ &= \frac{-6.15}{16} \\ &= 0.385\end{aligned}$$

- (c) (i) Parabolic reflector.
(ii) At the principal focus.
(iii) Spherical aberration.
15. (a) (i) The wavelength increases due to the increased speed. Water flows from shallow to deep region.
(ii) 20 boxes cover 10 m
1 box = 0.5 m

$$\begin{aligned}\text{Distance from B to C} &= 9 \times 0.5 \\ &= 4.5 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{Average velocity} &= \lambda f \\ &= 4.5 \times 100 \\ &= 450 \text{ m/s}\end{aligned}$$

- (iii) Frequency and amplitude.
(b) (i) Hard X-rays have quanta of higher energy than soft X-rays.
(ii) • Intensity.
• Accelerating potential at which they are produced.

16. (a) Charge per unit volt.

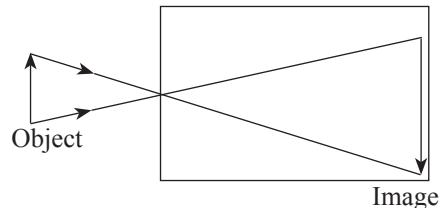
- (b) • Overlap area.
• Separation distance.
• Dielectric.

$$\begin{aligned}\text{(c) In series } C &= \frac{2 \times 2}{2 + 2} \\ &= 1 \mu\text{F}\end{aligned}$$

$$\begin{aligned}\text{Effective capacitance} &= 1 + 3 \\ &= 4 \mu\text{F}\end{aligned}$$

- (d) The ball is attracted to plate A where it acquires positive charge, hence repelled to plate B where it is neutralised by negative charges from the earth. This makes it to oscillate continually transferring charges between the plates.

17. (a)



$$\begin{aligned}\text{(b) Magnification} &= \frac{\text{image height}}{\text{object height}} \\ &= \frac{\text{image distance}}{\text{object distance}} \\ &= \frac{7.5}{0.1} \\ &= \frac{d}{0.15}\end{aligned}$$

$$d = 11.25 \text{ m}$$

- (c) The ratio of sine of angle of incidence to the sine of angle of refraction for a given pair of media is a constant.

$$\begin{aligned}\text{For liquid B, } n &= \frac{2}{x} \\ &= 1.44\end{aligned}$$

$$x = 1.38 \text{ cm}$$

$$\begin{aligned}\text{For liquid A, } n &= \frac{6}{y} \\ &= 1.36\end{aligned}$$

$$y = 4.41 \text{ cm}$$

$$\begin{aligned}\text{Total vertical displacement} &= (1.38 + 4.41) \text{ cm} \\ &= 5.79 \text{ cm}\end{aligned}$$

Marking Scheme 2(2)

1. Some electrons are transferred from one material to the other. The material that loses electrons becomes negatively charged while the one that gains electrons become positively charged.

2. $E = V + Ir$

Substituting;

$$E = 1.1 + 0.8 r \dots \dots \dots \text{(i)}$$

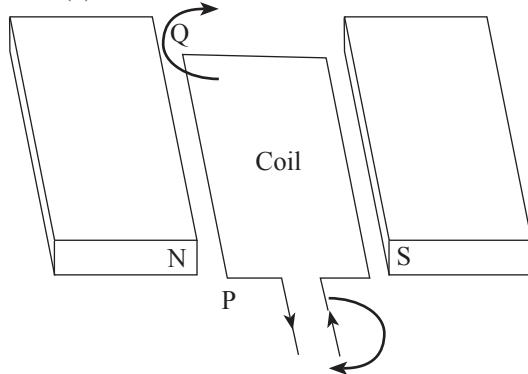
$$E = 1.25 + 0.5r \dots \dots \dots \text{(ii)}$$

Subtracting (ii) from (i), $0.15 = 0.3 r$

$$r = 0.5 \Omega \text{ and,}$$

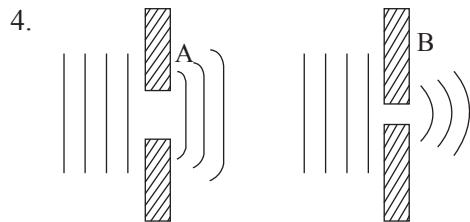
$$E = 1.5 \text{ V}$$

3. (a)



- (b)
- By increasing the number of turns in the coil.
 - By increasing the current flowing in the conductor.
 - By increasing strength of the magnet.

(Any two)



4. Power = I^2R

$$I^2 = \frac{50}{12.5}$$

$$I = 2 \text{ A}$$

6. Microwaves, infra-red, red light, green light and X-rays.

7. South pole on the solenoid, hence the polarity is North pole.

$$\begin{aligned}8. \text{ Frequency} &= \frac{3 \times 10^8}{180} \\ &= 1.67 \times 10^6 \text{ Hz}\end{aligned}$$

$$\begin{aligned}\text{Periodic time} &= \frac{1}{f} \\ &= 6 \times 10^{-7} \text{ s}\end{aligned}$$

- 9.
- To open the live and neutral sockets.
 - To carry away excess current during short circuit.

10. From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$\begin{aligned}\frac{1}{f} &= \frac{1}{15} - \frac{1}{6} \\ &= -\frac{1}{10}\end{aligned}$$

$$f = 10 \text{ cm}$$

11. Distance = speed \times time

$$2d = 1500 \times 3.5$$

$$d = 2625 \text{ m}$$

12. (a) (i) P – Cathode.
Q – Screen.

- (ii) As heater current flows in the circuit, the filament heats up the cathode causing it to emit electrons by thermionic emission.

$$= 5.6 \times 1.2$$

$$= 6.72 \text{ V}$$

- (b) (i) X-plates deflect the beam horizontally.

$$\text{Voltage across } 4\Omega = 4 \times 1.2$$

Y-plates deflect the beam vertically.

$$= 4.8 \text{ V}$$

- (ii) • To focus the beam.
• To provide the accelerating potential.

$$\begin{aligned} \text{Voltage across parallel connection} &= 6.72 - 4.8 \\ &= 1.92 \text{ V} \end{aligned}$$

- (iii) To prevent the beam from colliding with other particles which would reduce their KE.

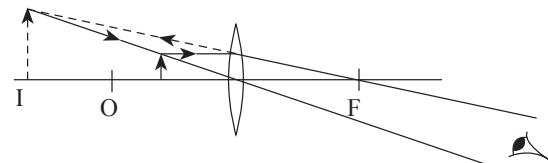
$$\begin{aligned} \text{Current through } 5 \text{ resistor} &= \frac{1.92}{3+5} \\ &= 0.24 \text{ A} \end{aligned}$$

- (c) • To provide a wider deflection of the beam.
• Makes the tube to be shorter.

$$\begin{aligned} \text{Voltage} &= 0.24 \times 5 \\ &= 1.2 \text{ V} \end{aligned}$$

13. (a) (i) Formation of hydrogen bubbles on the copper plate, leading to insulation of the plate.

14. (a)



- (ii) By using a polarizer, for example, potassium dichromate.
- (iii) $Q = It$

$$(b) (i) u + v = 68$$

$$u = 68 - v$$

$$\frac{v}{68-v} = 3$$

$$v = 51 \text{ cm}$$

$$(ii) \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{f} = \frac{1}{17} + \frac{1}{51} \dots \text{since}$$

$$u = (68 - 51) = 17 \text{ cm}$$

$$f = 12.75 \text{ cm}$$

- (b) (i) Parallel connection $\frac{2 \times 8}{2+8}$
 $= \frac{16}{10}$
 $= 1.6 \Omega$

In the new setting

$$\frac{1}{12.75} = \frac{1}{10} + \frac{1}{v}$$

$$v = -46.36 \text{ cm.}$$

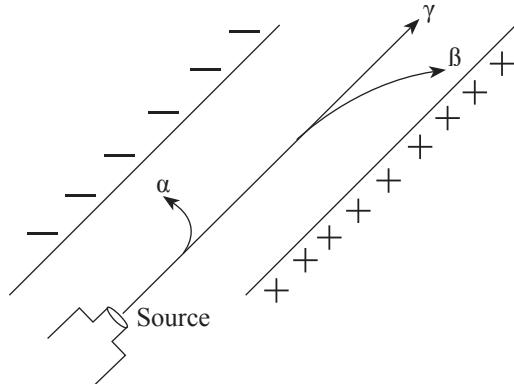
$$\text{Total resistance} = 1.6 + 4$$

$$= 5.6 \Omega$$

$$(ii) V_T = IR_T$$

The image is virtual, erect and magnified. (magnified image must be mentioned)

15. (a)



The alpha particle is attracted towards the negative plate since it is positively charged and the beta towards the positive since it is negatively charged. The gamma is not affected by the electric field.

(b) (i) Half-life is the time taken for half of the number of nuclides initially present in a radioactive element to decay.

(ii)

| Particles emitted per minute | Time (days) | Fraction decayed | Fraction decayed |
|------------------------------|-------------|------------------|------------------|
| 128 | 0 | 1 | 0 |
| 64 | 3 | $\frac{1}{2}$ | $\frac{1}{2}$ |
| 32 | 6 | $\frac{1}{4}$ | $\frac{3}{4}$ |
| 16 | 9 | $\frac{1}{8}$ | $\frac{7}{8}$ |
| 8 | 12 | $\frac{1}{16}$ | $\frac{15}{16}$ |

(iii) After 7 days,
fraction undecayed = $\frac{x}{128}$

$$\text{Fraction undecayed} = \frac{26}{128} \\ = 0.2$$

16. (a) $n_w = n_a \times n_g$

$$n_w = \frac{1}{1.33} \times 1.5$$

$$\frac{1.5}{1.33} = 1.128$$

$$\frac{1}{\sin c} = 1.128$$

$$\sin c = \frac{1}{1.128}$$

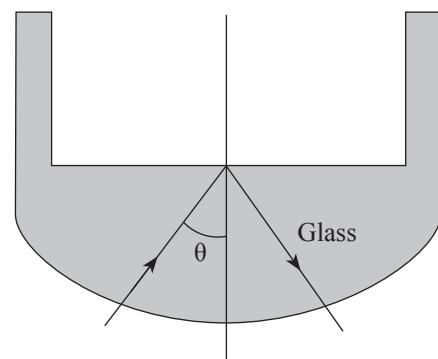
$$= 0.8866$$

$$c = 62.46^\circ$$

$$(b) \frac{1}{\sin c} = 1.5$$

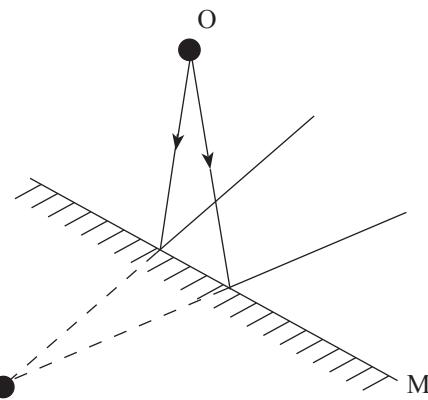
$$c = 41.8^\circ$$

The ray undergoes total internal reflection.



Marking scheme 2(3)

1.



2. Increase in leaf divergence implies a positively-charged rod. Decrease of leaf divergence implies a negatively charged rod.

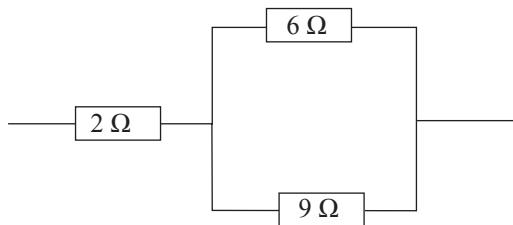
3. $\frac{a}{c} n_w = 1.33 = \frac{1}{\sin c}$
 $c = 48.75^\circ$.

From the above level, $\theta = 90 - 48.75^\circ$

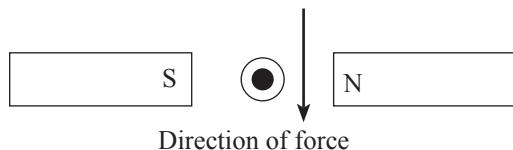
$$= 41.25^\circ \text{ above the horizontal surface.}$$

4. X-rays are produced when a fast moving electrons are stopped by a metal target while gamma rays occur as a result of energy changes in the nucleus of an atom.

5.



6. (a)



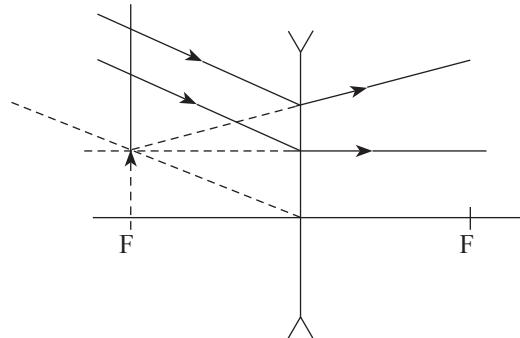
- (b) – Change the direction of magnetic field.
– Change the direction of current.

7. (i) Amplitude is represented by OP.

(ii) Wavelength is DE.

8. • Low internal resistance.
• Higher value of EMF.

9.



10. $1\frac{1}{2}$ wavelength = 12 divisions

1 wavelength = 8 divisions

Period = $8 \times 10 \text{ ms/div}$

$$= 8 \times 10^{-2} \text{ s}$$

$$\text{Frequency} = \frac{1}{T} = \frac{1}{8 \times 10^{-2}} = 12.5 \text{ Hz.}$$

11. (a) $x = 3, y = 2$.

(b) To sustain the reaction.

12. (a) (i) The phosphorus shares four of its outermost electrons with the four of germanium, forming four covalent bonds leaving one free electron. This electron serves as a charge carrier in the material.

(ii) No charge, because the number of protons and neutrons are equal.

(b) (i) There is no current in the 4Ω resistor, because it is reverse biased.

$$\text{Total Resistance} = 8 \Omega$$

$$\begin{aligned} I &= \frac{V}{R} \\ &= \frac{10}{8} \\ &= 1.25 \text{ A} \end{aligned}$$

(ii) D_2 is shorted

$$\frac{1}{R_T} = \frac{1}{8} + \frac{1}{4}$$

$$\begin{aligned}
 &= \frac{1+2}{8} \\
 &= \frac{3}{8} \\
 R_T &= \frac{8}{3} \\
 &= 2.67 \Omega \\
 I &= \frac{10}{2.67} \\
 &= 3.745 \text{ A}
 \end{aligned}$$

13. (a) (i) The needle is made magnetic through stroking end to end with one pole of the magnet.

(ii) It settles in a N-S direction.

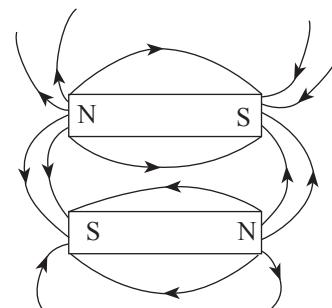
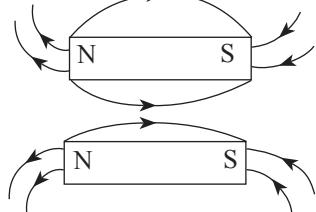
(iii) If the eye of the needle is North pole and it is brought close to the North pole of the magnet, it follows a path tracing a magnetic line of force.

- (b) End B is a south pole.

The steel bar becomes a magnet when current is on and also when current is switched off.

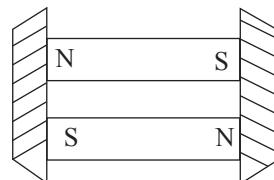
The soft iron core becomes a magnet when current is on but loses it when current is switched.

- (c)

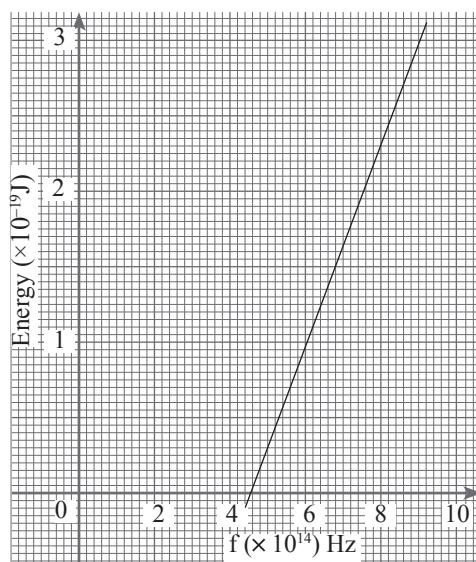


Arrangement (ii) is suitable in storing magnets in pairs.

- (d) Iron keepers ensure continuous magnetic field linkage to keep domains magnetically aligned.



14. (a) (i) The higher the intensity the higher the rate of photoelectrons. The higher the frequency the higher the kinetic energy of the emitted electrons.



$$(b) (i) \frac{(2.6 - 1.6) \times 10^{-19}}{8.5 - 1.6 \times 10^{14}}$$

$$\frac{1.0 \times 10^{-19}}{1.5 \times 10^{14}}$$

$$= 6.67 \times 10^{-34} \text{ Js}$$

$$(ii) f_o = 4.5 \times 10^{14} \text{ Hz}$$

$$(iii) w_o = h f_o$$

$$= 6.67 \times 10^{-34} \times 4.5 \times 10^{14}$$

$$= 30.015 \times 10^{-20}$$

$$= 3.0 \times 10^{-19} \text{ J}$$

15. (a) The cylindrical block. The induced or eddy currents oppose the motion producing them thus bringing the block to rest.

$$(b) (i) \frac{N_p}{N_s} = \frac{12}{1}$$

$$N_s = \frac{N_p}{12}$$

$$= \frac{1800}{12}$$

$$= 150$$

(ii) Input power

$$= \frac{100}{95} \times 500 = 526.3 \text{ W}$$

$$(iii) \frac{V_s}{V_p} = \frac{1}{12}$$

$$V_s = \frac{240}{12}$$

$$= 20 \text{ V}$$

$$(iv) \frac{I_p}{I_s} = \frac{V_s}{V_p}$$

$$I_s = \frac{500}{12}$$

$$= 25 \text{ A}$$

16. (a) (i) $4 \times 60 \times 3.5 = 840$

$$2 \times 75 \times 3.75 = 562.5$$

$$500 \times 0.25 = 125$$

$$100 \times 12 = 1200$$

Total

power = 840 + 562.5 + 125 + 1200
consumed

Total number of units = 2.7275 Kwh

$$(ii) \text{Total units consumed in 30 days}$$

$$= 2.7275 \times 30$$

$$= 81.825 \text{ Kwh.}$$

$$\text{Total cost} = 81.825 \times 13.0$$

$$= \text{Ksh. } 1063.7$$

- (b) (i) Transmitting power at low resistance, that is, thick cables.

Transmitting power at low current, that is, high voltage.

$$(ii) \text{Current through the cables}$$

$$= \frac{1.1 \times 10^6}{11 \times 10^3} = 100 \text{ A}$$

Power loss = I^2R

$$= (100^2) \times 1.8$$

$$= 18000 \text{ W}$$

$$\text{or } 18 \text{ kW}$$

Marking Scheme 2(4)

- The divergence is larger for the inside than for the outside. For the inside, all the charge is transferred to the can while for the outside charge is shared between the ball and the can.
- Virtual.
 - upright.
 - diminished.

$$3. \text{ (i) } I = \frac{P}{V}$$

$$= \frac{400}{240}$$

$$= 1.67 \text{ A}$$

$$\text{(ii) } R = \frac{P}{T^2}$$

$$= \frac{400}{(1.67)^2}$$

$$= 144 \Omega$$

$$\text{Total resistance} = (144 + 136)$$

$$= 280 \Omega$$

$$\text{Current } I = \frac{240}{280}$$

$$= 0.857 \text{ A}$$

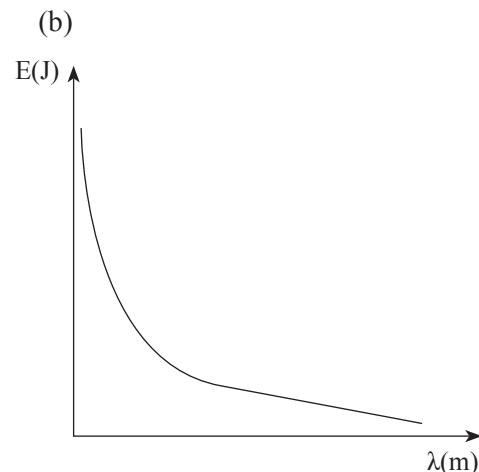
4.

| X-rays | Cathode rays |
|---|--|
| Penetrate matter | Have no penetrating power |
| Produced when fast moving electrons are stopped by metal target | Are a stream of fast moving electrons |
| Cannot be deflected by electric and magnetic field | Are deflected by electric and magnetic field |
| Have no momentum | Have momentum |

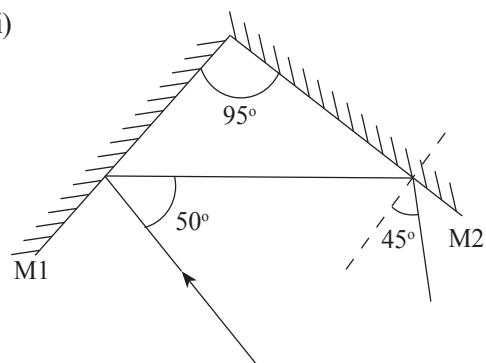
(Any two)

5. Boron has three electrons for bonding which is one less for covalent bonding with group 4 element.
6. (a) A photon is a quantised package of energy associated with an electromagnetic radiation while a

proton is a positively charged particle found in the nucleus of an atom.



7. (i)



(ii) 45°



$$A + 2 = 84$$

$$A = 82$$



$$B = 210$$

9. (i) As one moves from gamma to radio waves, the frequency decreases.

Since $E = hf$, the energy increases.

(ii) Infra-red.

10. At night, the temperature of air increases as one moves from the ground into the air above. Since the speed of sound is higher in warmer air the sound waves bend towards the ground making it possible to be heard more clearly. During the day, the temperature of air decreases as one moves up into the air from the ground. The speed of sound near the ground is higher and thus the wave is bent away from the ground.

11. Increase in vibrations of the atoms in the conductor increases the interference with the flow of electrons.

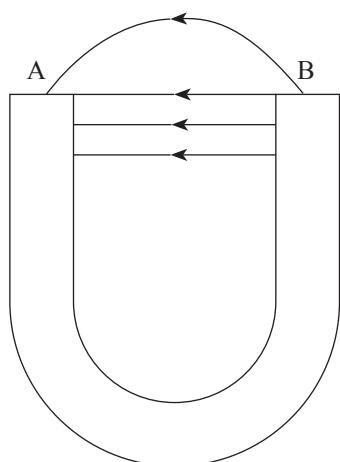
SECTION B

12. (a) (i) L is North pole and (ii) P is also South pole.

(b) (i) By induction.

(ii) Like poles repel, unlike poles attract.

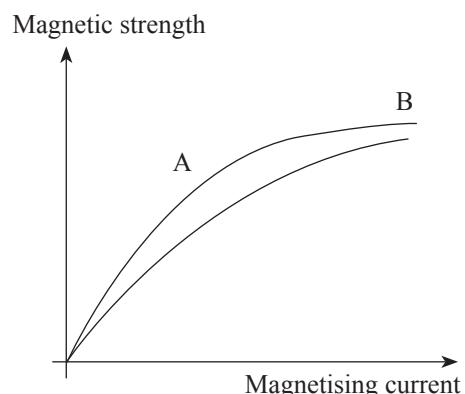
(c) (i) A – South, B – North



(d) (i) OA–The material is being magnetised.

AB – All domains have been aligned, the material is

magnetised.



The material takes longer time to magnetise.

$$13. (a) 0.2 \times 1.2 = 0.25 \times w$$

$$W = 0.2 \times 1.2 / 0.25$$

$$= 0.96 \text{ N}$$

$$(b) (i) \text{ New clockwise moment} = 1.2 \times 0.15 \\ = 0.18 \text{ N}$$

$$(ii) 0.25 F = 1.2 \times 0.15 \\ = 0.72 \text{ N}$$

$$(iii) 0.96 + F = 0.72 \\ F = 0.24 \text{ N}$$

Upward force of 0.24 N
(repulsive)

(iv) Polarity of P = North
Hence, polarity of A is North

14. (a) The distance of a particle from the rest position in a given direction.

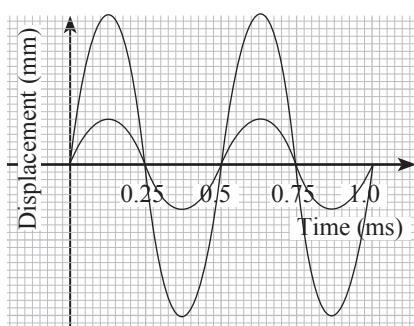
(b) (i) Amplitude = 4

$$(ii) \text{ Period} = 0.5 \times 10^{-3} \text{ s} \\ = 5 \times 10^{-4} \text{ s}$$

$$(iii) \text{ Frequency} = \frac{1}{5} \times 10^{-4} \text{ Hz}$$

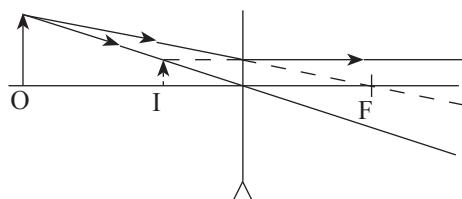
$$(c) \lambda = \frac{v}{f} = \frac{320}{2 \times 10^3} = 0.16$$

(d)



- (e) Radio waves are more easily diffracted since they have longer wavelength.

15. (a)



- (b) (i) From $m = \frac{v}{f} - 1$, slope $= \frac{1}{f}$
Taking the points (25, 0.6) and (70, 3.4)

$$\begin{aligned} \text{Slope} &= \frac{3.4 - 0.6}{70 - 25} \\ &= \frac{2.8}{45} \\ \frac{1}{\text{slope}} &= \frac{45}{2.8} \\ &= 16.07 \text{ cm} \end{aligned}$$

- (ii) x-intercept is the minimum distance for a real image to be formed.

$$(c) v = u + 36$$

$$u + \frac{36}{u} = 3$$

$$3u = u + 36$$

$$2u = 36$$

$$u = 18 \text{ cm}$$

$$\frac{1}{18} - \frac{1}{54} = \frac{1}{f}$$

$$3 - \frac{1}{54} = \frac{1}{f}$$

$$\frac{2}{54} = \frac{1}{f}$$

$$f = 27 \text{ cm}$$

16. (a) As the wave moves over shallow region its speed is increased compared to that over the deep area. This curves the wavefront to appear as if they are coming from a point F shown on the diagram.

- (b) (i) The image is bright towards right and weak towards left. The image is bright because the angle of incidence is greater than the critical angle. Total internal reflection takes place.

Towards left the image is less bright (weaker) since partial reflection takes place. The angle of incidence is below the critical angle.

- (ii) The angle of incidence must be equal or greater than the critical angle.

$$(iii) c = \frac{1}{2} \times 84$$

$$= 42$$

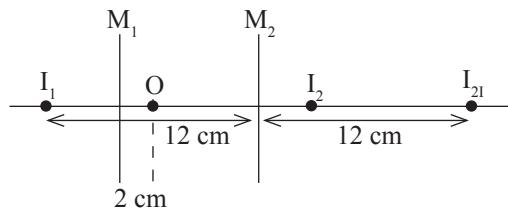
$$n = \frac{1}{\sin c}$$

$$= \frac{1}{\sin 42}$$

$$= 1.494$$

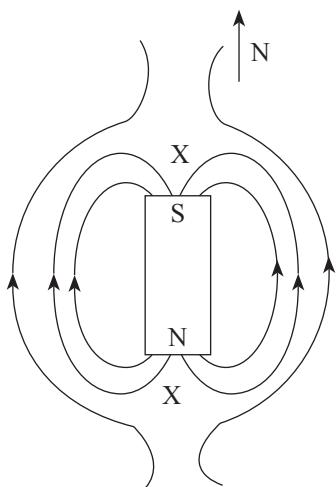
Marking Scheme 2(5)

1. (i) Infinite



$$\text{Distance} = 12 + 10 = 22 \text{ cm}$$

- 2.



X = neutral points

$$3. \frac{1}{\sin c} = \frac{4}{3}$$

Critical angle $c = 48.59^\circ$

$$\text{Maximum angle} = 48.59 \times 2 \\ = 97.2^\circ$$

4. The electromagnet attracts the armature which closes the contact C thus completing the circuit for the motor.

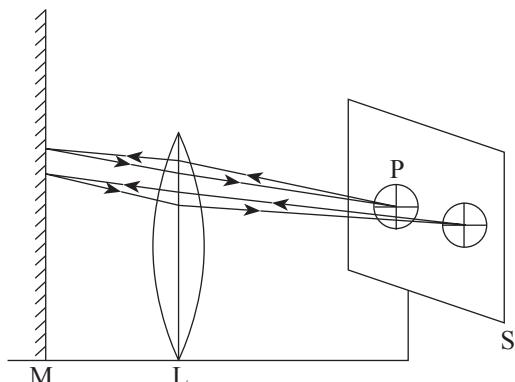
$$5. V = \lambda f$$

$$= 6.14 \times 10^{-7} \times 4.88 \times 10^{14} \\ = 2.996 \times 10^8 \text{ m/s}$$

6. A conductor is held on the hand and the other end made to touch the cap of the charged electroscope. Leaf divergence

decreases because electrons flow from the earth to neutralise the positive charge.

- 7.



Note: Rays from object to lens diverging, from lens to mirror image converging, rays from lens to mirror are parallel and also reflection from mirror to lens.

8. When an object is placed in their path they form a sharp shadow of the object.

9. Lead has high density.

10. Tungsten has a larger work function. Ultra violet light has a higher frequency than orange light hence provides higher energy.

11. As the temperature increases, more charge carriers are released from their bonds thus become available to conduct current.

$$12. \text{Resistance} = 70 \Omega$$

$$\text{Potential difference} = IR$$

$$= 20 \times 10^{-3} \times 70$$

$$= 1.4 \text{ V}$$

13. • Reflection.

- Refraction.

- Diffraction. (Any two)

14. From the equation $\epsilon = \frac{QA}{Vd}$

Introduction of a dielectric decreases the potential difference.

15. (a) (i) A – Manganese (IV) Oxide.

B – Ammonium chloride.

C – Carbon rod.

- (ii) A – Depolarizer.

C – Positive terminal.

D – Acts as a container as well as negative terminal.

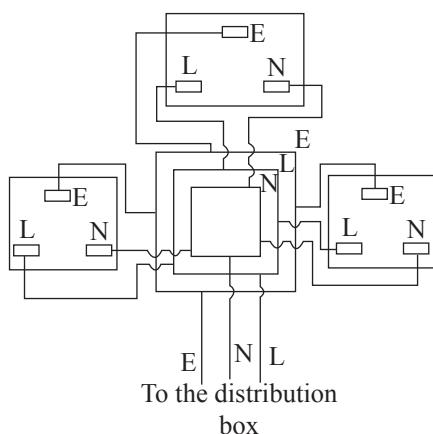
- (iii) Negative terminal.

- (iv) Because of internal resistance.

- (b) (i) The battery will supply current of 2A for 25 hours.

- (ii) • Draws larger current.
• Low internal resistance.

16. (a)



- Sockets are wired such that they tap into a ring circuit connected to the distribution box.

- Ring circuit is preferred since:

- It provides two alternative routes to the socket.

- (ii) Increased the current carrying capacity.

(b)

| Fault | Explanation |
|-------------------------------------|--|
| Fuse on the neutral wire | If it blows out, the entire circuit remains live. Fuses are connected along the live wire. |
| Switch S_2 on the neutral wire | When the switch is off, the rest of the circuit remains live. |
| Two bulbs L_2 and L_3 in series | – When one bulb goes off, the other one also goes off. – Voltage is shared. |

(Any two)

- (c) (i) When the bulb is connected to a 240 V supply, 75 joules of electrical energy is converted to light and heat energy per second.

$$(ii) P = \frac{V^2}{R}$$

$$75 = \frac{250^2}{75}$$

$$= \frac{250 \times 250}{75}$$

$$= 833.3 \Omega$$

$$(iii) H = mc\theta$$

$$= 1.5 \times 4.2 \times 10^3 \times 54$$

$$= 3.402 \times 10^5 \text{ J}$$

$$\text{Power} \times \text{time} = 340200$$

$$\text{Time} = \frac{340200}{1.2 \times 10^3}$$

$$= 283.5 \text{ s (4.73 minutes)}$$

17. (a) The alpha particles cause ionisation of the air between the plate and the grid. A current pulse is created in between the plate and the grid. This is registered as a spark.

(b) (i) $a = 57$ $b = 85$

(ii) A neutron bombards a heavy nuclide.

The heavy nuclide is split into two lighter nuclides.

More neutrons are created to sustain the reaction.

Large quantities of energy are released.

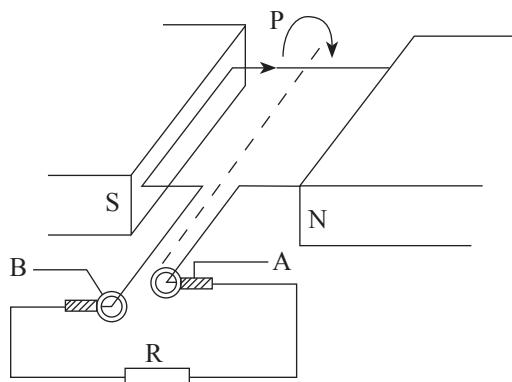
(c) (i) Gamma. High penetrative power.

(ii) Record the background radiation note the drop in gamma count-rate when the sheet of required thickness is in place. With thicker sheet the count-rate reduces.

18. (a) (i) A – Brush

B – Slip ring.

(ii)

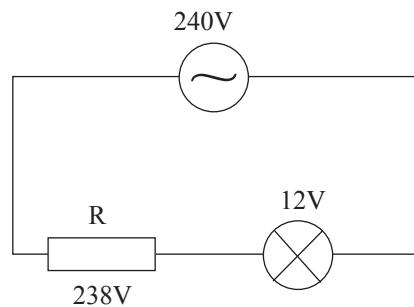


(iii) • Number of turns.

• Speed of rotation.

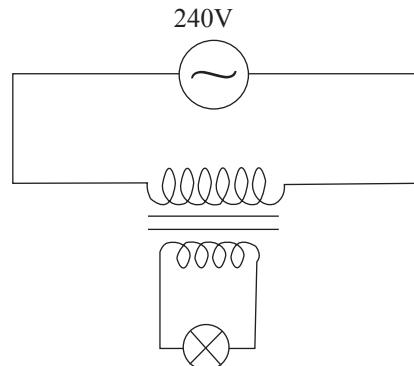
• Strength of magnet.

(b) Method I involving high loss of energy. The high loss energy is in the form of heat dissipated in the resistor connecting the lamp in series with a multiplier resistance that will require a p.d. of 238 V to pass the current flowing through the lamp at a p.d. of 12 V.



Method II – Using a transformer of turns ratio $240 : 12 = 20 : 1$.

Energy losses will be as a result of flux leakage, hysteresis, heat losses, eddy currents in the transformer and these can be minimised.



$$19. (a) (i) R_T = \frac{3 \times 6}{3 + 6} + 1$$

$$= \frac{18}{9} + 1$$

$$= 3 \text{ k}\Omega$$

$$I_T = \frac{9}{3 \times 10^3} \text{ A}$$

Voltage across $1 \text{ k}\Omega$

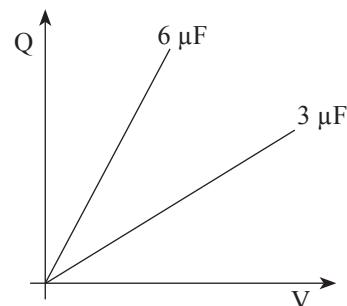
$$= 1 \times 10^3 \times 3 \times 10^{-3}$$

$$= 3 \text{ V}$$

$$\begin{aligned} \text{Voltage across } 6 \text{ k}\Omega &= \frac{6}{6 \times 10^3} \\ &= 6 \text{ V} \end{aligned}$$

$$\begin{aligned} I \text{ through } 6 \text{ }\Omega &= \frac{6}{6 \times 10^3} \\ &= 1 \times 10^{-3} \text{ A} \end{aligned}$$

(b) (i)



The gradient of $6 \mu\text{F}$ is twice that of $3 \mu\text{F}$.

(ii) $Q = CV$

$$= 9 \times 10^{-6} \times 3$$

$$= 2.7 \times 10^{-5} \text{ C.}$$