Collins CSEC® Physics Workbook answers

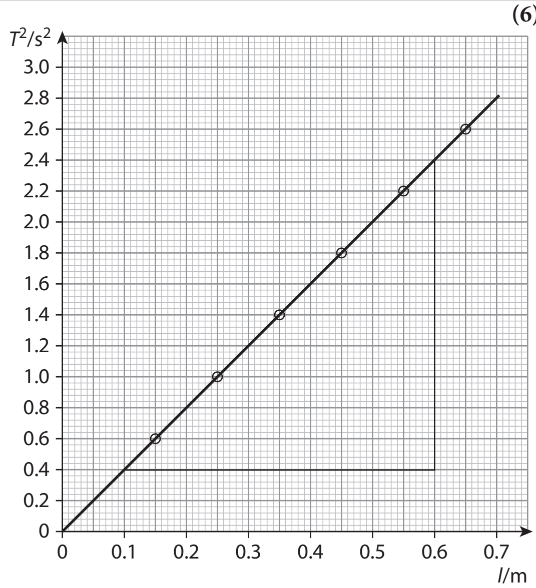
A1 Scientific method

1. a)

Time taken for 20 oscillations t/s	15.5	20.1	23.7	26.9	29.8	32.4
Length l/m	0.150	0.250	0.350	0.450	0.550	0.65
Period T/s	0.775	1.005	1.185	1.345	1.490	1.620
T^2/s²	0.601	1.010	1.404	1.809	2.220	2.624

(6)

b)



(10)

c) Slope $= \frac{\text{change in } T^2}{\text{change in } l}$ **(1)**

Slope $= \frac{2.4 - 0.4}{0.6 - 0.1}$ **(2)**

$= 4.0$ s²/m **(1)**

d) $S = \frac{39.4}{g}$

$4 = \frac{39.4}{g}$ **(1)**

$4g = 39.4$

$g = \frac{39.4}{4}$

$g = 9.85$ ms^{-2} **(1)**

2. a) Density is the mass per unit volume. **(2)**

SI unit – kgm^{-3} **(1)**

b) Mass of 1 steel marble in grams $= \frac{336}{10} = 33.6$ g **(1)**

Mass of 1 steel marble in kg $= \frac{33.6}{1000} = 0.0336$ kg **(1)**

c) Volume of 10 steel marbles = 92 – 50 = 42 cm³

Volume of 1 steel marble in cm³ $= \frac{42}{10} = 4.2$ cm³

Volume of 1 steel marble in m³ $= \frac{4.2}{1 \times 10^6}$

$= 4.2 \times 10^{-6}$ m³ **(2)**

d) Density of steel $= \frac{\text{mass}}{\text{volume}}$ **(1)**

$= \frac{0.0336}{4.2 \times 10^{-6}}$ **(1)**

$= 8000$ kgm^{-3} **(1)**

e) Relative density of steel $= \frac{\text{density of steel}}{\text{density of water}}$ **(1)**

$= \frac{8000}{1000}$ **(1)**

$= 8$ **(1)**

3.

	Quantity being measured	Instrument most suitable
1	Diameter of a wire	Micrometer screw guage
2	Mass of a coin	Electronic balance
3	Temperature of boiling water	Thermometer
4	Electric current flowing in a circuit	Ammeter
5	Period of a pendulum	Stopwatch

(5)

4. a)
1. May have recorded the length of the pendulum incorrectly, especially if the length is being measured with a metre rule from a point other than zero. **(1)**
2. May have used the incorrect time for the period of the swing of the pendulum, especially if the time taken for multiple swings is being measured. **(1)**

b)
1. Find the time for 20 swings and then find the time for one swing (period).
2. Ensure that the distance from the fixed point and the centre of mass of the bob is measured. Use a metre rule to measure the length of the string and a micrometre screw gauge to measure the diameter of the bob.
3. Repeat the experiment using different lengths. For each length measure the corresponding period.
4. Plot a graph of T^2 against l and draw the line of best fit.

A2 Vectors

1. a) A scalar quantity has magnitude only. **(1)**

A vector quantity has magnitude and direction. **(2)**

b) Scalar quantity

Any one of: mass, distance, speed, energy, power **(1)**

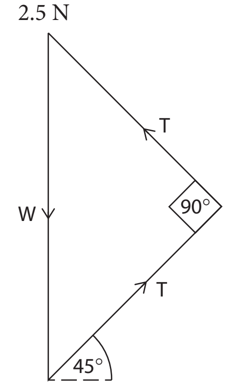
Vector quantity

Any one of: velocity, acceleration, force, displacement **(1)**

c) i) 4.3 N **(1)**

ii) 2.5 N **(1)**

d) i)



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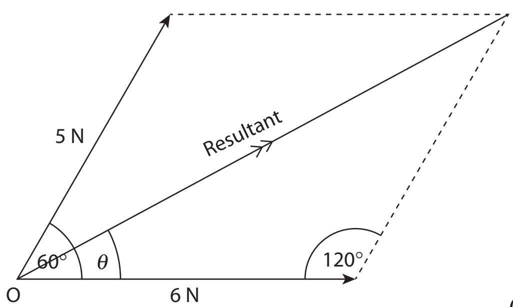
ii) Using Pythagoras' theorem (since one of the angles in the triangle is 90°)

$W^2 = 500^2 + 500^2$ **(1)**

$W^2 = 500000$ **(1)**

$W = \sqrt{500000} = 707$ N **(1)**

2. a)



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Resultant force = 9.5 N **(1)**

b) 27° **(1)**

A3 Statics

1. a)

Fundamental quantity	SI Unit	Symbol
Mass	**kilogram**	**kg**
Length	metre	**m**
Time	**second**	s
Temperature	**Kelvin**	**K**

(6)

b) i) $W = F \times d$ **(1)**

$= N \times m$

$= Nm$ **(1)**

ii) Joule **(1)**

iii) $P = \frac{F \times d}{t}$

$= \frac{ma \times d}{t}$

$= kgms^{-2} \times ms^{-1}$

$= kgm^2s^{-3}$ **(1)**

iv) Watt **(1)**

2. a) Moment of a force is the force multiplied by the perpendicular distance from a fulcrum. **(2)**

SI Unit – Nm **(1)**

b) The sum of the clockwise moments about a point **(1)** is equal to the sum of the anticlockwise moments **(1)** about the same point. **(1)**

c) i) Sum clockwise moments = sum of anticlockwise moments **(1)**

$(20 \times 0.14) + (50 \times 0.30) = X \times 0.04$ **(1)**

$17.8 = 0.04\,X$ **(1)**

$X = \frac{17.8}{0.04}$

$X = 445$ N **(1)**

ii) Total upward force = total downward force **(1)**

$445 = Y + 20 + 50$ **(1)**

$Y = 445 - 20 - 50$

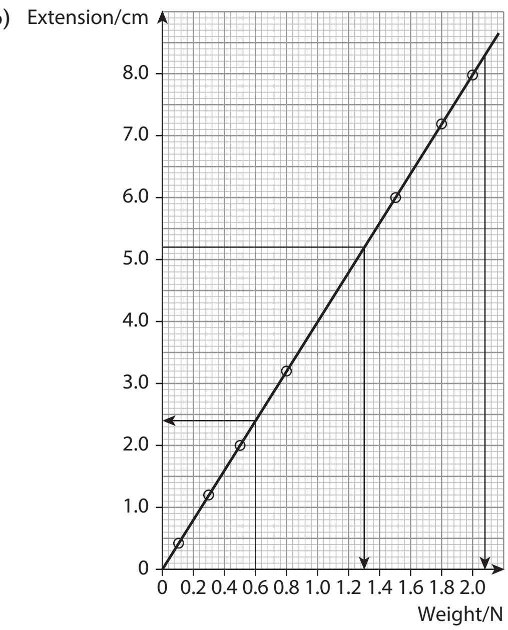
$Y = 375$ N **(1)**

3. a)

Mass/g	10	30	50	80	100	150	180	200
Weight/N	0.1	0.3	0.5	0.8	1.0	1.5	1.8	2.0
Extension/cm	0.4	1.2	2.0	3.2	4.0	6.0	7.2	8.0

(4)

b)



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c) Slope $= \frac{\text{change in extension}}{\text{change in weight}}$ **(1)**

$= \frac{8.3 - 0}{2.5 - 0}$ **(1)**

$= 3.32$ cm N^{-1} **(1)**

d) spring constant $= \frac{1}{S}$

$= \frac{1}{3.32}$ **(1)**

$= 0.301$ Ncm^{-1} **(1)**

e) i) Extension = 85.2 – 80 = 5.2 cm **(1)**

From the graph, Weight = 1.3 N **(1)**

Therefore, the mass $= \frac{W}{g} = \frac{1.3}{10} = 0.13$ kg (or 130 g) **(1)**

ii) Weight = mg

$= 0.060 \times 10$ **(1)**

$= 0.6$ N **(1)**

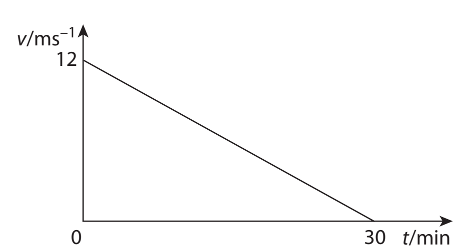
From the graph, the extension = 2.4 cm **(1)**

A4 Dynamics

1. a) i) Velocity is the rate of change of displacement. ms^{-1} **(2)**

ii) Acceleration is the rate of change of velocity. ms^{-2} **(2)**

b) i)



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ii) Deceleration $= \frac{\text{change in velocity}}{\text{time taken}}$ **(1)**

$= \frac{12 - 0}{(30 \times 60)}$ **(1)**

$= 6.67 \times 10^{-3}$ ms^{-2} **(1)**

iii) Distance travelled = area under the graph **(1)**

$= \frac{1}{2} \times (30 \times 60) \times 12$ **(1)**

$= 10{,}800$ m (10.8 km) **(1)**

iv) $F = ma$ (1)
$= 3.0 \times 10^7 \times 6.67 \times 10^{-3}$ (1)
$= 2.0 \times 10^5$ N (1)

2. a) The rate of change of momentum is (1)
proportional to the applied force (1)
and takes place in the direction in which the force acts. (1)

b) A force is required for motion. (1)
The velocity is proportional to the force. (1)
Increasing the force increases the velocity. (1)

c) i) Aristotle, $F = 0$ (1)
Newton, $F = 0$ (1)
ii) Aristotle, F is constant but not zero. (1)
Newton, $F = 0$ (1)
iii) Aristotle, F is constant and now halved. (1)
Newton, $F = 0$ (1)

3. a) i) Linear momentum is the product of a body's mass and velocity. (2)
ii) In a closed system (1)
the total momentum before a collision is equal (1)
to the momentum after the collision. (1)

b) Since both cars are at rest after the collision,
the total momentum = 0 (1)
Both cars have the same mass and are travelling at the same speed in opposite directions.
Velocity is a vector quantity so (1)
total momentum before collision = $mv + (-mv) = 0$ (1)
Therefore, the law of conservation of momentum applies. (1)

c) Total momentum before collision = Total momentum after collision (1)
$(0.12 \times V) + (4.5 \times 0) = (0.12 + 4.5) \times 4.2$ (1)
$0.12\,V = 19.40$ (1)
$V = \frac{19.40}{0.12}$
$V = 162$ ms^{-1} (1)

4. a) i) Displacement is the distance moved in a stated direction and is a vector quantity. (1)
Distance is a scalar quantity. (1)
ii) If a car starts at a point A and travels in a circular path a distance of 100m (1)
and returns to the point A (1)
the displacement will be zero. (1)

b) i) Acceleration $= \frac{(v - u)}{t}$ (1)
$= \frac{(20 - 0)}{120}$ (1)
$= 0.167$ ms^{-2} (1)
ii) Force $= m \times a$ (1)
$= 500 \times 0.167$ (1)
$= 83.5$ N (1)
iii) Distance travelled = area under the graph
$= \frac{1}{2}(20 \times 120) + (20 \times 380) + \frac{1}{2}(20 \times 350)$
$= 12\,300$ (1)
iv) Average speed $= \frac{\text{Total distance travelled}}{\text{total time taken}}$ (1)
$= \frac{12300}{850}$ (1)
$= 14.5$ ms^{-1} (1)
v) Linear momentum $= m \times v$ (1)
$= 500 \times 20$ (1)
$= 10{,}000$ kgms^{-1} (1)

5. a) Newton's first law states that a body stays at rest or if moving continues to move with uniform velocity unless acted upon by an external force. (2)
Newton's second law states that the rate of change of momentum is proportional to the applied force and takes place in the direction in which the force acts. (2)
Newton's third law states that if a body A exerts a force on body B, then body B exerts an equal and opposite force on body A. (2)

b) Mass is the amount of matter contained in a body OR a measure of a body's inertia. (1)
Weight is the force experienced by a mass when placed in a gravitational field. (1)

c) The Newton is defined as the force required to give a mass of 1kg an acceleration of 1 ms^{-2}. (2)

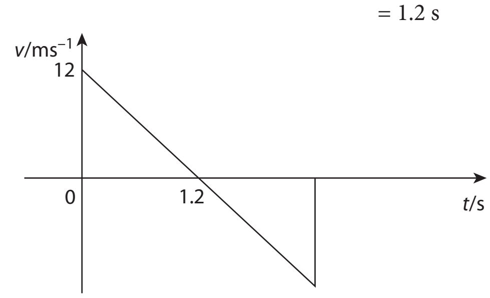
d) i) Gravitational force due the Earth (1)
ii) The tension in the string (1)
iii) The friction between the tyres and the road (1)

e) i) In order to maintain circular motion (1)
an unbalanced force is required to provide the acceleration. (1)
This force is provided by the gravitational force of attraction (1)
by the Earth on the satellite. (1)
ii) The Earth exerts a gravitational force on the satellite and (1)
the satellite exerts an equal (1)
but opposite force on the Earth. (1)

6. a) Initial momentum $= m \times v$ (1)
$= 0.01 \times 12$ (1)
$= 0.12$ kgms^{-1} (1)

b) time taken to reach maximum height $= \frac{(v - u)}{a}$ (1)
$= \frac{(0 - 12)}{-10}$ (1)
$= 1.2$ s (1)

c)



(3)

d) Area under the graph between $t = 0$ and $t = 1.2$ s. (1)

e) Maximum vertical height $= \frac{1}{2} \times 1.2 \times 12$ (1)
$= 7.2$ m (1)

7. a) 2 ms^{-1} (1)

b) $v = u + at$
$= 0 + (10 \times 3)$
$= 30$ ms^{-1} (1)

A5 Energy

1. a) i) Energy is the capacity to do work. (1)
ii) Energy can neither be created (1)
nor destroyed but (1)
can be converted from one form to another. (1)

b) i) Electrical energy ⟶ Light + Heat (3)
ii) Potential energy ⟶ Kinetic energy + Sound (3)
iii) Chemical energy ⟶ Kinetic energy + Heat (3)

c) i) $E_p = mgh$ (1)
$= 0.1 \times 10 \times 1.2$ (1)
$= 1.2$ J (1)

ii) Loss in potential energy = gain in kinetic energy (1)
$1.2 = \frac{1}{2} \times 0.1 \times v^2$ (1)
$v = \sqrt{\frac{(2 \times 1.2)}{0.1}}$
$v = 4.9$ ms^{-1} (1)

iii) $W = F \times d$ (1)
$1.2 = F \times 2 \times 10^{-2}$ (1)
$F = 60$ N (1)

2. a) i) Work is the force multiplied by the distance moved in the direction of the force. (1)

ii) $E_p = mgh$ (1)
$= 120 \times 10 \times 0.8$ (1)
$= 960$ J (1)

iii) $W = F \times d$ (1)
$= 200 \times 8$ (1)
$= 1600$ J (1)

iv) Work is done against friction while the box is moving up the ramp. (1)
Energy is converted into heat and sound. (1)
The gain in potential energy must therefore be less than the work done by the 200 N force, in order for the law of conservation of energy to apply. (1)

v) Efficiency $= \frac{\text{Useful output}}{\text{Input}} \times 100$ (1)
$= \frac{960}{1600} \times 100$ (1)
$= 60$ % (1)

A6 Hydrostatics

1. a) Pressure is the force acting normally per unit area. (2)

b) Pascal Pa (1)

c) Barometer, U-tube manometer, Bourdon gauge (*Any 2*) (2)

d) $W = mg$ (1)
$= 55 \times 10$
$= 550$ N (1)
$P = \frac{F}{A}$ (1)
$= \frac{550}{2.2 \times 10^{-3}}$ (1)
$= 2.5 \times 10^5$ Pa (1)

2. a) $p = \rho gh$ (1)
$= 1150 \times 10 \times 45$ (1)
$= 5.18 \times 10^5$ Pa (1)

b) Total pressure $= 5.18 \times 10^5 + 100 \times 10^3$ (1)
$= 6.18 \times 10^5$ Pa (1)

3. a) A body wholly or partially submerged in a fluid experiences an upthrust (1)
which is equal to the weight of the fluid displaced. (1)

b) i) Volume of water displaced $= A \times h$ (1)
$= 0.32 \times 0.75$ (1)
$= 0.24$ m^3 (1)

ii) $\rho = \frac{m}{V}$
$m = \rho \times V$ (1)
$= 1000 \times 0.24$ (1)
$= 240$ kg (1)

iii) $W = mg$ (1)
$= 240 \times 10$ (1)
$= 2400$ N (1)

iv) Weight of oil drum = 2400 N (1)

v) $p = \rho gh$ + atmospheric pressure (1)
$= (1000 \times 10 \times 0.75) + 1 \times 10^5$ (1)
$= 7500 + 1 \times 10^5$ (1)
$= 1.075 \times 10^5$ Pa (1)

4. a) $m = \rho V$ (1)
$= 1250 \times (0.18 \times 3.8 \times 10^{-4})$ (1)
$= 8.55 \times 10^{-2}$ kg (1)

b) $W = mg$
$= 8.55 \times 10^{-2} \times 10$ (1)
$= 0.855$ N (1)

c) mass of fluid displaced $= \rho V$
$= 750 \times (0.18 \times 3.8 \times 10^{-4})$ (1)
$= 5.13 \times 10^{-2}$ kg (1)
Uphthrust = weight of fluid displaced (1)
$= 5.13 \times 10^{-2} \times 10$
$= 0.513$ N (1)

d) Reading on spring balance $= 0.855 - 0.513 = 0.342$ N (1)

5. a) $p = \frac{F}{A}$ (1)
$= \frac{150}{2 \times 10^{-4}}$ (1)
$= 7.5 \times 10^5$ Pa (1)

b) $p = 7.5 \times 10^5$ Pa (1)

c) $F = p \times A$ (1)
$= 7.5 \times 10^5 \times 3 \times 10^{-4}$ (1)
$= 225$ N (1)

B1 Nature of heat

1. a) Heat was an invisible fluid called caloric. (1)
Caloric could neither be created nor destroyed and was present in all matter. (1)
Temperature rises due to the addition of caloric. (1)
Temperature falls due to the removal of caloric. (1)

b) Lack of experimental evidence to show that a hot body weighed more than a cold one. (1)
It was difficult to weigh a hot body accurately when the temperature was changing. (1)

c) i) Horses were used to turn a blunt drill bit.
The drill bit was used to bore a brass cannon. (1)
The brass cannon and the brass borings became very hot. (1)
This heating effect continued as long as the drilling continued. (1)

ii) Thermal energy can be created. (1)
Hence it is not a material substance. (1)
Thermal energy is produced when work is done against friction, as in the case of the drilling. (1)

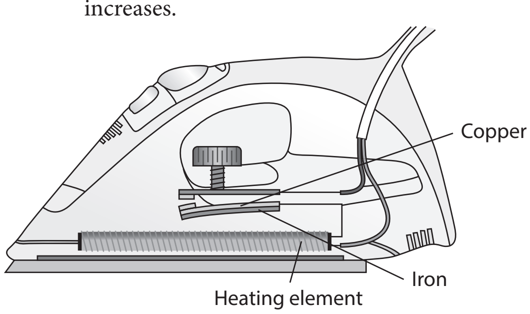
B2 Macroscopic properties and phenomena

1. a) Change in volume of a liquid
Change in volume of a gas
Change in electrical resistance of a metal
Generation of an e.m.f.
Any two (1 mark each)

b) i) Temperature of pure melting ice **(1)**
Lower fixed point = 0 °C **(1)**
ii) Temperature of steam above pure boiling water at normal atmospheric pressure **(1)**
Upper fixed point = 100 °C **(1)**
c) Mercury is opaque. **(1)**
Mercury does not 'wet' glass. **(1)**
d) Can measure rapidly changing temperatures **(1)**
Can measure temperatures remotely **(1)**

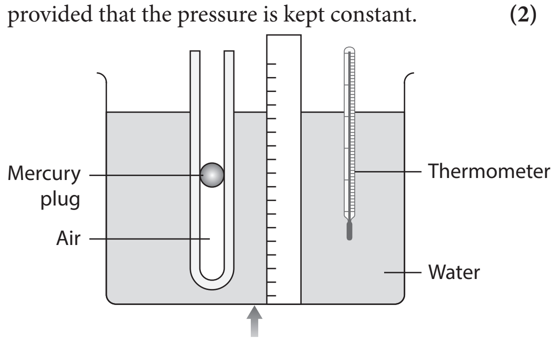
2. a) Gas is made up of many small similar particles **(1)** moving randomly at high speeds **(1)**
b) i) Molecules are moving randomly at high speeds. **(1)**
They collide with the walls of the container. **(1)**
They undergo a change in momentum and **(1)** therefore exert a force on the walls of the container. **(1)**
The force acts on the surface area of the inner walls $\left(p = \frac{F}{A}\right)$ **(1)**
ii) As the temperature increases the kinetic energy of the molecules increases. **(1)**
They collide more frequently with the walls of the container. **(1)**
There is greater change in momentum and therefore a greater force is exerted on the walls of the container. **(1)**
Therefore the pressure inside the container increases. **(1)**

3.



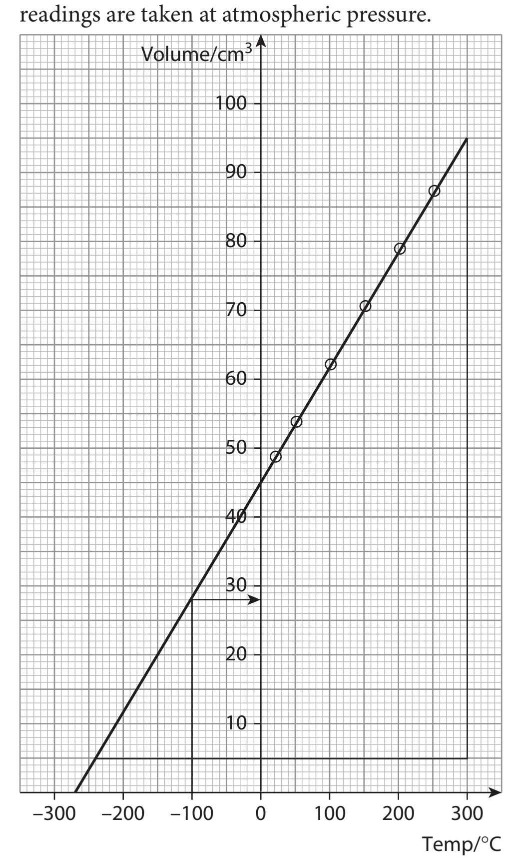
The copper strip expands more than the iron strip when heated by the heating element; **(1)**
bi-metallic strip bends downwards; **(1)**
electrical circuit is broken; **(1)**
when bi-metallic strip cools it returns to its original position. **(1)**

4. a) The volume of a fixed mass of gas is directly proportional to its thermodynamic temperature, provided that the pressure is kept constant. **(2)**
b)



Set up the apparatus as shown above. **(1)**
Record the length of the air column. **(1)**
Record the temperature of the water. **(1)**
Heat the water and record several corresponding values of the length of air column and temperature. **(1)**
The pressure will remain constant provided that all readings are taken at atmospheric pressure. **(1)**

c)



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d) From the graph volume = 28 cm³ **(1)**
e) From the graph temperature = −270 °C **(1)**
f) This is absolute zero. **(1)**
g) Gradient = $\frac{\text{change in volume}}{\text{change in temperature}}$ **(1)**
$= \frac{95 - 5}{300 - (-240)}$ **(1)**
$= 0.167\ \text{cm}^3\ \text{°C}^{-1}$ **(2)**

5. a) The pressure of a fixed mass of gas is inversely proportional to its volume provided that the temperature is kept constant. **(2)**
b) The pressure of a fixed mass of gas is directly proportional to its absolute temperature provided the volume is constant. **(2)**
c) $T_1 = 27 + 273 = 300$ K **(1)**
$T_2 = 67 + 273 = 340$ K **(1)**
$p_1 = 190$ kPa
$\frac{p_1}{T_1} = \frac{p_2}{T_2}$ **(1)**
$\frac{190}{300} = \frac{p_2}{340}$ **(1)**
$p_2 = \frac{340 \times 190}{300}$
$p_2 = 215$ kPa **(1)**
d) $T_1 = 27 + 273 = 300$ K
$T_2 = 67 + 273 = 340$ K
$p_1 = 190$ kPa
$V_1 = V$
$V_2 = 1.05$ V **(1)**
$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ **(1)**

$\frac{190 \times V}{300} = \frac{p_2 \times 1.05V}{340}$ **(1)**

$1.05\, p_2 V = \frac{340 \times 190 \times V}{300}$ **(1)**

$p_2 = \frac{340 \times 190 \times V}{1.05V \times 300}$ **(1)**

$p_2 = 205\text{kPa}$ **(1)**

B3 Thermal measurements

1. a) $E = ml_f$ **(1)**
$= 0.08 \times 3.4 \times 10^5$ **(1)**
$= 2.72 \times 10^4$ J **(1)**

b) $E = mc\Delta T$ **(1)**
$= 0.08 \times 4.2 \times 10^3 \times (8 - 0)$ **(1)**
$= 2.688 \times 10^3$ J **(1)**

c) Energy lost by lime juice = energy used to melt ice + energy gained by melted ice
$= 2.72 \times 10^4 \text{ J} + 2.688 \times 10^3$ J
$= 2.989 \times 10^4$ J **(2)**

d) Energy lost by lime juice = $mc\Delta T$
$2.989 \times 10^4 = 0.32 \times c \times (29 - 8)$
$c = \frac{2.989 \times 10^4}{0.32 \times 21}$
$c = 4.45 \times 10^3 \text{ Jkg}^{-1}\,°\text{C}^{-1}$ **(3)**

2. a) Energy per second = 850×4
$= 3400 \text{ W } (\text{Js}^{-1})$ **(2)**

b) Energy absorbed by pot per second = $0.65 \times 3400 = 2210 \text{ Js}^{-1}$ **(1)**
$E = P \times t$ **(1)**
$= 2210 \times 40 \times 60$
$= 5.304 \times 10^6$ J **(1)**

c) Energy = $C\Delta T$ **(1)**
$= 8200 \times 75$ **(1)**
$= 6.15 \times 10^5$ J **(1)**

d) Efficiency = $\frac{E_o}{E_1} \times 100$ **(1)**
$= \frac{6.15 \times 10^5}{5.304 \times 10^6} \times 100$ **(1)**
$= 11.6\ \%$ **(1)**

3. a) Evaporation is the change in state of a liquid into a vapour without reaching its boiling point. **(2)**
Boiling is the process by which a liquid changes into a vapour at a particular temperature and pressure. **(2)**

b) Temperature is proportional to the average kinetic energy of all the molecules. **(1)**
The molecules with a high kinetic energy are able to escape from the surface of the liquid. **(1)**
The average kinetic energy of the remaining molecules decreases. **(1)**
Hence the temperature of the remaining liquid falls. **(1)**

4. a) Specific heat capacity *c,* is the amount of energy required to raise the temperature of 1 kg of a substance by 1 degree. **(2)**
Heat capacity *C,* is the amount of energy required to raise the temperature of a substance by 1 degree. **(2)**

b) $C = mc$ **(1)**

c) Latent heat of fusion is the amount of energy required to change 1 kg of a solid into a liquid without a change in temperature. **(3)**

d) i) $E = mc\Delta T$ **(1)**
$= 150 \times 2.0 \times 10$ **(1)**
$= 3000$ J **(1)**

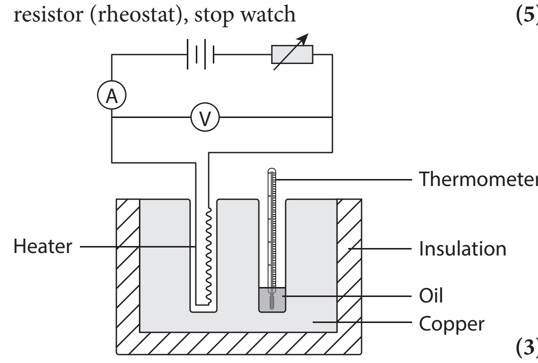
ii) $E = ml_f$ **(1)**
$= 150 \times 340$ **(1)**
$= 51000$ J **(1)**

iii) $E = mc\Delta T$ **(1)**
$= 150 \times 4.2 \times 25$ **(1)**
$= 15750$ J **(1)**

iv) Total energy supplied = 3000 + 51000 + 15750
$= 69750$ J **(1)**
$P = \frac{E}{t}$
$= \frac{69750}{690}$ **(1)**
$= 101$ W **(1)**

5. a) Ammeter, voltmeter, electric heater, power supply, oil, lagging, copper block, thermometer, variable resistor (rheostat), stop watch **(5)**

b)



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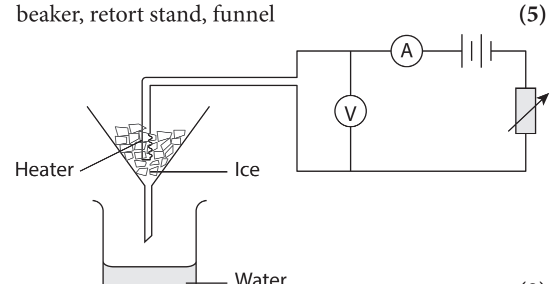
c) Energy supplied by the heater = IVt **(1)**
Energy gained by copper block = $mc\,(T_2 - T_1)$ **(1)**
Where
I – current flowing through heater
V – potential difference across heater
t – duration of heating
m – mass of copper block
c – specific heat capacity of copper
T_1 – initial temperature of copper block
T_2 – final temperature of copper block
Energy supplied by heater = Energy gained by copper block (assuming no heat losses) **(1)**
$IVt = mc\,(T_2 - T_1)$
$c = \frac{IVt}{m(T_2 - T_1)}$ **(1)**

d) Insulate the copper block. **(1)**
Repeat the experiment by changing I but measuring the same temperature change. **(1)**

6. a) Ammeter, voltmeter, battery, heater, stop watch, ice, beaker, retort stand, funnel **(5)**

b)



(3)

c) Energy supplied by the heater = IVt **(1)**
Energy gained by ice = ml_f **(1)**
Where
I – current flowing through heater
V – potential difference across heater

t – duration of heating
m – mass of ice
l_f – specific latent heat of fusion of ice
Energy supplied by heater = Energy used to melt the ice **(1)**

$$IVt = m\,l_f$$

$$l_f = \frac{IVt}{m}$$ **(1)**

B4 Transfer of thermal energy

1. a) Conduction, convection, radiation **(3)**

b) Double walled glass with vacuum between – Heat lost by conduction and convection reduced **(4)**
Silvered glass surfaces in vacuum – Heat lost by radiation is reduced **(2)**

2. a) Copper tubes – copper is a good conductor of heat. **(1)**
Blackened surface – black surfaces are good absorbers of heat. **(1)**
Glass – allows short-wave radiation to enter. The re-radiated long-wave radiation is trapped by glass. **(1)**

b) Short-wave radiation easily penetrates the glass. **(1)**
The re-radiated waves have a longer wavelength and cannot pass through glass. **(1)**
The radiation becomes trapped and the temperature increases. **(1)**

c) CO_2 is a greenhouse gas. **(1)**
It behaves like the glass in the glasshouse effect. **(1)**
More CO_2 in the atmosphere causes global warming and can lead to climate changes. **(1)**

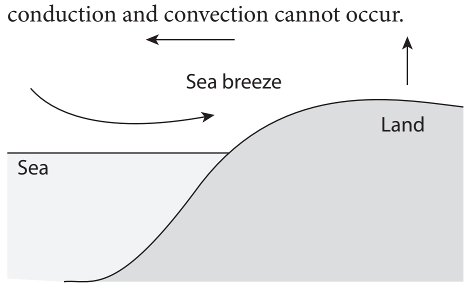
3. a) Conduction is the flow of heat through matter from a region of higher temperature to a region of lower temperature without the flow of matter as a whole. **(2)**

b) Convection is the flow of heat through a fluid from a region of higher temperature to a region of lower temperature by the bulk movement of the fluid. **(2)**

c) Radiation is the flow of heat from a region of high temperature to a region of low temperature by means of electromagnetic waves. **(2)**

4. a) Radiation **(1)**
Vacuum exists between the Earth and the Sun, so **(1)**
conduction and convection cannot occur. **(1)**

b)



In the day time, the land heats up faster than the sea. **(1)**
Hot air rises above land. **(1)**
Cooler heavier air rushes in from above the sea surface. **(1)**

c) i) B **(1)**
ii) Black surfaces are better absorbers than shiny ones. **(1)**

d) i) A **(1)**
ii) Black surfaces emit radiation better than shiny ones. **(1)**

e) Good absorbers are also good emitters of radiation. **(1)**

C1 Wave motion

1. a) i) Wavelength is the distance between two successive points in phase *OR* **(1)**
The distance between two successive crests *OR*
The distance between two successive troughs.
ii) Frequency is the number of cycles per second. **(1)**
iii) Amplitude is the maximum displacement from the equilibrium or rest position. **(1)**

b) i) 0.8 cm **(1)**
ii) $T = 0.4$ s
$f = \frac{1}{T}$ **(1)**
$= \frac{1}{0.4}$ **(1)**
$= 2.5$ Hz **(1)**
iii) $v = f\lambda$ **(1)**
$= 2.5 \times 1.5 \times 10^{-2}$ **(1)**
$= 3.75 \times 10^{-2}\ \text{ms}^{-1}$ **(1)**

2. a) i) A progressive wave transmits energy from one point to another. **(2)**
ii) A transverse wave is one in which the particles in the wave oscillate at right angles to the direction of travel of the wave. **(2)**
iii) A longitudinal wave is one in which the particles in the wave oscillate parallel to the direction of travel of the wave. **(2)**

b) A progressive wave – water wave **(1)**
A transverse wave – light **(1)**
A longitudinal wave - sound **(1)**

3. a) Frequency $= \frac{1}{T}$
$= \frac{1}{(20 \times 10^{-3})}$
$= 50$ Hz **(3)**

b) $V = f \times \lambda$
$= 50 \times 4 \times 10^{-2}$
$= 2\ \text{ms}^{-1}$ **(3)**

C2 Sound

1. a) Stand at one end of a long room. **(1)**
Measure the length of the room using a tape measure. **(1)**
Using two blocks of wood, hit them to make a sound. **(1)**
Record the time taken between hitting the blocks and hearing the echo using a stop watch. **(1)**
Speed of sound $= \frac{(2 \times \text{length of room})}{\text{time}}$ **(1)**

b) $\lambda = \frac{v}{f}$ **(1)**
$= \frac{340}{250}$ **(1)**
$= 1.36$ m **(1)**

c) $d = st$ **(1)**
$= 340 \times 9$ **(1)**
$= 3060$ m **(1)**

2. a) In a sound wave the particles oscillate parallel to the direction of travel of the wave. **(2)**

b) Pitch – frequency **(1)**
Loudness – amplitude **(1)**

c) Light is a transverse wave/Sound is a longitudinal wave. **(1)**
Light travels faster than sound in air. **(1)**
Light can travel through a vacuum/Sound cannot. **(1)**

d) 20 Hz to 20 kHz **(2)**

3. **a)** Sound waves have a wavelength comparable to the width of the door; therefore sound waves diffract on passing through the doorway and spread out into the kitchen. Light waves have very much shorter wavelengths, so no diffraction is observed and the light waves travel in straight lines. **(4)**
   b) i) Regions of sound and no sound **(2)**
   ii) Interference **(1)**
   iii) Waves from S_1 and S_2 interfere **(1)**
   Region of sound – two crests meet and constructive interference occurs **(2)**
   Region of no sound – a crest and a trough meet and destructive interference occurs **(2)**
4. Medicine – Ultrasound used obtain images of a baby in the womb of a woman **(2)**
   Industry – Ultrasound is used to detect hairline fractures in metals **(2)**

C3 Electromagnetic waves

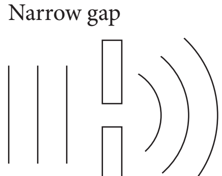
1. **a)** Travel at 3.0×10^8 ms^{-1} **(1)**
   Can travel in a vacuum **(1)**
   Can be diffracted, reflected and interfere **(1)**
   Consist of oscillating electric and magnetic fields **(1)**
   b) Visible light, infrared radiation, microwaves **(3)**
   c) $\lambda = \frac{v}{f}$ **(1)**
   $= \frac{3 \times 10^8}{2 \times 10^{10}}$ **(1)**
   $= 0.015$ m
   $= 1.5$ cm **(1)**
   d)

Electromagnetic wave	**Source**	**Use**
infrared radiation	remote controls	to control TVs, CD player
X-rays	X-ray tube	produce X-rays of bones
microwaves	cellular phone	communications
visible light	sun	photosynthesis

(6)

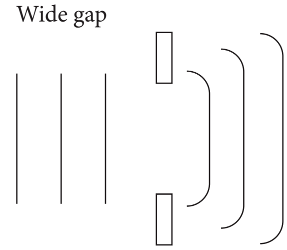
C4 Light waves

1. **a)** Newton – light is made up of particles (corpuscles) **(1)**
   Huygens – Light is a wave **(1)**
   b) Wave theory **(1)**
   c) Corpuscular theory **(1)**
2. **a)** Diffraction – the spreading of waves as they pass through a gap or past the edge of an object. **(1)**
   b) Light has a very short wavelength. **(1)**
   Light casts sharp shadows. **(1)**
   c) Narrow gap



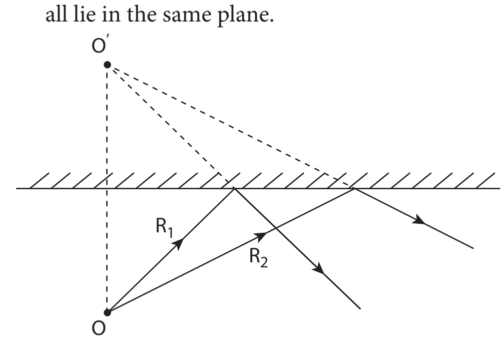
(3)

Wide gap



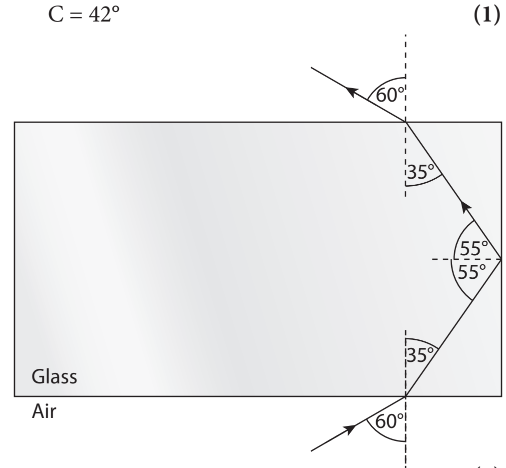
(3)

   d) The wavelength remains the same. **(1)**
   e) The wavelength is comparable to the width of the gap **(1)**
3. **a)** 1. The angle of incidence is equal to the angle of refraction. **(1)**
   2. The incident ray, the reflected ray and the normal all lie in the same plane. **(1)**
   b)



(4)

4. **a)** Bending light as a result of change in speed caused by travel in different media **(2)**
   b) Light travels between two media of different optical densities. **(1)**
   The speed of light changes between the media. **(1)**
   This causes the direction of light to change (bend). **(1)**
   c) i) $n = \frac{\sin i}{\sin r}$ **(1)**
   $1.5 = \frac{\sin 60°}{\sin r}$ **(1)**
   $\sin r = \frac{\sin 60°}{1.5}$
   $\sin r = 0.577$
   $r = 35°$ **(1)**
   ii) $n = \frac{1}{\sin C}$ **(1)**
   $1.5 = \frac{1}{\sin C}$ **(1)**
   $\sin C = \frac{1}{1.5}$
   $\sin C = 0.667$
   $C = 42°$ **(1)**
   iii)



(4)

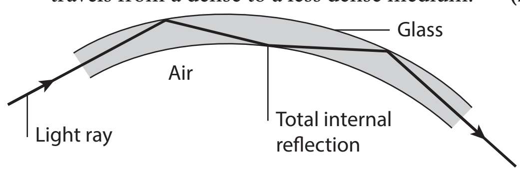
60°

5. a) i) Refractive index $n = \frac{\sin\text{ (angle of incidence)}}{\sin\text{ (angle of refraction)}}$ **(2)**

ii) Critical angle is the angle of incidence for which the angle of refraction is 90° **(1)**
as a ray travels from a dense to a less dense medium. **(1)**

iii) Total internal reflection occurs when the angle of incidence is greater than the critical angle as a ray travels from a dense to a less dense medium. **(2)**

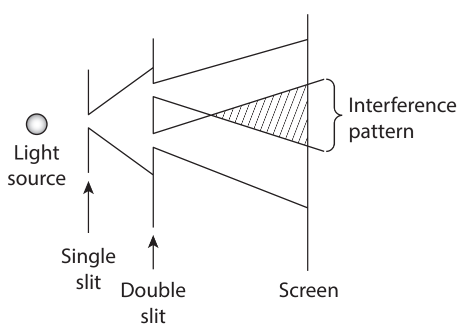
b)



When a light ray enters one end of the glass, it strikes the inner walls of the glass. **(1)**
The angle of incidence is greater than 42°. **(1)**
Total internal reflection occurs and the light ray travels through the glass. **(1)**

c) Endoscope, periscope **(2)**

6. a)



(5)

b) Bright and dark fringes on a screen **(1)**

c) Bright fringe – constructive interference occurs **(1)**
– two crests meet **(1)**
– resultant amplitude is twice that of either wave **(1)**
Dark fringe – destructive interference occurs **(1)**
– a crest and a trough meet **(1)**
– the resultant amplitude is zero **(1)**

d) Light spreads out beyond the double slits and causes the two sets of waves to overlap and interfere. **(1)**

7. a) $n = \frac{v_1}{v_2}$ **(1)**
$= \frac{3.0 \times 10^8}{1.9 \times 10^8}$ **(1)**
$= 1.58$ **(1)**

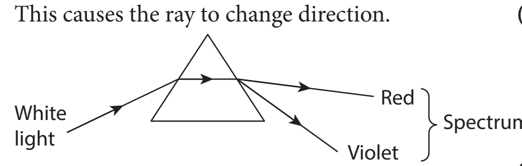
b) $f = \frac{v}{\lambda}$ **(1)**
$= \frac{3.0 \times 10^8}{1.2 \times 10^{-6}}$ **(1)**
$= 2.5 \times 10^{14}$ Hz **(1)**

c) $\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ **(1)**
$\frac{3.0 \times 10^8}{1.9 \times 10^8} = \frac{1.2 \times 10^{-6}}{\lambda_2}$
$\lambda_2 = \frac{(1.9 \times 10^8 \times 1.2 \times 10^{-6})}{3.0 \times 10^8}$ **(1)**
$\lambda_2 = 7.6 \times 10^{-7}$ m **(1)**

d) ${}_a n_g = \frac{\sin i}{\sin r}$ **(1)**
$\frac{1}{1.5} = \frac{\sin 30°}{\sin r}$ **(1)**
$\sin r = \sin 30° \times 1.5$
$\sin r = 0.75$
$r = 48.6°$ **(1)**

e) Speed of light decreases from air to glass. **(1)**
This causes the ray to change direction. **(1)**

f)

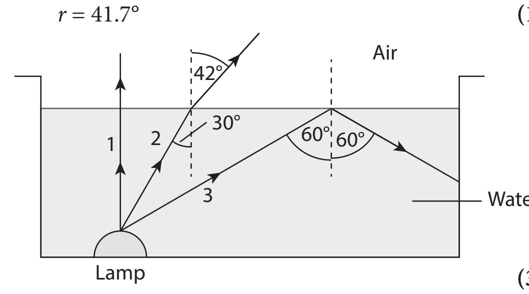


(3)

8. a) The refractive index $= \frac{1}{\sin C}$ where C is the critical angle **(1)**
$1.33 = \frac{1}{\sin C}$ **(1)**
$\sin C = \frac{1}{1.33}$
$\sin C = 0.752$
$C = 48.8°$ **(1)**

b) ${}_a n_w = 1.33$
${}_w n_a = \frac{1}{1.33} = 0.752$ **(1)**
${}_w n_a = \frac{\sin i}{\sin r}$
$0.752 = \frac{\sin 30°}{\sin r}$ **(1)**
$\sin r = \frac{\sin 30°}{0.752}$
$\sin r = 0.665$
$r = 41.7°$ **(1)**

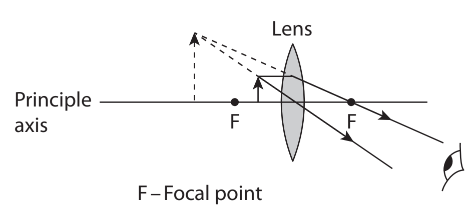
c)



(3)

C5 Lenses

1. a)



(4)

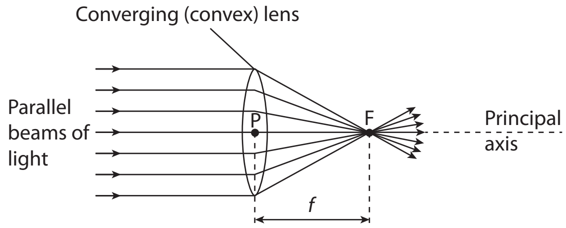
b) Virtual **(1)**

2. a) $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ **(1)**
$\frac{1}{f} = \frac{1}{12} + \frac{1}{4}$ **(1)**
$\frac{1}{f} = \frac{1}{3}$
$f = 3$ cm **(1)**

b) Magnification $= \frac{v}{u}$ **(1)**
$= \frac{4}{12}$ **(1)**
$= \frac{1}{3}$ **(1)**

c) Height of image = magnification × object height **(1)**
$= \frac{1}{3} \times 2.5$ **(1)**
$= 0.833$ cm **(1)**

3.



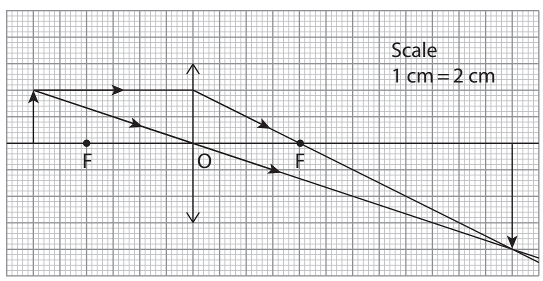
Principle axis – horizontal line passing through optical centre of lens **(1)**

F – focal point **(1)**

f – focal length **(1)**

P – Optical centre **(1)**

4. a)



i) image distance = 24 cm **(1)**
ii) height of image = 8 cm **(1)**
iii) magnification = $\frac{v}{u} = \frac{8}{4} = 2$ **(1)**

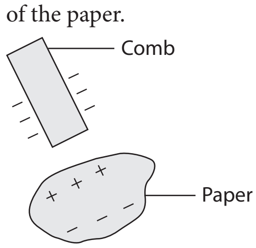
b) A projector **(1)**

D1 Electrostatics

1. a) Friction causes electrons to flow from the cloth to the polythene rod. **(1)**
The polythene rod has an excess of electrons. **(1)**
The cloth loses electrons and become positively charged. **(1)**

b) Friction causes electrons to flow from the perspex rod to the cloth. **(1)**
The cloth has an excess of electrons. **(1)**
The perspex rod loses electrons and becomes positively charged. **(1)**

c) Rubbing the pen charges it. **(1)**
The charged pen polarizes the molecules in the paper. **(1)**
Electrons move away from one side of the paper to opposite end. **(1)**
One end becomes positively charged and the other end becomes negatively charged.
The end of the pen closest to the paper attracts the paper because it has a charge opposite to that of the paper. **(1)**



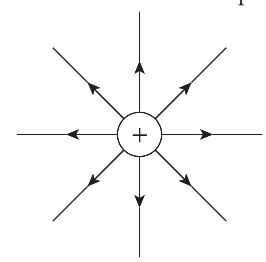
d) i) B to A **(1)**

ii) $Q = It$ **(1)**
$= 4 \times 10^{-6} \times 2 \times 10^{-3}$ **(1)**
$= 8 \times 10^{-9}$ C **(1)**

iii) $n = \frac{Q}{e}$ **(1)**
$= \frac{8 \times 10^{-9}}{1.6 \times 10^{-19}}$ **(1)**
$= 5 \times 10^{10}$ electrons **(1)**

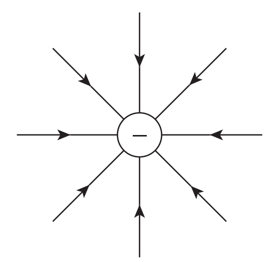
2. a) The region around a charged body **(1)**
where an electric force is experienced **(1)**

b) i)



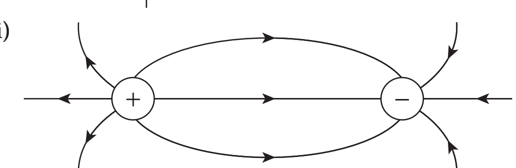
(3)

ii)



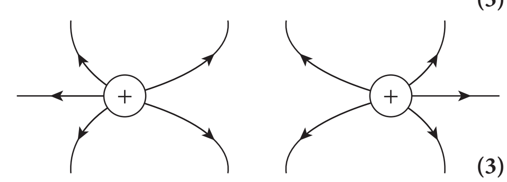
(3)

iii)



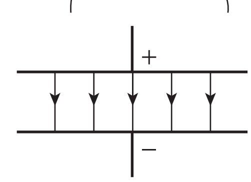
(3)

iv)



(3)

v)



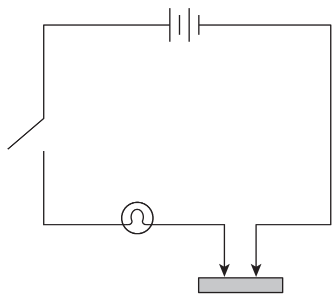
(3)

c) Hazard – electric shock/injury/death **(1)**
Use – electrostatic spraying/photocopying/dust extraction **(1)**

D2 Current electricity

1. a) A conductor conducts electricity. **(1)**
An insulator does not conduct electricity. **(1)**

b) Conductors – iron nail, graphite rod **(2)**
Insulators – plastic spoon, piece of rubber **(2)**

c) 

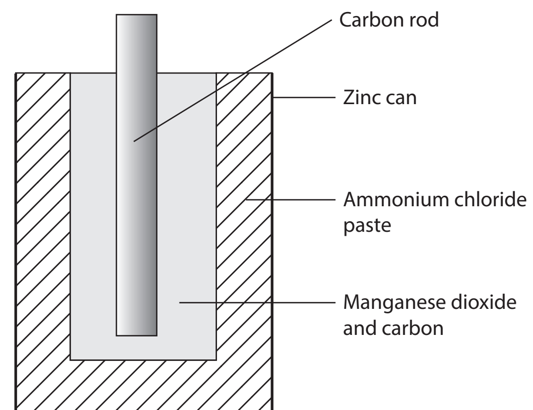
(4)

2. a) The flow of charge (1)
   b) Coulomb (1)
   c) A copper wire – electrons (1)
   A sodium chloride solution – sodium ions and chloride ions (2)
3. a) $Q = It$ (1)
   $= 2.5 \times 10^{-3} \times 2 \times 60$ (1)
   $= 0.3$ C (1)
   b) $n = \frac{Q}{e}$ (1)
   $= \frac{0.3}{1.6 \times 10^{-19}}$ (1)
   $= 1.88 \times 10^{18}$ (1)
4. a) Alternating currents reverse direction regularly with time. (1)
   Direct currents flow in one direction. (1)
   b) i) Direct current (1)
   ii) Direct current (1)
   iii) Alternating current (1)
5. a) Period: 20 ms (1)
   Peak value: 2.5A (1)
   b) Frequency $= \frac{1}{\text{Period}}$
   Period $= 2 \times 10^{-2}$
   $f = \frac{1}{T}$
   $= \frac{1}{20 \times 10^{-3}}$
   $= 50$ Hz (3)

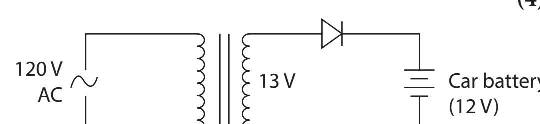
D3 Electrical quantities

1. a) Potential difference is the work done in moving each unit of electrical charge across the conductor $\left(V = \frac{W}{Q}\right)$ (1)
   per unit Coulomb of charge $\left(V = \frac{W}{Q}\right)$ (1)
   b) Volt (1)
   c) $P = IV$ (1)
   $= 8 \times 220$ (1)
   $= 1760$ W (1)
   d) i) $I = \frac{P}{V}$ (1)
   $= \frac{650}{220}$ (1)
   $= 2.95$ A (1)
   ii) $E = P \times t$ (1)
   $= 650 \times 5 \times 60$ (1)
   $= 1.95 \times 10^5$ J (1)
2. a) $P = IV$ (1)
   $= 0.4 \times 6.0$ (1)
   $= 2.4$ W (1)
   b) $E_p = mgh$ (1)
   $= 0.60 \times 10 \times 1.5$ (1)
   $= 9$ J (1)
   c) $P = \frac{W}{t}$ (1)
   $= \frac{9}{20}$ (1)
   $= 0.45$ W (1)
   d) Efficiency $= \left(\frac{\text{Power output}}{\text{Power input}}\right) \times 100$ (1)
   $= \left(\frac{0.45}{2.4}\right) \times 100$ (1)
   $= 18.8$ % (1)
3. a) $Q = It$ (1)
   $= 0.1 \times 20$ (1)
   $= 2$ C (1)
   b) $V = \frac{W}{Q}$ (1)
   $= \frac{240}{2}$ (1)
   $= 120$ V (1)

D4 Circuit components

1 a) 

(4)

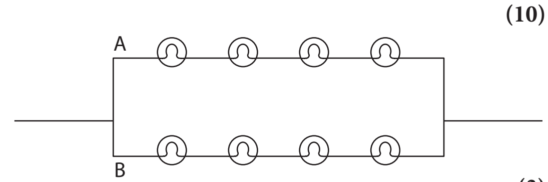
b) 

(4)

c)

	Zinc-carbon primary cell	**Lead-acid battery**
Terminal voltage	1.5 V	12.0 V
Maximum current	small	large
Internal resistance	high	low
Portability	small and light	large and heavy
Rechargeability	some can be recharged	can be recharged

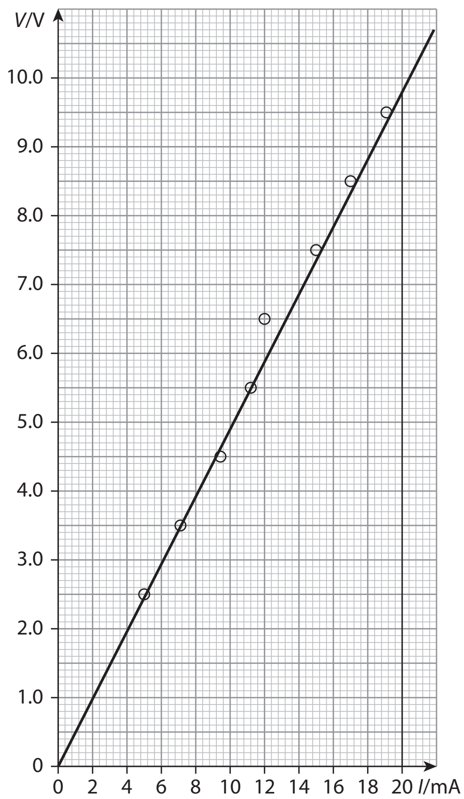
(10)

2. a) 

(3)

   b) All the lights in string A will not light. (1)
   c) All the lights in string A will continue lighting. (1)
   All the lights in string B will not light. (1)

3. a)



(8)

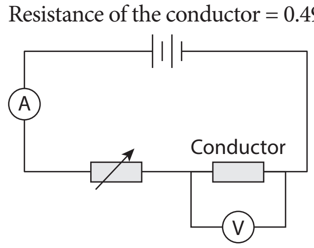
b) Slope $S = \frac{\Delta V}{\Delta I}$ **(1)**

$= \frac{9.8 - 0}{20 - 0}$ **(1)**

$= 0.49 \text{ VmA}^{-1}$ **(1)**

Resistance of the conductor $= 0.49 \times 10^3 = 490\ \Omega$ **(1)**

c)



(4)

Steps

1. Set up the circuit diagram shown.
2. Record the current *I* and the potential difference *V*. (1)
3. Change the current flowing in the circuit by adjusting the variable resistor. (1)
4. Record the new current *I* and potential difference *V*. (1)
5. Repeat steps 3 and 4 to obtain a series of readings. (1)

4. a) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ **(1)**

$\frac{1}{R_T} = \frac{1}{5} + \frac{1}{5}$ **(1)**

$\frac{1}{R_T} = \frac{2}{5}$ **(1)**

$R_T = \frac{5}{2} = 2.5\ \Omega$ **(1)**

b) $R_T = R_1 + R_2$ **(1)**

$= 10 + 2.5$ **(1)**

$= 12.5\ \Omega$ **(1)**

c) $I = \frac{V}{R}$ **(1)**

$= \frac{4.5}{12.5}$ **(1)**

$= 0.36$ A **(1)**

d) $V = IR$ **(1)**

$= 0.36 \times 10$ **(1)**

$= 3.6$ V **(1)**

e) $V_{BC} = 4.5 - 3.6 = 0.9$ V **(1)**

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

$= \frac{0.9}{5}$

$= 0.18$ A **(1)**

5. a) An ammeter is connected in series with the component. **(1)**
It will affect the magnitude of the current being measured. **(1)**
Its resistance must be as close to zero as possible. **(1)**

b) A voltmeter is connected in parallel with the component. **(1)**
Current will flow through the voltmeter and affect the potential difference being measured. **(1)**
Its resistance should therefore be very large. **(1)**

6. a) 1. Independent use of each appliance. **(1)**
2. If one appliance goes faulty, all the rest will continue working. **(1)**

b) Live, neutral and ground (Earth) **(3)**

c) A fuse is connected to the live wire. **(1)**
An electrical fault may cause a large current to flow. **(1)**
The fuse blows and stops the current from flowing. **(1)**

d) The earth wire has a low resistance and allows a path of least resistance to the ground. **(1)**
It is usually connected to the frame of the appliance.
If a live wire touches the frame, a large current flows to Earth and causes the fuse to blow. **(1)**

e) i) $I = \frac{P}{V}$ **(1)**

$= \frac{1100}{120}$ **(1)**

$= 9.2$ A **(1)**

ii) $I = \frac{P}{V}$ **(1)**

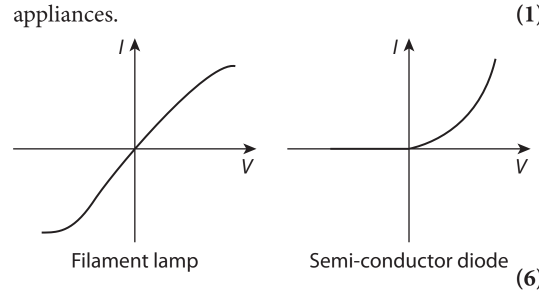
$= \frac{120}{120}$ **(1)**

$= 1$ A **(1)**

iii) Electric iron – 10 A **(1)**
TV – 2A **(1)**

f) Large currents can damage electrical components in appliances. **(1)**
Low currents can cause devices not to function as intended. **(1)**
Fluctuating currents can cause electrical fires in appliances. **(1)**

7. a)

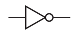
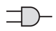
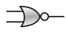


(6)

b) Resistance increases as current increases. **(1)**

D5 Electronics

1. a)

Logic Gate	Symbol
Not	
And	
Nor	

b) AND Gate

A	B	
0	0	0
0	1	0
1	0	0
1	1	1

(3)

NOR Gate

A	B	
0	0	1
0	1	0
1	0	0
1	1	1

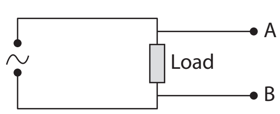
(3)

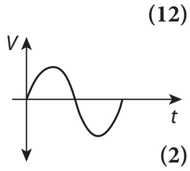
b)

A	B	C	D	E
0	0	0	1	1
0	1	0	0	0
1	0	0	1	1
1	1	1	0	1

(12)

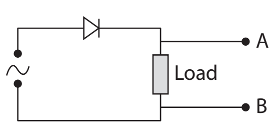
2. a) i)

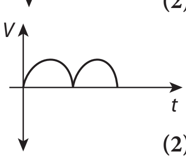




(2)

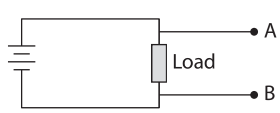
ii)

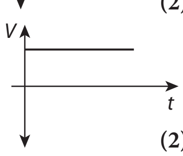




(2)

iii)





(2)

b) Both are direct currents **(1)**

3.

A	B	C	x	y	z
0	0	0	0	0	0
0	1	0	0	0	0
1	0	0	0	0	0
1	1	0	0	0	0
0	0	1	0	0	0
0	1	1	0	1	1
1	0	1	1	0	1
1	1	1	1	1	1

(12)

The alarm sounds when: **(3)**

1. The pressure is greater than 200 kPa, the temperature is less than 500 °C and the flow rate is greater than 10^3 m^3s^{-1}
2. The temperature is greater than 500 °C, pressure is less than 200 kPa and the flow rate is greater than 10^3 m^3s^{-1}
3. The temperature is greater than 500 °C and the pressure is greater than 200 kPa and the flow rate is greater than 10^3 m^3s^{-1}

4. Electronic devices continue to get smaller as technology advances. **(1)**
Logic gates and microprocessors are found in many electronic devices (laptops, smart phones, washing machine, toys). **(1)**
These electronic devices makes everyday tasks much easier (microwave cooking, washing, drying, cable TV, Internet). **(1)**
Any reasonable attempt to explain the impact of advances in technology.

D6 Magnetism

1. a) A magnetic material is one that is attracted by a magnet. **(1)**
A non-magnetic material is one that is not affected by a magnet. **(1)**

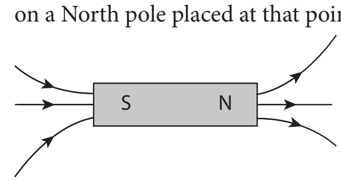
b) The paper clip is metallic. **(1)**
When the magnet is brought close to the un-magnetized material
the dipoles (tiny magnets) in the material align themselves. **(1)**
Opposite poles attract (one end of a dipole and one end of the magnet).

c) Permanent magnet – steel and magnadur **(2)**
Temporary magnet – iron and mumetal **(2)**

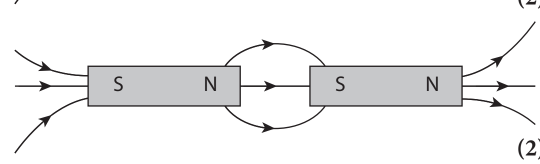
2. a) The region around a magnet **(1)**
where a force is experienced. **(1)**

b) The direction of the force acting **(1)**
on a North pole placed at that point in the field. **(1)**

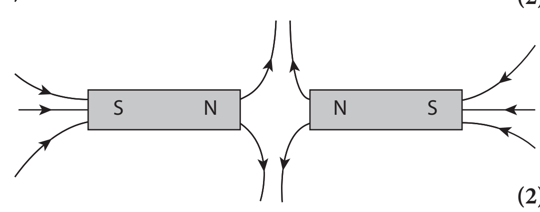
c)



(2)



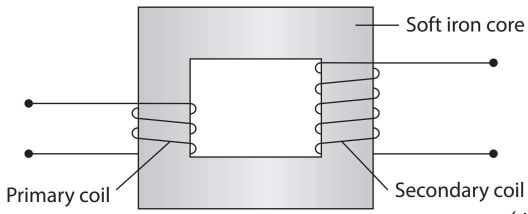
(2)



(2)

D7 Electromagnetism

1 a)



(4)

b) Core is made of soft iron. (1)
Core is laminated. (1)
Coils are made of thick copper wires. (1)

c) The alternating current in the primary coil sets up an alternating magnetic field. (1)
The secondary coil is situated in the changing magnetic field. (1)
According the Faraday's law an e.m.f. is induced in the secondary coil. (1)
If the secondary coil is connected to a load, a current flows through it. (1)

d) i) $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ (1)

$\frac{120}{1.2 \times 10^3} = \frac{200}{N_s}$ (1)

$N_s = \frac{200 \times 1.2 \times 10^3}{120}$

$N_s = 2000$ (1)

ii) $I_p V_p = I_s V_s$ (1)

$I_p \times 120 = 0.4 \times 1.2 \times 10^3$ (1)

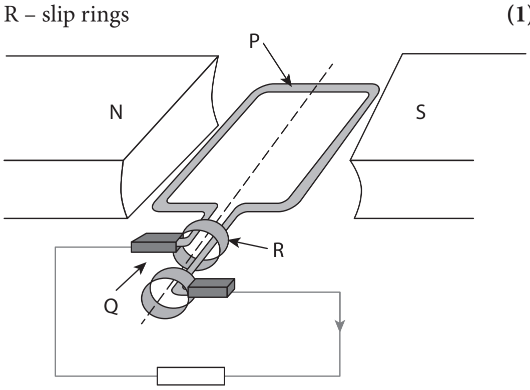
$I_p = \frac{(0.4 \times 1.2 \times 10^3)}{120}$

$I_p = 4$ A (1)

iii) Transformers can step up and step down voltages easily, but operate using AC. (1)
For a given power, if the transmission voltage is high, the current can be low. (1)
This means that there are less power losses in the transmission lines ($P = I^2R$). (1)

2. a) P – coil (1)
Q – brushes (1)
R – slip rings (1)

b)



(1)

c) When the coil moves inside the magnetic field, there is relative motion between the conductor and the field. (1)
An e.m.f is induced in the coil (Faraday's law). (1)
Since there is a closed circuit, a current flows through the resistor. (1)

d) $I = \frac{V}{R}$ (1)

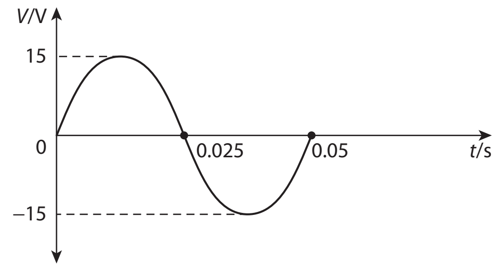
$= \frac{15}{5}$ (1)

$= 3$ A (1)

e) $T = \frac{1}{f}$ (1)

$= \frac{1}{20}$

$= 0.05$ s (1)



(5)

f) Increase the speed of rotation of the coil (1)
Use more powerful magnets (1)

3. a) i) Galvanometer needle deflects (1)
in a particular direction. (1)

ii) Galvanometer needle returns to the zero position. (1)

iii) Galvanometer needle deflects (1)
in the opposite direction. (1)

b) i) Galvanometer needle stays at the zero position. (1)

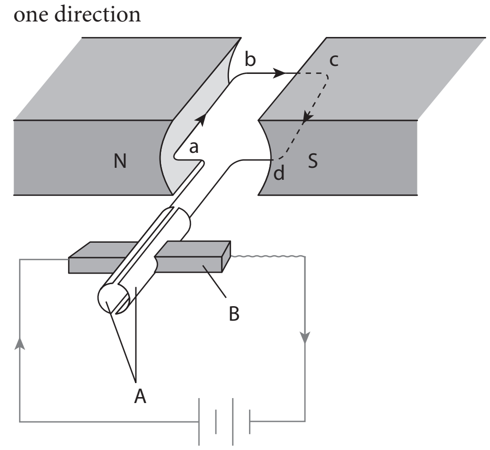
ii) Galvanometer needle deflects left and right about the zero position. (1)

iii) Galvanometer needle deflects left and right about the zero position (1)
but the magnitude of the deflection is greater than in b(ii). (1)

4. a) A – split ring commutator (1)
B – brushes (1)

b) To allow for the current flowing in the coil to reverse direction so that the coil moves in only one direction (1)

c)



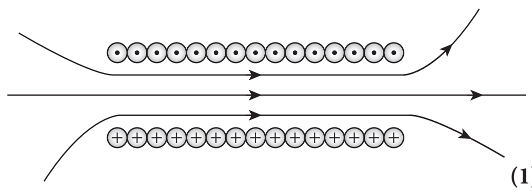
(1)

d) Current flows from a to b.
The wire ab experiences a downward force according to Fleming's left-hand rule. (1)
Current flows from c to d.
The wire cd experiences an upward force according to Fleming's left-hand rule. (1)
The forces acting on ab and cd produce a couple (1)
and cause the coil to rotate in an anticlockwise direction. (1)

The inertia of the coil causes it to continue moving past the vertical position. **(1)**
The split ring commutator reverses the direction of the current flowing in the coil and causes the coil to rotate in one direction. **(1)**

e) *Any two from:*
1. Increase the current flowing through the coil **(1)**
2. Increase the strength of the magnetic field **(1)**
3. Increase the number of turns of wire in the coil **(1)**

5. a)



(1)

b) A – Insulation **(1)**
B – Contacts **(1)**
C – Armature **(1)**
D – Electromagnet **(1)**
E – Coil **(1)**

c) When a current flows in the coil E **(1)**
the electromagnet is energized. **(1)**
The electromagnet pulls the armature C towards D. **(1)**
The contact B closes and **(1)**
the secondary circuit is now closed. **(1)**

6. a) The magnetism in an electromagnet can be turned on and off. This is not so for a permanent magnet. **(1)**

b) Magnetic relay, electric bell etc. **(1)**

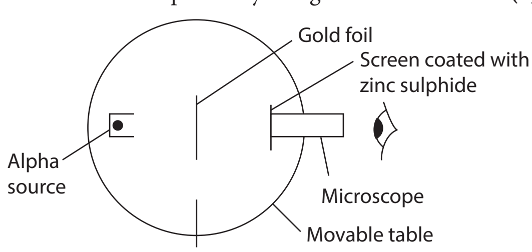
c) Increase the current flowing through the coil **(1)**
Increase the number of turns used to make the electromagnet **(1)**

E1 Models of the atom

1. a) Plum pudding model **(1)**
The atom is a positively charged sphere **(1)**
in which electrons are distributed to make the atom electrically neutral. **(1)**

b) Electrons orbit a positively charged nucleus **(3)**

c)



Experiment is set up as shown in the diagram. **(1)**
Alpha particles are projected towards a thin sheet of gold foil. **(1)**
The alpha particles are viewed through a microscope. The slide/screen on the microscope is coated with zinc sulphide. **(1)**
An alpha particle is seen as a flash of light on the screen.

Observations
1. Most of the alpha particles passed through the gold foil. **(1)**
2. Some alpha particles were deflected. **(1)**
3. Some alpha particles returned to the source. **(1)**

Conclusion
1. Most of the atom is empty space. **(1)**
2. The nucleus is very small and positively charged. **(1)**

E2 Structure of the atom

1. a) i) Atomic number is the number of protons inside the nucleus of an atom. **(1)**

ii) Mass number is the total number of protons and neutrons inside the nucleus. **(1)**

iii) Neutron number is the number of neutrons inside the nucleus of an atom. **(1)**

b)

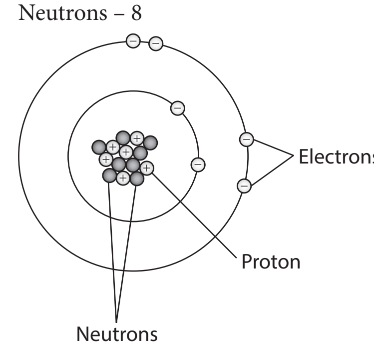
Particle	Location	Relative Mass	Relative Charge
Electron	orbiting the nucleus	$\frac{1}{1840}$	−1
Proton	inside the nucleus	1	+1
Neutron	inside the nucleus	1	0

(6)

c) Shell model shows the arrangement of electrons and gives the exact position in the periodic table (period and group) **(1)**

d) i) Electrons – 6 **(1)**
Protons – 6 **(1)**
Neutrons – 8 **(1)**

ii)



(5)

e) i) Isotope – atoms of an element that have the same atomic number **(1)**
but different mass number **(1)**

ii)

	Sodium-23	Sodium-24
Number of electrons	11	11
Number of protons	11	11
Number of neutrons	12	13

(6)

iii) $^{25}_{11}Na$ **(1)**

E3 Radioactivity

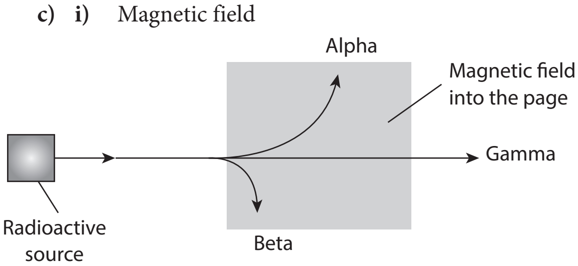
1. a)

Type of radiation	Nature of the radiation	Charge	Stopped by
Alpha-particle	helium nuclei 2 protons and 2 neutrons	+2	a few cm of paper
Beta-particle	fast-moving electron	−1	a few mm of aluminium
Gamma ray	electromagnetic wave	0	a few metres of concrete

(9)

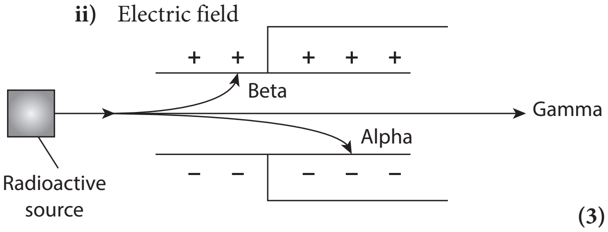
b) Alpha – short and thick tracks of equal length (3)
Beta – thinner tracks of variable length (2)

c) i) Magnetic field



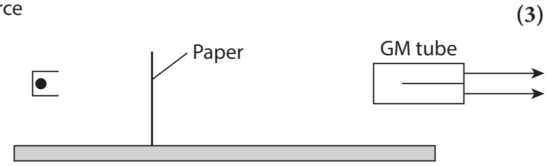
(3)

ii) Electric field



(3)

d)



Apparatus – GM tube, alpha source, beta source, metre rule, sheets of paper, sheets of aluminium (1)
Place source on a solid surface and place the GM tube in front of the source. (1)
Place a metre rule between the source and the GM tube. (1)
Place a sheet of paper/sheet of aluminium between the source and the GM tube and record the variation in count rate. (1)

2. a) i) A radioisotope is an isotope of an element that is unstable and (1)
emits one or more of the following – alpha particles, beta particles or gamma rays. (1)

ii) The half-life of a radioactive isotope is the average time taken for the activity (or number of atoms) to decrease by half its initial value. (2)

b) Radiotherapy – cancer treatment (1)
Tracers – detecting leaks/thyroid function (1)
Carbon dating (1)

c) i) Number of half-lives = $\frac{24}{8} = 3$ (1)
8000 ⟶ 4000 ⟶ 2000 ⟶ 1000 Bq (1)
Activity of sample after 3 half-lives = 1000Bq (1)

ii) 8000 ⟶ 4000 ⟶ 2000 ⟶ 1000 ⟶ 500 Bq (1)
Elapsed time = 4 half-lives (1)
Elapsed time = 4 × 8 = 32 days (1)

iii) Statement is incorrect. (1)
Radioactive decay is independent of factors external to the nucleus, therefore heating has no effect. (1)

3. a) E – energy (1)
m – mass defect (1)
c – speed of light (1)

b) *For:*
1. More energy per gram than fossil fuel of equivalent mass (2)
2. Fossil fuels can be used for other purposes (e.g. detergents/plastics etc.) (2)

Against:
1. Disposal of radioactive waste material is challenging. It is dangerous to the environment. (2)
2. Risk of radioactive disasters/nuclear meltdown (2)

c) mass on left-hand side = 235.0439 + 1.0087
= 236.0526 u (1)
mass on right-hand side = 89.9195 + 143.9230 + (2 × 1.0087) = 235.8599 u (1)
mass defect = 236.0526 − 235.8599 = 0.1927 u (1)
mass defect in kg = $0.1927 \times 1.66 \times 10^{-27}$
$= 3.19882 \times 10^{-28}$ kg (1)
$E = mc^2$ (1)
$= 3.19882 \times 10^{-28} \times (3.0 \times 10^{8})^2$ (1)
$= 2.8789 \times 10^{-11}$ J (1)

4. a) Use forceps to handle sample (1)
Always point sample away from body (1)
Sample should be kept in a sealed box when not in use (1)

b) 50 ⟶ 25, t = 19 min (1)
40 ⟶ 20, t = 21 min (1)
20 ⟶ 10, t = 20 min (1)
Average half-life of sample $B = \frac{(19 + 21 + 20)}{3}$
= 20 min

c) Radioactive decay is a random process. (1)

d) Sample A has a long half-life when compared to sample B. (1)

e) No change in graph (1)
Radioactive decay is not unaffected by factors external to the nucleus (1)

5. a) $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ (2)

b) $^{228}_{88}Ra \rightarrow {}^{224}_{86}Rn + {}^{4}_{2}He$ (1)

$^{224}_{86}Rn \rightarrow {}^{220}_{84}Po + {}^{4}_{2}He$ (1)

$^{220}_{84}Po \rightarrow {}^{212}_{80}Pb + 2{}^{4}_{2}He$ (1)

$^{212}_{80}Pb \rightarrow {}^{212}_{81}Bi + {}^{0}_{-1}e$ (1)