YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAM
Higher 2

CANDIDATE NAME			
CG		INDEX NO	

PHYSICS 9749/01

Paper 1 Multiple Choice **19 September 2025**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.
Write your name, class and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

The document consists of **16** printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T / K	=	$T / ^\circ C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{\left(x_0^2 - x^2\right)}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + ...$
resistors in parallel,	$1 / R$	=	$1/R_1 + 1/R_2 + ...$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

1 What is the best estimate for the density of an average adult male?

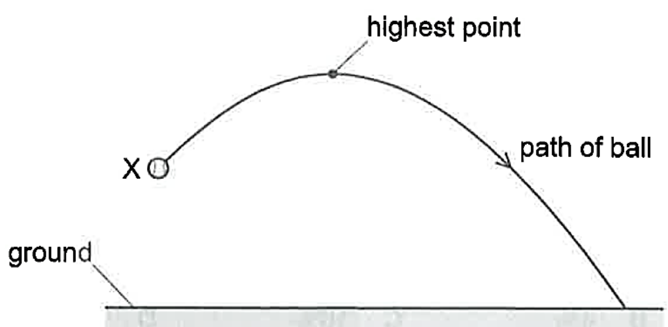
A 10^{-3} g cm^{-3} **B** 10^{0} g cm^{-3} **C** 10^{3} g cm^{-3} **D** 10^{6} g cm^{-3}

2 An aeroplane is stationary at one end of a runway. It accelerates uniformly and takes off 35 s later, having travelled a distance of 560 m.

What are the acceleration and take-off speed of the aeroplane?

	acceleration / m s^{-2}	take-off speed / m s^{-1}
A	0.46	16
B	0.46	32
C	0.91	16
D	0.91	32

3 A tennis ball is hit at point X and then follows the path shown.



The air resistance on the ball is negligible.

How is the ball moving at its highest point?

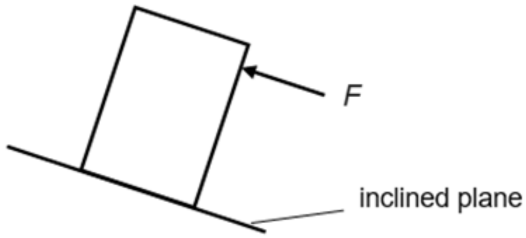
A It has zero velocity both vertically and horizontally.

B It has zero acceleration vertically and non-zero velocity horizontally.

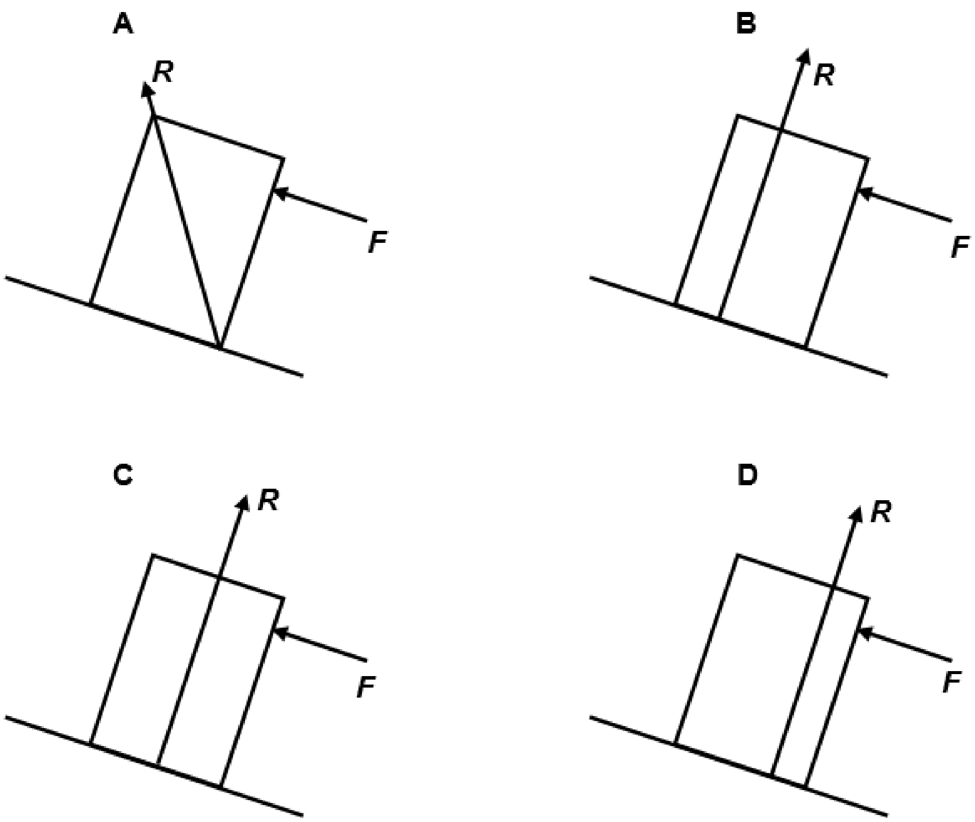
C It is accelerating vertically and has zero velocity horizontally.

D It is accelerating vertically and has non-zero velocity horizontally.

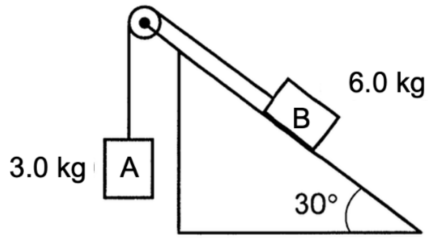
4 The figure below shows a uniform block resting on a smooth inclined plane, supported by a force *F* to prevent it from moving.



Which one of the following diagrams correctly shows the force *R* exerted by the inclined plane on the block?



5 Blocks A and B are connected by a light cord running over a frictionless, light pulley as shown below.



Which of the following statements is correct?

A Block A moves down with an acceleration of 9.81 m s^{-2}.

B Block A moves up with an acceleration of 3.27 m s^{-2}.

C Block B moves up the slope with an acceleration of 3.27 m s^{-2}.

D Blocks A and B do not experience any acceleration.

6 A car travels along a road at a constant speed of 25 m s^{-1}. Its power output is 30 kW. The total resistive force on the car is proportional to the square of its speed.

What power will be required for the car to travel at a constant speed of 40 m s^{-1}?

A 48 kW **B** 77 kW **C** 120 kW **D** 200 kW

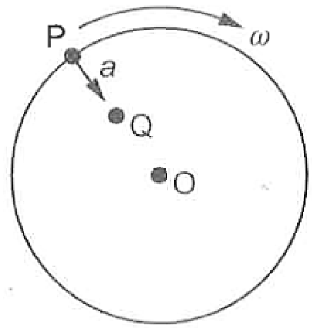
7 A small wind turbine contains a generator that is used to generate electricity. Every second, 10.7 kg of air arrives at its blades with a speed of 5.0 m s^{-1} and leaves the blades with a speed of 2.5 m s^{-1}.

The efficiency of the generator is 70%.

What could be the output potential difference (p.d.) and current of the turbine?

	p.d. / V	current / A
A	8.0	3.0
B	25	2.8
C	25	4.0
D	36	4.0

8 A disc of radius 6.0 cm rotates about its centre O. P is a point on the circumference and Q is halfway between O and P.

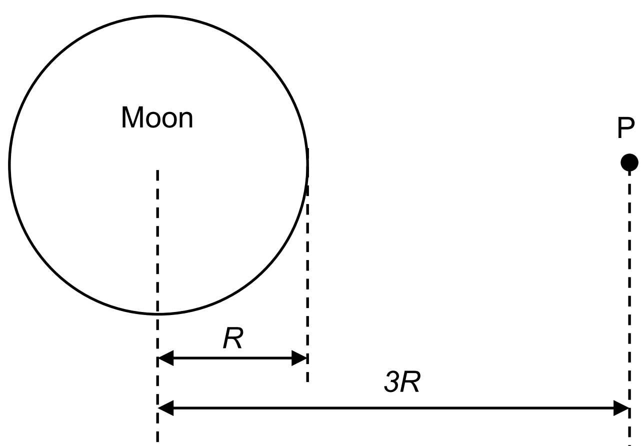


At Q, the angular velocity ω is 3.0 rad s^{-1} and the centripetal acceleration a is 27 cm s^{-2}.

Which row gives the values of these quantities at P?

	ω / rad s^{-1}	a / cm s^{-2}
A	3.0	27
B	3.0	54
C	6.0	110
D	6.0	220

9 A stationary object is released from a point P a distance 3*R* from the centre of the Moon which has a radius *R* and mass *M*.



Which one of the following expressions gives the speed of the object hitting the Moon?

A $\sqrt{\frac{4GM}{3R}}$ **B** $\sqrt{\frac{2GM}{R}}$ **C** $\sqrt{\frac{4GM}{R}}$ **D** $\sqrt{\frac{GM}{R}}$

10 The acceleration of free fall on the surface of the Earth is 6 times its value on the surface of the Moon.

The mean density of the Earth is $\frac{5}{3}$ times the mean density of the Moon.

What is the ratio of the radius of Earth to the radius of the Moon?

A 1.9 **B** 3.6 **C** 6.0 **D** 10

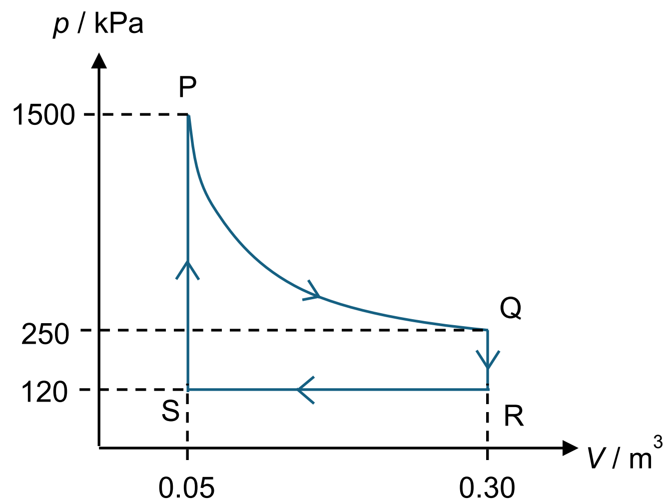
11 A container filled with an ideal gas is at a temperature of 100 °C. The root-mean-square (r.m.s.) speed of the gas molecules is 350 m s^{-1}.

The temperature of the gas is increased to 200 °C.

What is the new r.m.s. speed of the gas molecules?

A 394 m s^{-1} **B** 444 m s^{-1} **C** 495 m s^{-1} **D** 700 m s^{-1}

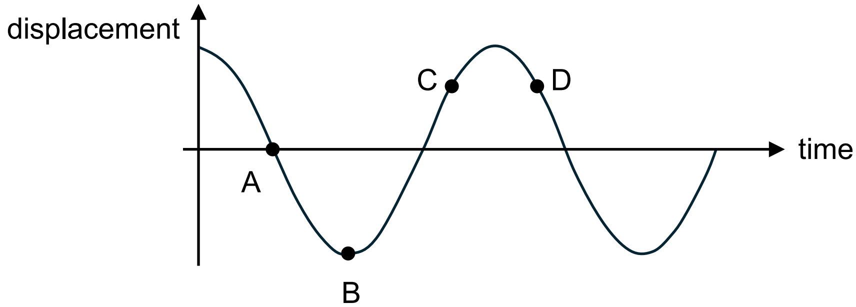
12 A sample of an ideal gas is taken through the cycle (P → Q → R → S → P) as shown below.



Given that the work done by the gas in process P → Q is 120 kJ, what is the net heat supplied to the gas in one cycle?

A −90 kJ **B** 0 J **C** 30 kJ **D** 90 kJ

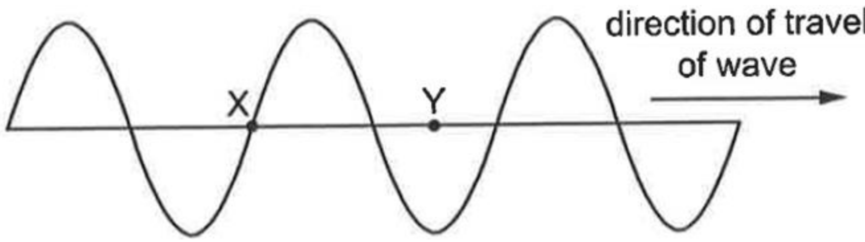
13 The diagram below shows a displacement – time graph of a body performing simple harmonic motion.



At which one of the points **A**, **B**, **C** or **D**, is the body travelling and accelerating in the same direction?

14 A transverse wave moves to the right.

X and Y are points in the path of the wave.



Which statement about the oscillations at X and at Y is correct?

A The oscillations at X and Y are in phase.

B The frequency of oscillations at X is greater than the frequency of oscillations at Y.

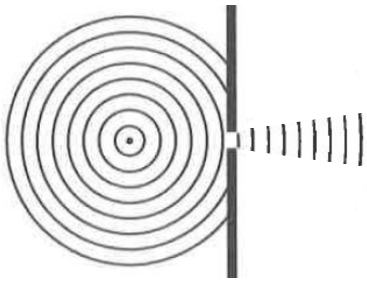
C The oscillations at X and Y have a phase difference of π rad.

D The oscillations at X and Y have the same period.

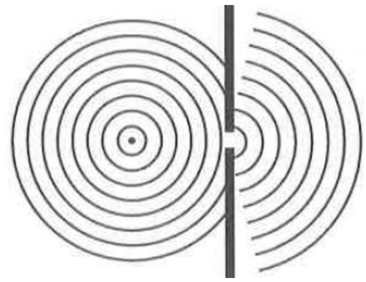
15 Water ripples on a ripple tank approach a narrow gap in a barrier. The width of the gap is equal to the wavelength.

Which diagram shows a possible pattern of the ripples after passing through the barrier?

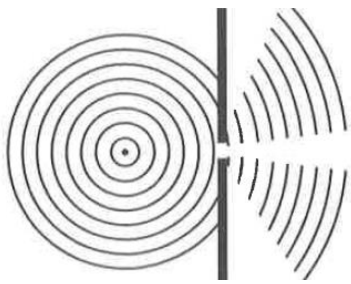
A



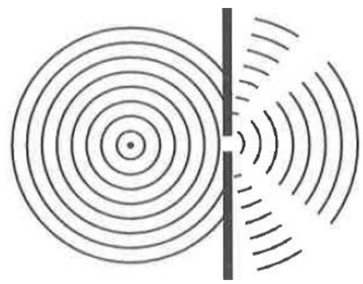
B



C



D



16 A beam of monochromatic light of wavelength 600 nm is incident normally on a diffraction grating that has 3.0×10^3 lines per centimetre.

What is the maximum number of bright fringes produced by light transmitted through this grating?

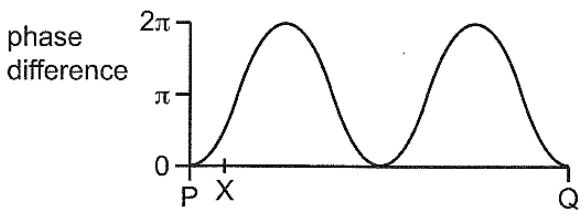
A 5 **B** 10 **C** 11 **D** 13

17 The diagram shows a stationary wave formed on a wire PQ at a given instant in time.

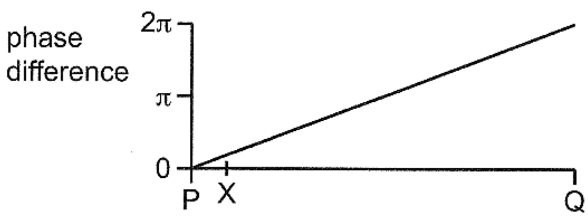
The phase difference is measured between point X and different points on the wire.

Which graph represents the variation of this phase difference with distance along the wire?

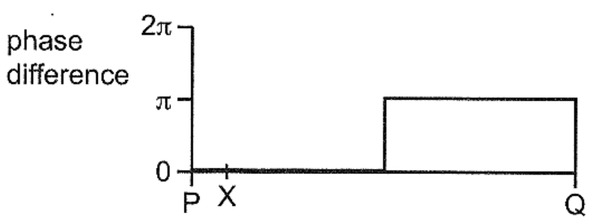
A



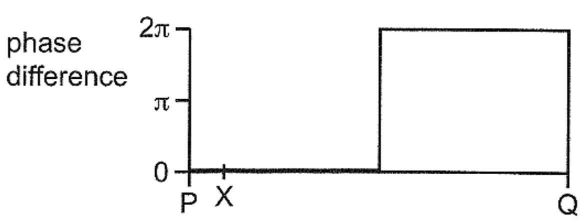
B



C



D



18 Electric field strength is defined as force per unit positive charge on a small test charge.

Why is it necessary for the test charge to be small?

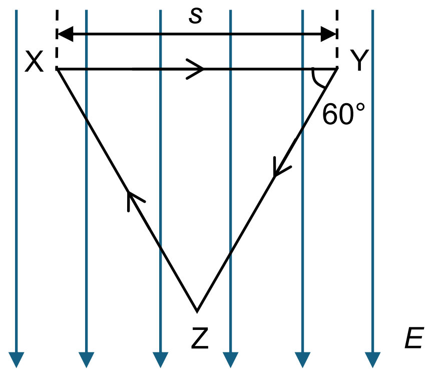
A So that the test charge does not distort the electric field

B So that the force on the test charge is small

C So that the test charge does not create any forces on nearby charges

D So that Coulomb's law for point charges is obeyed

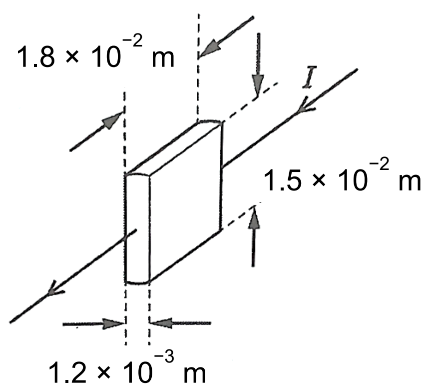
19 The diagram below shows three points X, Y and Z forming an equilateral triangle of side *s* in a uniform electric field of strength *E*. A unit positive test charge is moved from X to Y, from Y to Z and from Z back to X.



Which of the following correctly gives the work done against electrical forces in moving the charge along the various parts of this path?

	X to Y	Y to Z	Z to X
A	0	– *Es* cos 60°	+ *Es* cos 60°
B	+ *Es*	+ *Es* sin 60°	– *Es* sin 60°
C	0	+ *Es* sin 60°	– *Es* sin 60°
D	0	– *Es* sin 60°	+ *Es* sin 60°

20 A current of 30 mA passes through a slice of semi-conducting material of dimensions as shown.

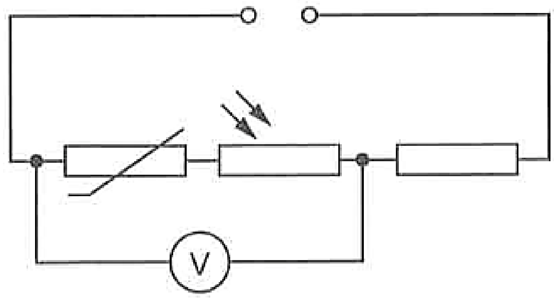


The slice dissipates 300 mW of heat energy.

What is the resistivity of the semiconductor under these conditions?

A 0.010 Ω m **B** 0.33 Ω m **C** 75 Ω m **D** 380 Ω m

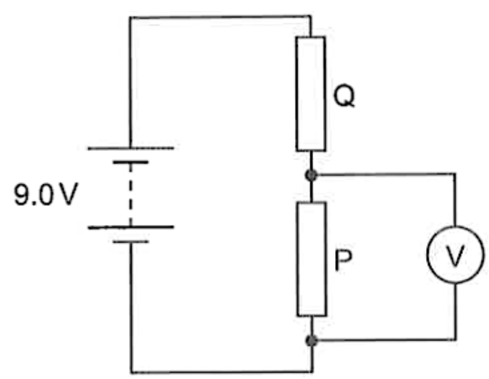
21 A NTC thermistor, a LDR and a fixed resistor are connected in series to a power supply. A voltmeter is placed across the thermistor-LDR combination.



Which conditions of brightness and temperature will produce the smallest reading on the voltmeter?

	temperature	**brightness**
A	high	high
B	high	low
C	low	high
D	low	low

22 Two resistors, P and Q, are connected in series to a 9.0 V battery with negligible internal resistance.



The resistance of the voltmeter is equal to the resistance of P.

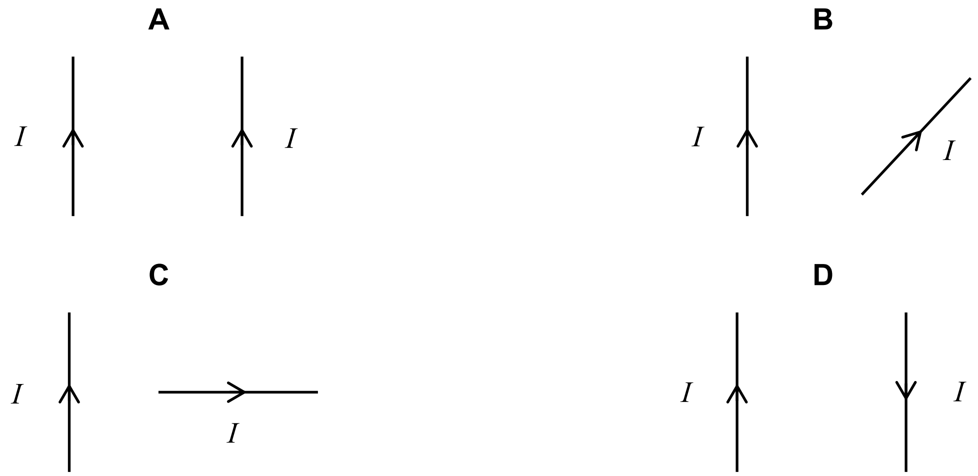
The reading on the voltmeter is 6.0 V.

What is the value of the ratio $\dfrac{\text{resistance of the voltmeter}}{\text{resistance of Q}}$?

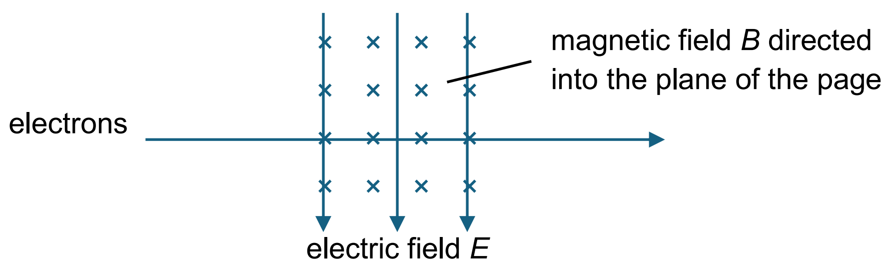
A 0.50 **B** 0.25 **C** 2.0 **D** 4.0

23 In each diagram, two wires are shown, each carrying a constant current I.

In which diagram will the force between the wires, due to the currents, be zero?



24 A beam of electrons enters a region in which there are magnetic and electric fields directed at right angles. It passes straight through without deviation.



A second beam of electrons travelling twice as fast as the first is directed along the same line.

How is this second beam deviated?

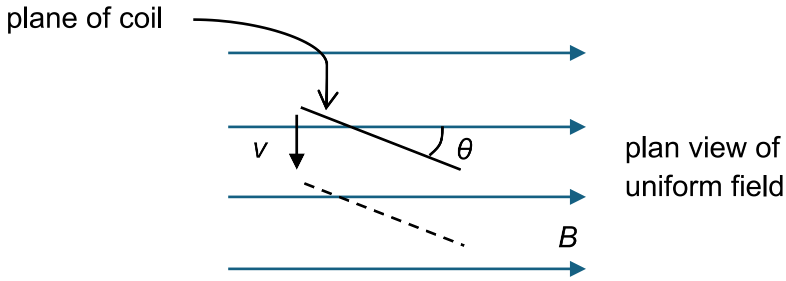
A downwards in the plane of the paper

B upwards in the plane of the paper

C out of the plane of the paper

D into the plane of the paper

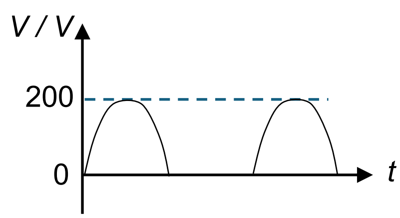
25 A plane coil of wire containing *N* turns each of area *A* is placed so that the plane of the coil makes an angle θ with the direction of a uniform magnetic field of flux density *B*. The coil is now moved with a velocity *v* downwards as shown.



What is the e.m.f. induced in the coil?

A zero **B** *NABv* **C** *NABv* cos θ **D** *NABv* sin θ

26 Half-wave rectification of an alternating sinusoidal voltage of amplitude 200 V gives the waveform as shown.



What is the r.m.s voltage?

A 70.7 V **B** 100 V **C** 141 V **D** 200 V

27 A source of electromagnetic radiation emits photons. The intensity is measured at a fixed point near the source. The wavelength of the radiation is then gradually increased but the rate at which photons are emitted remains constant.

Which statement explains the effect this has on the measured intensity?

A Photon energy decreases and intensity decreases.

B Photon energy decreases and intensity increases.

C Photon energy decreases and intensity remains constant.

D Photon energy increases and intensity increases.

28 In a X-ray tube operating at 20 kV, the accelerating electrons hit the target material to produce X-rays.

What is the ratio of the de Broglie wavelength of the incident electrons to the cut-off wavelength of the X-rays produced?

A 0.0044 **B** 0.14 **C** 7.1 **D** 230

29 Antimony-124 undergoes radioactive decay, with a half-life of 60 days, to become tin-124, which is stable.

Initially a sample of antimony-124 contains no tin-124.

How long would have passed for the ratio of number of tin-124 nuclei to number of antimony-124 nuclei to be 5?

A Between 60 days and 120 days

B 120 days

C Between 120 days and 180 days

D More than 180 days

30 During a single fission event of uranium-235 in a nuclear reactor, the total mass lost is 0.231 u.

The reactor is 25% efficient.

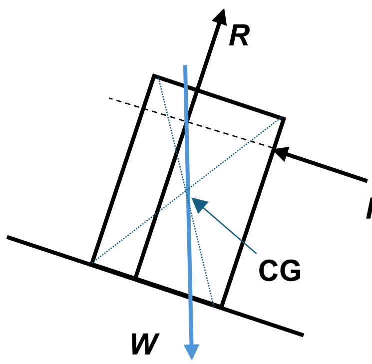
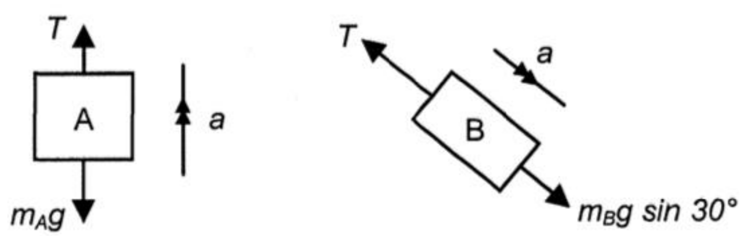
How many events per second are required to generate 900 MW of power?

A 1.0×10^{14} **B** 2.6×10^{19} **C** 1.0×10^{20} **D** 4.4×10^{20}

2025 JC2 Preliminary Examinations

H2 Physics Paper 1 Solutions

Qn	Answer	Explanation
1	**B**	Mass of an average male adult ~ 80 kg Average height ~170 cm Average width ~40 cm Average "thickness" ~20 cm $\text{density} = \dfrac{80 \times 1000}{(170)(50)(20)} = 0.6 \text{ g cm}^{-3} \approx 1 \text{ g cm}^{-3}$ OR The human body is mainly made up of water. And density of water is 1 g cm^{-3}. A human float just barely on water. So it is about the same density as water.
2	**D**	$s = ut + \frac{1}{2}at^2$ $560 = 0 + \frac{1}{2}a(35)^2$ $a = 0.91 \text{ m s}^{-2}$ $v = u + at$ $= 0 + (0.914)(35)$ $= 32 \text{ m s}^{-1}$
3	**D**	Option A is incorrect because at highest point, it has zero velocity vertically but still has non-zero horizontally. Option B is incorrect because the ball has non-zero vertical acceleration throughout the whole motion. In fact, the value of this vertical acceleration is g and is pointing downwards. Option C is incorrect as it is accelerating vertically throughout the whole motion including the highest point. The value of this vertical acceleration is g. But it has non-zero horizontal velocity. Option D is correct as it is accelerating vertically throughout the whole motion including the highest point. It has non-zero horizontal velocity throughout the whole motion, including the highest point.

4	**B**	There are three forces acting concurrently on the block. Besides R and F, the weight W of the block acts at the CG. The CG is determined by the intersection of the diagonals. By extending the lines of action of the three forces, they must intersect at the same point. The other options do not satisfy this. 
5	**D**	Let the tension in the cord be T and the acceleration of both blocks be a.  For A: $F_{net} = T - m_Ag = m_Aa$ $T = 3.0(a+g)$ For B: $F_{net} = T - m_Bg\sin 30° = m_Ba$ $T = 6.0(a+0.5g)$ Combining both equations $3.0(a+g) = 6.0(a+0.5g)$ $3a + 3g = 6a + 3g$ $a = 0$
6	**C**	$F_{engine} = F_{drag} = kv^2$ $P_{engine} = F_{engine}v = kv^3$ $\frac{P_{40}}{P_{25}} = \frac{40^3}{25^3} = \frac{P_{40}}{30 \text{ kW}}$ $P_{40} = 120 \text{ kW}$

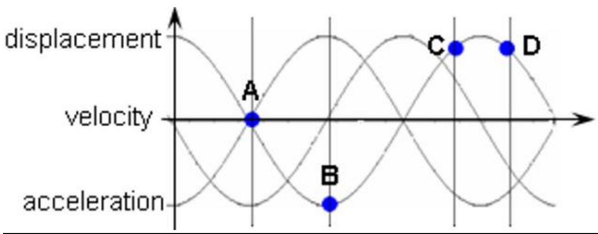
7	**B**	Energy transferred to turbine per unit time = Loss of KE per unit time $P_{in} = \frac{\frac{1}{2}m(u^2 - v^2)}{t} = \frac{\frac{1}{2}(10.7)(5.0^2 - 2.5^2)}{1.0} = 100.3 \text{ W}$ $P_{out} = 0.70P_{in} = 70 \text{ W}$ $P_{out} = IV = 2.8(25) = 70 \text{ W}$
8	**B**	Angular velocity (ω = 3.0 rad s^{-1}) at any point of the circle is constant. Hence options C and D are wrong. $\because r_P = 2r_Q$ $a_c = r\omega^2$ $\therefore a_{cP} = 2a_{cQ} = 54 \text{ cm s}^{-2}$
9	**A**	According to conservation of energy: $GPE_P + KE_P = GPE_S + KE_S$ $-\frac{GMm}{3R} + 0 = -\frac{GMm}{R} + \frac{1}{2}mv^2$ $v = \sqrt{\frac{4GM}{3R}}$
10	**B**	$g = \frac{GM}{r^2} = \frac{G(\rho V)}{r^2} = \frac{G\rho}{r^2}\left(\frac{4}{3}\pi r^3\right)$ $= \frac{4}{3}G\pi\rho r$ $\Rightarrow r \propto \frac{g}{\rho}$ $\frac{r_E}{r_M} = \left(\frac{g_E}{g_M}\right)\left(\frac{\rho_M}{\rho_E}\right)$ $= (6)\left(\frac{3}{5}\right)$ $= 3.6$
11	**A**	$U = \frac{3}{2}kT = \frac{1}{2}m\langle c^2\rangle$ $c_{rms} \propto \sqrt{T}$ $\frac{c_{rms}}{350} = \sqrt{\frac{200 + 273.15}{100 + 273.15}}$ $c_{rms} = 394 \text{ m s}^{-1}$ B – didn't square root the temperature C – didn't convert to K D – assumed doubled temperature results in doubled rms speed.

<table>
<tr><td>12</td><td>D</td><td>No work done in processes Q → R and S → P.

Work done on gas R → S = $p\Delta V = 120000(0.30 - 0.05) = 30000$ J

For cyclic process, no change in internal energy.

$\Delta U = Q + W$
$0 = Q + (-120000 + 30000)$
$Q = 90000$ J
$= 90$ kJ</td></tr>
<tr><td>13</td><td>D</td><td>Since the displacement – time graph is a cosine function, the related velocity – time and acceleration – time graph are negative sine and negative cosine graph.



<table>
<tr><th></th><th>v</th><th>a</th><th>Remark</th></tr>
<tr><td>A</td><td>negative</td><td>zero</td><td>-</td></tr>
<tr><td>B</td><td>zero</td><td>positive</td><td>-</td></tr>
<tr><td>C</td><td>positive</td><td>negative</td><td>opposite direction</td></tr>
<tr><td>D</td><td>negative</td><td>negative</td><td>same direction</td></tr>
</table></td></tr>
<tr><td>14</td><td>D</td><td>Option A: Incorrect, the phase angle of X (0°) and Y (270°)) is different.

Option B: Incorrect, both the period and frequency of X and Y are the same.

Option C: Incorrect, the phase difference is 270 – 0 = 270°, or 1.5 π rad.

Option D: Correct. Period and frequency at points X and Y are the same.</td></tr>
<tr><td>15</td><td>B</td><td>Fact from question: Since the width of gap is equal to wavelength of ripple, there should be significant diffraction after passing through the gap.

Option A: Wrong, as there is limited diffraction of the waves.

Option B: Correct, since the width of the gap is equal to the wavelength of the ripple, diffraction occurs and the waves spread out with wavelength the same as before.

Option C: Wrong, as there is a break (or zero displacement) in the diffracted wavefronts

Option D: Wrong, as there are breaks (or zero displacement) in the diffracted wavefronts</td></tr>
</table>

16	**C**	$d\sin\theta_n = n\lambda$ $\frac{1}{(3.0\times10^3)\times10^2}\sin 90^\circ = n(600\times10^{-9})$ $n = 5.5$ The total images produced = 5 + 1 + 5 = 11 A – did not account for both sides of the central bright fringe B – did not account for the central bright fringe (0^{th} order) D – counted 6 fringes on both sides (n = 6).
17	**C**	PQ is a stationary wave with two loops. The nodes are at the ends P, Q and in the middle. The antinodes are at the middle of each loop. Within the loop, the phase difference is zero. Between adjacent loops, the phase difference is π radian
18	**A**	The test charge needs to be small so that it does not distort the electric field. The test charge itself should not alter the field that it is attempting to measure.
19	**D**	Work done against electrical force is the work done in moving the charge by an external force where the external force is equal in magnitude but opposite in direction to the electric force. Since the electrical field is acting downwards, the electric force and external force F_{ext} is acting downwards and upwards respectively. $W = F_{ext}\, s \cos\theta = qEs\cos\theta$ *where θ is the angle between external force and displacement* For X to Y: The angle between the F_{ext} and s is 90°. $W = 0$ For Y to Z: The angle between the F_{ext} and s is 150°. $W = qEs\cos 150^\circ = -Es\sin 60^\circ$ For Z to X: The angle between the F_{ext} and s is 30°. $W = qEs\cos 30^\circ = +Es\sin 60^\circ$
20	**B**	$P = I^2R$ $0.300 = 0.030^2R$ $R = 333\ \Omega$ $R = \frac{\rho L}{A}$ $333 = \frac{\rho(1.8\times10^{-2})}{1.2\times10^{-3}(1.5\times10^{-2})}$ $\rho = 0.33\ \Omega\ \text{m}$
21	**A**	To have smallest reading, both devices must have the lowest possible p.d. values across them. Hence, the lower their individual resistances, the lower their p.d. will be. For NTC thermistor, high temperature leads to lower resistance. For LDR, high brightness leads to lower resistance.

22	**D**	$\because R_P = R_{Voltmeter}$ $R_{P+Voltmeter} = 0.5R_V$ Voltmeter reading, $V = \dfrac{R_{P+Voltmeter}}{R_{P+Voltmeter} + R_Q}(9.0)$ $6.0 = \dfrac{0.5R_V}{0.5R_V + R_Q}(9.0)$ $\dfrac{2}{3} = \dfrac{0.5R_V}{0.5R_V + R_Q}$ $R_V + 2R_Q = 1.5R_V$ $2R_Q = 0.5R_V$ $\dfrac{R_V}{R_Q} = 4.0$
23	**C**	A: When the currents in both wires flow in the same direction, the wires attract each other. B: When the currents are vertical and slanted respectively, each wire still produces a magnetic field that affects the other. Accordingly to Flemings' Left Hand Rule, the magnetic force has a component that is attractive. C: When the currents are vertical and horizontal respectively, each wire still produces a magnetic field that affects the other. However, the magnetic force acting on the wire is neither attractive nor repulsive. D: When the currents in both wires flow in opposite directions, the wires repel each other.
24	**A**	When the velocity of the second beam of electrons doubles, the downwards magnetic force acting on the electrons doubles. With the upwards electric force remains unchanged, the resultant force is acting downwards, deflecting the electrons downwards.
25	**A**	When the coil is moving without rotating in a uniform magnetic field, there is no change in magnetic flux linkage. Hence, according to Faraday's law, there is no e.m.f. induced.
26	**B**	$P_{half-wave} = \dfrac{1}{2}P_{full-wave}$ $\dfrac{\left(V_{rms,half-wave}\right)^2}{R} = \dfrac{1}{2}\dfrac{\left(V_{rms,full-wave}\right)^2}{R}$ $= \dfrac{\left(\dfrac{1}{\sqrt{2}}V_{rms,full-wave}\right)^2}{R}$ $V_{rms,half-wave} = \dfrac{1}{\sqrt{2}}V_{rms,full-wave}$ $= \dfrac{1}{\sqrt{2}}\dfrac{V_0}{\sqrt{2}} = \dfrac{200}{2} = 100 \text{ V}$

27	**A**	$\text{Intensity} = \dfrac{\text{Rate of EM radiation energy transferred}}{\text{Normal Area}}$ $I = \left(\dfrac{E_{total}}{t}\right)\left(\dfrac{1}{A}\right)$ $= \left(\dfrac{Nhf}{t}\right)\left(\dfrac{1}{A}\right)$ $= \left(\dfrac{N}{t}\right)\left(\dfrac{hc}{\lambda}\right)\left(\dfrac{1}{A}\right)$ The rate of photon flow is constant (*N/t* is constant). Since the wavelength increases, the intensity of the radiation decreases.
28	**B**	Based on loss of EPE of e to KE just before hitting target, de Broglie's wavelength of incident electron $\lambda_{\text{dB}} = \dfrac{h}{p} = \dfrac{h}{\sqrt{2meV}}$ Cut-off (minimum) wavelength of X-ray produced $\lambda_{\text{cut-off}} = \dfrac{hc}{eV}$ $\dfrac{\lambda_{\text{dB}}}{\lambda_{\text{cut-off}}} = \dfrac{1}{c}\sqrt{\dfrac{eV}{2m}} = \dfrac{1}{3.0\times10^{8}}\sqrt{\dfrac{(1.60\times10^{-19})(20\times10^{3})}{2(9.11\times10^{-31})}} = 0.14$ Option A : 0.0044 , Did not convert 20 kV to 20 000 V. Option C : 7.1, Inverse of ratio (1/0.14) Option D : 230, Inverse of ratio (1/0.0044)
29	**C**	$\dfrac{N_{tin}}{N_{anti}} = 5$ $\dfrac{N_{\text{anti remaining}}}{N_{total}} = \dfrac{N_{anti}}{N_{tin}+N_{anti}} = \dfrac{1}{5+1} = \dfrac{1}{6}$ after 2 half lives (120 days), $\dfrac{N_{anti}}{N_{total}} = \dfrac{1}{4}$ after 3 half lives (180 days), $\dfrac{N_{anti}}{N_{total}} = \dfrac{1}{8}$ Hence, for the ratio to be 1/6, the time that has passed is between 2 half-lives (120 days) and 3 half-lives (180 days).

30	**C**	Energy released per event $= \Delta mc^2 = (0.231)(1.66\times10^{-27})(3.0\times10^{8})^2$ $= 3.45114\times10^{-11}$ J Nuclear power generated $= \dfrac{\text{electric power}}{\text{effeciency}} = \dfrac{900\times10^{6}}{0.25}$ $= 3.6\times10^{9}$ J s^{-1} Number of events per unit time $= \dfrac{\text{nuclear power}}{\text{energy per event}} = \dfrac{3.6\times10^{9}}{3.45144\times10^{-11}}$ $= 1.0\times10^{20}$ s^{-1}

YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG

INDEX NO

PHYSICS 9749/02

Paper 2 Structured Questions

3 September 2025

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 2	
1	**/ 8**
2	**/ 6**
3	**/ 6**
4	**/ 12**
5	**/ 9**
6	**/ 7**
7	**/ 11**
8	**/ 21**
Penalty	
Paper 2 Total	
	/80

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows a velocity-time graph for a 150 kg rocket moving vertically.

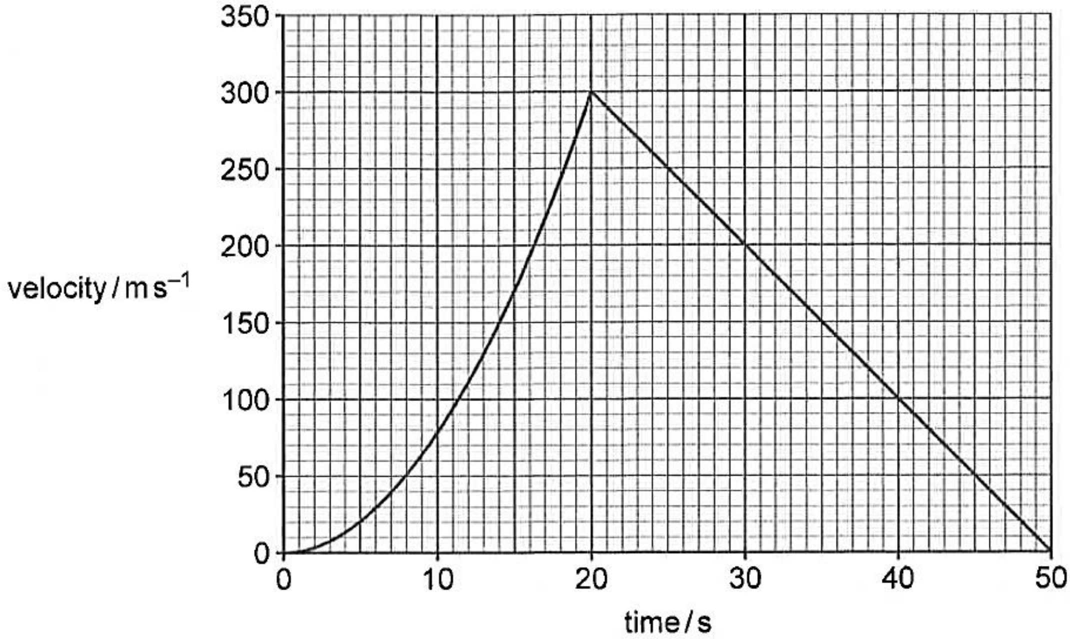


Fig. 1.1

(a) **(i)** Use Fig. 1.1 to determine the maximum acceleration of the rocket. Show your construction in Fig 1.1.

maximum acceleration = ……………...……... m s^{-2} [2]

(ii) Hence, determine the maximum thrust experienced by the rocket. You may assume that the mass of the fuel is negligible compared to the mass of the rocket.

maximum thrust = …………………………. N [2]

(b) Suggest and explain what happens to the rocket from time = 20 s to 50 s.

……..…………………………………………………………………………………………………..……

……..…………………………………………………………………………………………………..……

……… [2]

(c) On Fig. 1.2, sketch the variation with time of the vertical displacement *s* of the rocket from its starting position when *t* = 0 s.

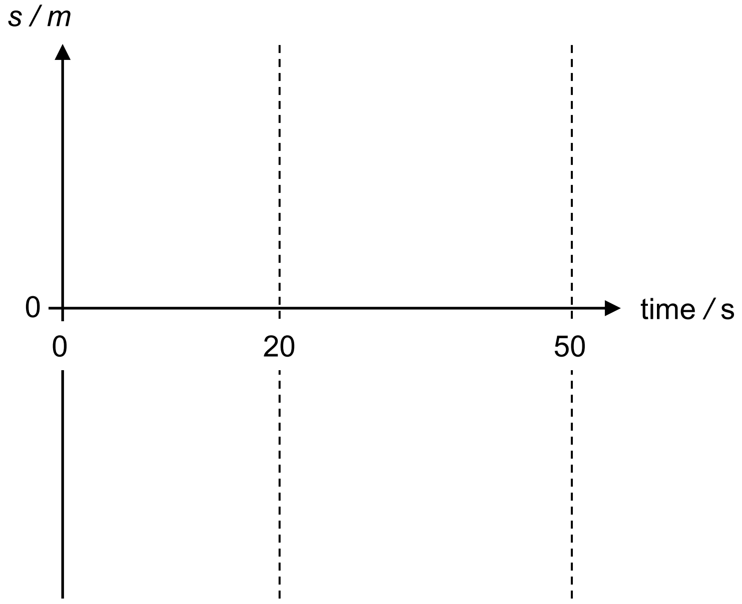


Fig. 1.2

[2]

[Total: 8]

2 **(a)** State the origin of the upthrust acting on a body in a fluid.

……..……………………………………………………………………………………………..……

……..…………………………………………………………………………………………. [1]

(b) **(i)** A deflated balloon has a mass of 12 g. It is then inflated with helium until it forms a spherical balloon of diameter of 30 cm.

The helium-filled ballon is attached by a light string to the bottom of an empty tank as shown in Fig 2.1.

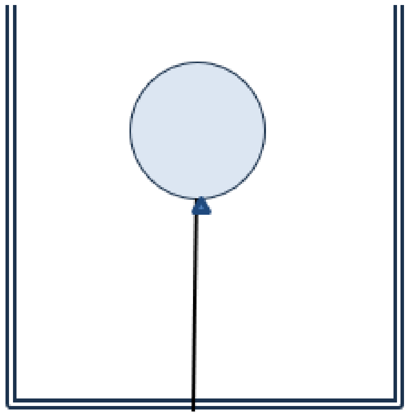


Fig. 2.1

The density of air is 1.29 kg m^{-3} while the density of helium is 0.18 kg m^{-3}.

Calculate the tension in the string.

tension = …………………………. N [3]

(ii) The tank is gradually filled with water until the balloon is fully submerged as shown in Fig. 2.2.

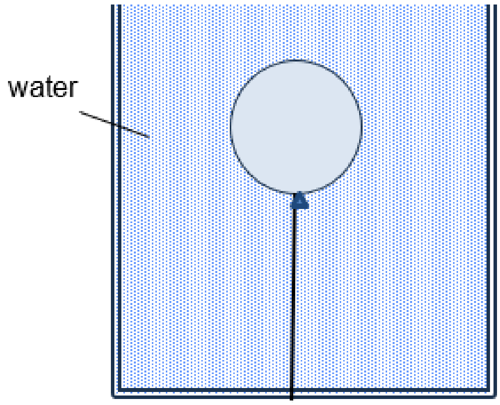


Fig. 2.2

State and explain whether the tension in the string increases, decreases or stays the same when the balloon is fully submerged.

……

……

…….. [2]

[Total: 6]

3 In a theme park ride, passengers ride a cart which completes a vertical circle, as shown in Fig 3.1. The loop has a radius of 7.0 m and a passenger of mass 60 kg is travelling at 12 m s^{-1} when the cart is at the highest point of the loop.

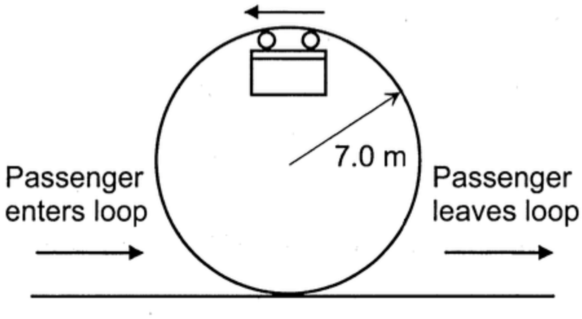


Fig 3.1

(a) Calculate for the passenger:

(i) the normal contact force acting on him due to the cart at the highest point

normal reaction force = …………….……... N [2]

(ii) his velocity at the lowest point.

velocity = ……………………... m s^{-1} [2]

(b) Operators of this ride must ensure that the speed at which the passengers reach the top of the loop is above a certain minimum value.

Explain the need for this minimum speed.

………

………

……. [2]

[Total: 6]

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4 **(a)** A fixed mass of an ideal gas has volume 1.5×10^{-2} m^3 at pressure 4.4×10^5 Pa and temperature of 65 °C.

(i) Using energy considerations, explain what is meant by an *ideal gas*.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(ii) Determine the number of molecules in the gas sample.

number of molecules = …………………... [2]

(iii) Determine the total internal energy of the gas sample.

total internal energy = …………………... J [2]

(b) The gas in **(a)** is now heated to 150 °C while maintaining constant pressure. The volume of the gas after heating is 1.9×10^{-2} m^3.

(i) Calculate the work done by the gas during this process.

work done by the gas = …………………... J [2]

(ii) The molar heat capacity is the amount of heat supplied to one mole of gas to raise its temperature by one kelvin.

Determine the molar heat capacity for this gas.

molar heat capacity = …………………... J mol^{-1} K^{-1} [4]

[Total: 12]

5 A metal block hangs vertically from one end of a spring. The other end of the spring is tied to a thread that passes over a pulley and is attached to a vibrator that is fixed in position, as shown in Fig. 5.1.

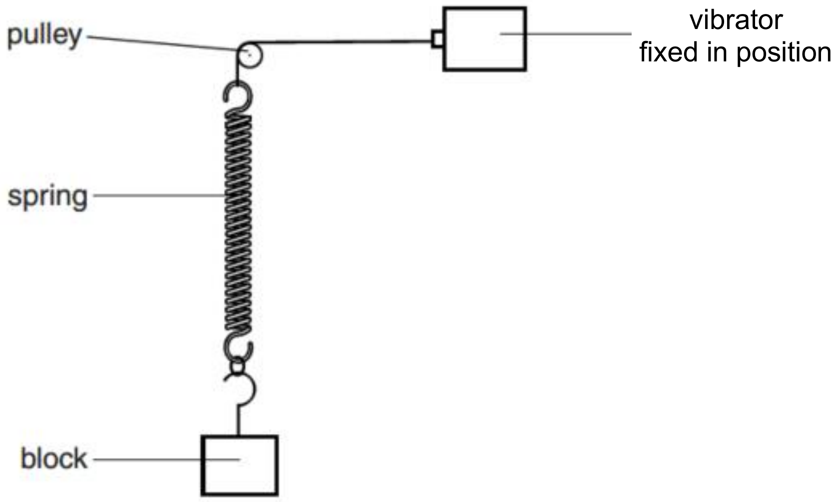

Fig. 5.1

(a) The vibrator is switched off.

The metal block of mass 120 g is displaced vertically and then released. The variation with time t of the displacement y of the block from its equilibrium position is shown in Fig. 5.2.

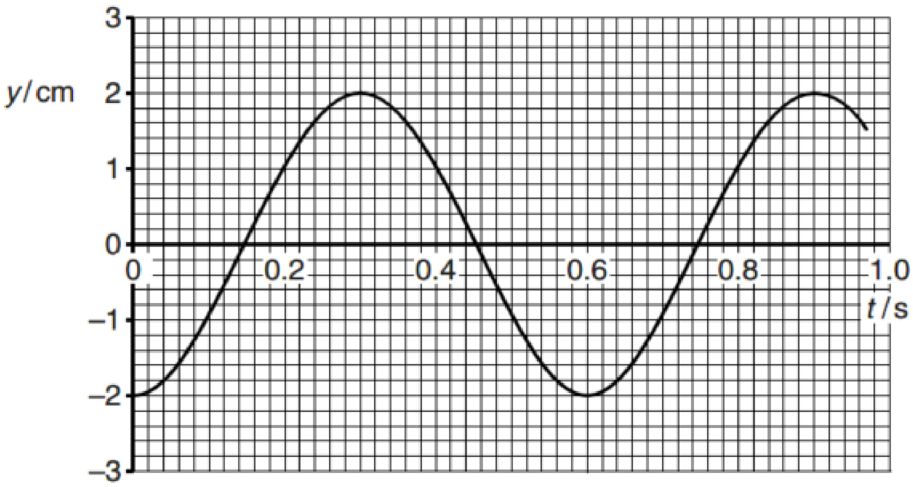

Fig. 5.2

For the oscillation of the block, calculate:

(i) the angular frequency ω

ω = ………………….. rad s $^{-1}$ [2]

(ii) the total energy.

energy = ………………….. J [2]

(b) State what is meant by resonance.

……..……………………………………………………………………………………..……

……………..…………………………………………………………………………………. [1]

(c) The vibrator is now switched on.

The frequency of the vibrator is varied from 0.7*f* to 1.3*f* where *f* is the frequency of oscillation of the block in **(a)**.

For the block, complete Fig. 5.3 to show the variation with frequency of the amplitude of oscillation. Label this line A. [2]

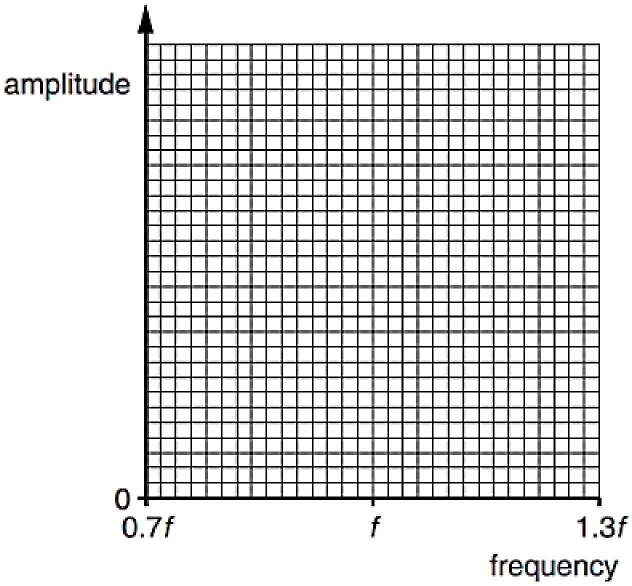

Fig. 5.3

(d) Light feathers are now attached to the block in **(c),** increasing the effective cross-sectional area.

The frequency of vibrator is once again varied from 0.7*f* to 1.3*f*. The new amplitude of oscillation is measured for each frequency.

On Fig. 5.3, draw a line to show the variation with frequency of the amplitude of oscillation. Label this line B. [2]

[Total: 9]

6 An ideal transformer is illustrated in Fig. 6.1.

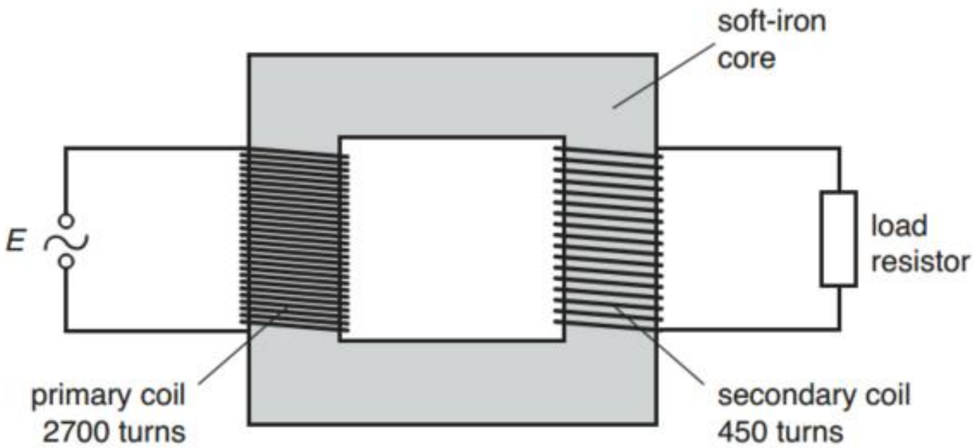

Fig. 6.1

(a) Explain why the input voltage to the transformer is alternating, rather than constant.

………

………

………

………

……. [2]

(b) The primary coil of the transformer has 2700 turns. The secondary coil has 450 turns.

The e.m.f. *E* applied across the primary coil is given by the expression

$$E = 220\sin(100\pi t)$$

where *E* is measured in volts and *t* is the time in seconds.

Calculate the root-mean-square (r.m.s.) e.m.f. induced in the secondary coil.

r.m.s. e.m.f. = ………………….. V [3]

(c) The average current in the load resistor is zero.

Explain why there is a heating effect in the resistor.

………

………

………

…………………………………………………………………………………………………… [2]

[Total: 7]

7 The electron in the hydrogen atom absorbs or emits electromagnetic radiation when it moves between different energy levels. The visible part of the spectrum emitted by the hydrogen atom can be seen in the laboratory by applying a high voltage to a hydrogen gas discharge tube.

(a) Describe the difference in appearance between the emission line spectrum and absorption line spectrum for the hydrogen gas.

………

………

……… [1]

(b) Some electron energy levels of the hydrogen atom are illustrated in Fig. 7.1.

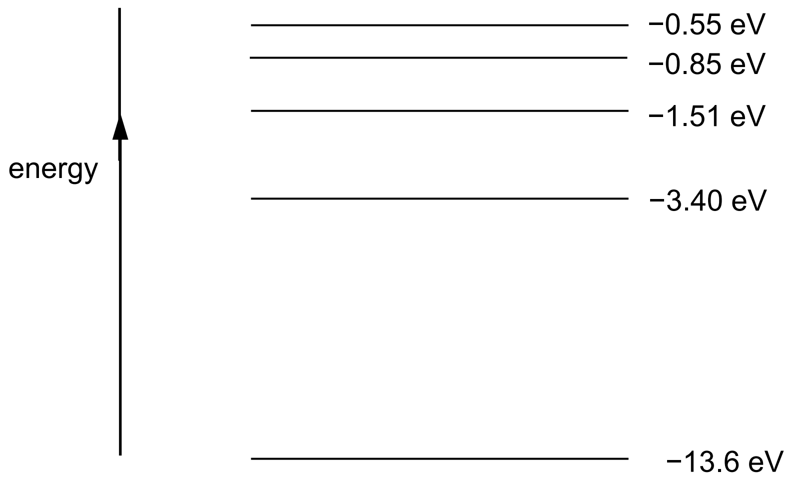

Fig. 7.1 (not to scale)

(i) The wavelength of violet light is approximately 400 nm.

By calculating the energy, in eV, of a photon of violet light, explain why electron transitions to energy level -13.6 eV do not result in emission in the visible spectrum.

………

………

………

………

……… [4]

(ii) The minimum energy of a photon of visible light is 1.6 eV.

Use Fig. 7.1 to determine, for the electron energy levels shown:

1. the number of lines that lie in the visible spectrum

number = ………………………… [1]

2. the longest wavelength of photons in this visible spectrum.

wavelength = …………………………. m [2]

(c) The radiation emitted from the transitions between level -3.40 eV to -13.6 eV as shown in Fig. 7.1 is incident on the surface of a sheet of tungsten.

Tungsten has a work function energy of 4.5 eV.

Calculate the maximum energy of an electron emitted from the tungsten by this radiation.

energy = …………………………. eV [2]

(d) Explain why it is not possible for X-ray radiation to be emitted from a hydrogen atom.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

[Total: 11]

8 Read the passage below and answer the questions that follow.

Battey Electric Vehicles: The Power Revolution

Battery Electric Vehicles (BEVs) represent a revolutionary shift in transportation technology, operating solely on electrical energy stored in their onboard battery packs to power their electric motors for propulsion.

The heart of every BEV lies in its sophisticated battery system. These batteries are monitored through a battery management system that measures the open circuit voltage (OCV) to determine the state of charge (SOC), which is the amount of electrical energy left in the battery as a percentage of the total capacity. The relationship between OCV and SOC for two prevalent lithium-ion variants — the lithium-iron-phosphate (LFP) cell and the lithium nickel manganese cobalt (Li-NMC) cell — is illustrated in Fig 8.1.

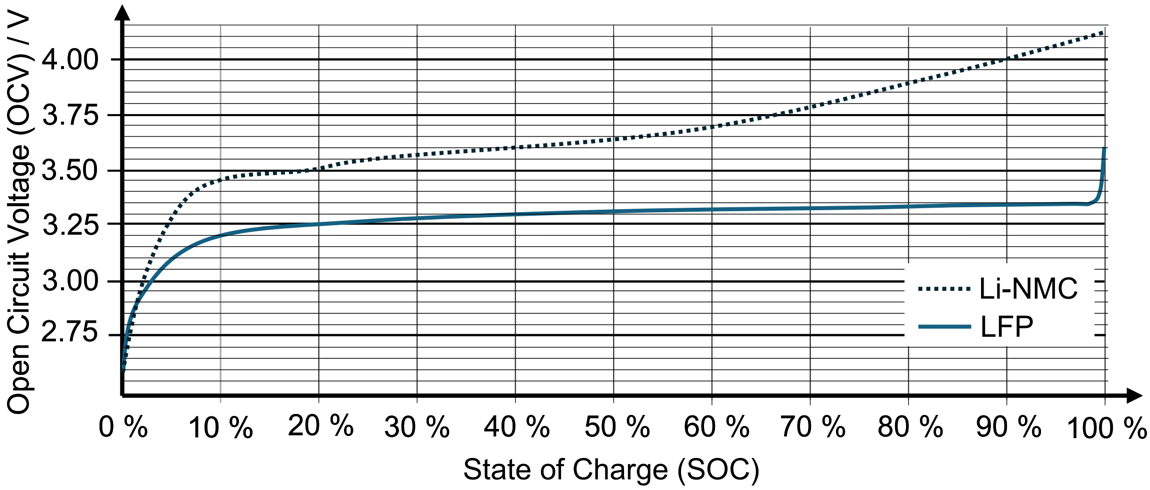

Fig. 8.1

The technological leap from traditional lead-acid batteries to modern lithium-ion systems has been remarkable. Contemporary lithium-ion batteries boast an impressive energy density ranging from 0.90 to 2.63 GJ m^{-3}, dwarfing the 0.36 GJ m^{-3} capacity of their lead-acid predecessors. However, when compared to conventional fuels like petroleum (34 GJ m^{-3}) and ethanol (24 GJ m^{-3}), there remains significant room for advancement.

Yet, the seemingly lower energy density of electric batteries is substantially compensated by their superior efficiency. BEVs demonstrate remarkable energy conversion capabilities, transforming over 77% of electrical energy from the grid into mechanical power at the wheels. This stands in stark contrast to conventional petrol internal combustion engine (ICE) vehicles, which convert merely 25% of petroleum's stored energy into usable power.

The popularity of BEVs in Singapore has been rising such that in 2024, an electric vehicle became the bestselling car. This market-leading electric vehicle combines sporty aesthetics with practical dimensions of 4.46 m length, 1.62 m height, and 1.88 m width. Despite its substantial fully loaded mass of 2100 kg, it achieves remarkable performance metrics, accelerating from 0 to 100 km h^{-1} in 10.1 seconds, thanks to its low drag coefficient of 0.29 and robust maximum power of 100 kW.

(a) An average internal combustion engine (ICE) car using petroleum as its fuel can carry about 0.055 m^3 of petroleum.

(i) Calculate:

1. the total energy stored in the petroleum

total energy stored = ……………………… GJ [2]

2. the range of the car if it needs an average of 0.086 GJ of useful energy to cover 100 km

range = ……………………………. km [3]

3. the fuel efficiency of the car, which is the average distance covered per unit volume of petroleum consumed.

fuel efficiency = ……………………… km m^{-3} [2]

(ii) Show that the smallest volume of lithium-ion battery required to cover the same range as the ICE car is 0.23 m^3.

You may assume that the rate of energy consumption per distance travelled for the electric car is the same as that as for an ICE car.

[2]

(iii) Hence, suggest why cars powered by lithium-ion batteries have significantly smaller average range compared to ICE cars.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………. [1]

(b) **(i)** Using Fig. 8.1, determine the average change in open circuit voltage (OCV) per 1% change in state of charge (SOC) for both types of batteries in the range of 10% to 90 %.

average change in OCV for Li-NMC battery = ……………………… V per 1%

average change in OCV for LFP battery = ……………………… V per 1%

[3]

(ii) Hence, explain whether it is more accurate to monitor the capacity of an Li-NMC battery or an LFP battery using the Open Circuit Voltage (OCV).

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

…………………………………………………………………………………………………. [1]

(c) The drag force F_D on a car can be calculated using the equation

$$F_D = \frac{1}{2}\rho v^2 CA$$

where ρ is the density of air, v is the speed of the car, A is the cross-sectional area and C is the drag coefficient.

(i) Given that the drag coefficient C is unitless, use SI base units to show that the equation is homogeneous.

[2]

(ii) Given that the density of air is 1.29 kg m^{-3}, determine the speed of the market-leading electric car when its motor is operating at maximum power.

speed = ………………………… m s^{-1} [3]

(iii) Suggest why it is difficult for the car to obtain the top speed.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

………………………………………………………………………………………………… [2]

[Total: 21]

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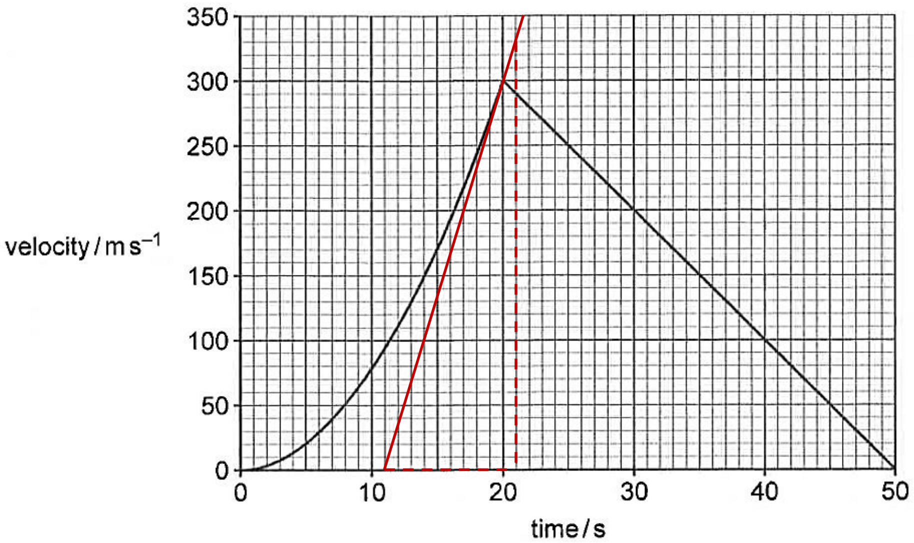
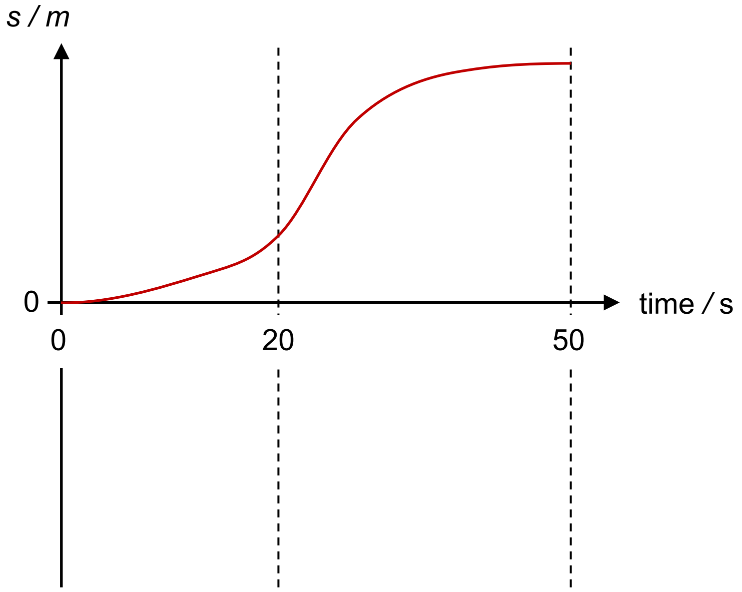
2025 YIJC JC2 Preliminary Examination
H2 Physics Paper 2 Solution

1	**(a)**	**(i)**	 Tangent line drawn correctly at time = 20 s Correct read off for 2 points - coordinates (11, 0) & (21, 330) $a = \dfrac{330-0}{21-11}$ $= 33 \text{ m s}^{-2}$ (allowed accuracy range: $30 \text{ m s}^{-2} \le a \le 36 \text{ m s}^{-2}$)	**M1** **A1**
			Most were able to link the gradient to the acceleration. However, the common mistake lies in the accuracy of determining the maximum acceleration by drawing the tangent line at the point of greatest slope.	
		(ii)	$F_{net} = ma$ $\text{thrust} - mg = ma$ $\text{thrust} = mg + ma = 150(9.81) + 150(33)$ $= 6421 \approx 6400 \text{ N } (2sf)$ Allow ECF	**C1** **A1**
			Some assumed the maximum thrust is the maximum net force. Some confused upthrust (aka buoyant force) with thrust (forward push) of the rocket.	
	(b)		(Taking upwards as positive, from the convention of the velocity-time graph) The engine of the rocket is turned off / The fuel has been used up. The upward moving rocket is now subjected to (constant) weight downwards, causing the rocket to slow down (decelerate) at a constant rate (due to free fall)	**B1** **B1**
			Some did not explain the cause for the velocity decreasing. Some attributed it to the rocket attaining terminal velocity. *Some thought that the rocket stops at t = 20s (max height here) and immediately starts to fall after that.*	

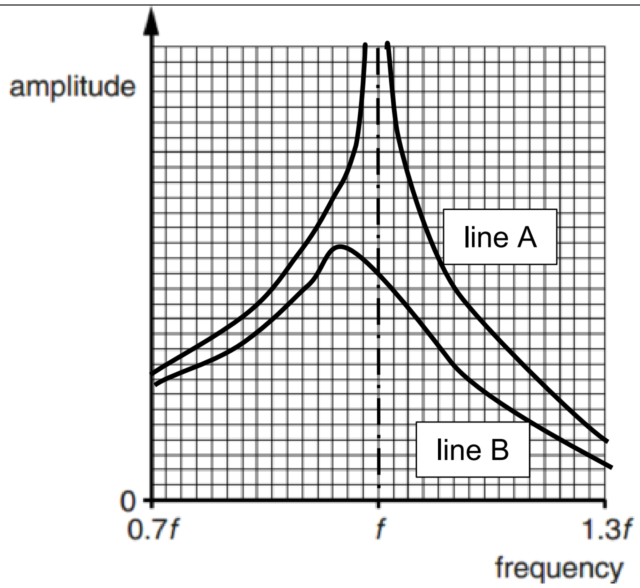
	(c)		 Correct shape: Increasing gradient from 0 to 20s and decreasing gradient from 20 s to 50 s. Increasing displacement throughout motion. Zero gradient at t = 0s and 50 s.	**B1** **B1**
			Common mistakes • *stating that the turning point was at t = 20s. (the velocity is always positive)* • *the graph between t = 0 to 20 s is not parabolic (ie initial gradient is zero)* • *the graph between t = 20 to 50 s is a straight line (velocity is not constant).*	

2	**(a)**	The origin of the upthrust acting on a body in a fluid is the pressure difference between the top and bottom surface of the body.		**B1**
		Many students quoted Archimedes' principle instead of stating how upthrust comes about.		
	(b)	**(i)**	Upthrust = $\rho_{air}Vg = (1.29)\left[\frac{4}{3}\pi(0.15)^3\right](9.81)$ = 0.179 N Weight of helium = $\rho_{helium}Vg = (0.18)\left[\frac{4}{3}\pi(0.15)^3\right](9.81)$ = 0.0250 N The net force on the balloon is zero. Weight of balloon material + Weight of helium + Tension = Upthrust (0.012)(9.81) + 0.0250 + T = 0.179 T = 0.036 N	**C1** **C1** **A1**
			Many students are unsure of which density is to be used to determine upthrust or weight of helium. Some forgot to include the weight of the balloon material.	
		(ii)	Water is denser than air so the upthrust will increase. Hence, the tension will increase.	**M1** **A1**
			Generally well done although some students did not know/state that water is denser than air.	

3	**(a)**	**(i)**	$F_{net} = F_C$ $N + W = \frac{mv^2}{r}$ $N + 60(9.81) = \frac{60 \times 12^2}{7.0}$ $N = 646$ N	 **C1** **A1**
			Many know that the normal contact force is related to the centripetal force. However, some wrongly think that the centripetal force is equal to the normal contact force, or to the normal contact force minus the weight.	
		(ii)	$KE_{top} + GPE_{top} = KE_{bot} + GPE_{bot}$ $\Delta GPE = KE_{bot} - KE_{top}$ $mg(14.0) = \frac{1}{2}m\left(v_{bot}{}^2 - 12^2\right)$ $v_{bot} = 20.46 \approx 20$ m s^{-1}	 **C1** **A1**
			Some wrongly thought that the normal contact force calculated in (a)(i) could be used here, without recognising that the normal contact force must be greater than the weight in order to provide the required centripetal force towards the centre of the circular motion. Those who correctly applied conservation of energy needed to account for all forms of energy involved, especially the kinetic energy at the top of the circular motion.	
	(b)		If the speed is too slow, the centripetal (or net) force required to complete the loop is reduced. Since the net force is equal to the sum of the weight and normal reaction force from the cart, and weight is fixed, reducing the centripetal (or net) force required will reduce the normal contact force until it is zero, and the rider will lose contact with the cart. OR Speed must be large enough so that weight alone is insufficient to provide the centripetal force. Hence, contact force experienced by the man will be greater than zero and remain in contact with the loop when travelling above the minimum speed. Accept explanation based on equations.	**B1** **B1** **(B1)** **(B1)**
			Challenging. Some wrongly tried to use conservation of energy to explain that falling off the loop is due to a lack of kinetic energy. Many simply stated that a minimum speed is needed for the man and the cart to continue moving in circular motion or not fall off the loop, without further elaboration. Others correctly noted that falling off the loop occurs when the normal contact force becomes zero, but they needed to relate this back to the minimum speed required.	

4	**(a)**	**(i)**	An ideal gas is defined as a gas that <u>has zero internal / microscopic potential energy</u> and all its <u>internal energy is only contributed by the microscopic kinetic energy</u> of its molecules.	**B1** **B1**
			Many candidates were careless with their phrasing, most commonly missing out on 'internal' or 'microscopic' and not providing evidence that they understand that that this is talking about energy at molecule level. Candidates can score a max of 1 mark if they miss out on this. *Answers also lack precision due to usage of words like 'mostly' or 'close to'.*	
		(ii)	$pV = NkT$ $4.4\times10^{5}\times1.5\times10^{-2} = N\times1.38\times10^{-23}\times(65+273.15)$ $N = 1.4139\times10^{24} \approx 1.4\times10^{24}$	**C1** **A1**
			Most common error is mixing up moles and the number of molecules.	
		(iii)	$E_K = \frac{3}{2}kT$ $U = NE_K = 1.4\times10^{24}\left[\frac{3}{2}(1.38\times10^{-23})(65+273.15)\right]$ $U = 9897 = 9900$ J	**C1** **A1**
			Generally ok, but common errors include forgetting N or 3/2.	
	(b)	**(i)**	$W = p\Delta V$ $W = 4.4\times10^{5}(1.9-1.5)\times10^{-2}$ $W = 1760$ J Deduct A1 if work done calculated is negative	**C1** **A1**
			Generally well done, but some candidates attempted to calculate new volume using change in temperature. They do not understand the concepts of change in U and work done.	
		(ii)	$\Delta U = \frac{3}{2}Nk(\Delta T)$ $= \frac{3}{2}(1.41\times10^{24})(1.38\times10^{-23})(150-65) = 2480$ J **Change in internal energy** $n = \frac{N}{N_A}$ $= \frac{1.41\times10^{24}}{6.02\times10^{23}}$ $n = 2.342$ mol **Find Q** **Q = (2.342)C(150-65)** **Applying the first law of thermodnamics** $\Delta U = W_{on} + Q_{in}$ $Q_{in} = \Delta U - W_{on}$ $nC(\Delta T) = \Delta U - W_{on}$ $2480 + 1760 = (2.342)C(150-65)$ $C = 21$ J mol^{-1} K^{-1}	**C1** **C1** **C1** **A1**

			Generally poorly done *Most candidates did not find change in U, and instead used U directly.* *They also assumed Q to be same value as W or U, or sub W wrongly into first law equation.* *There was also some confusion with the term molar heat capacity, with some candidates finding molecular heat capacity or mass-specific heat capacity.*

5	**(a)**	**(i)**	$\omega = \frac{2\pi}{T}$ $\omega = \frac{2\pi}{0.60}$ $\omega = 10.47 \approx 10$ rad s^{-1}	**C1** **A1**
			Well done by most students.	
		(ii)	Energy $= \frac{1}{2} m\omega^2 x_0^2$ $= \frac{1}{2} \times 0.120 \times 10.5^2 \times 0.020^2$ $= 2.63 \times 10^{-3} \approx 2.6 \times 10^{-3}$ J	**C1** **A1**
			Well done by most students.	
	(b)		Resonance is the phenomenon that occurs when the driving frequency of the driver is the same as (very close to) the natural frequency of the driven system, resulting in maximum transfer of energy from the driver to the driven system.	**B1**
			Most students indicated natural frequency and driving frequency in their answers. *To score the full marks, students need to mention energy transfer.*	
	(c)		 smooth curve with correct shape and amplitude never zero and line extends from 0.7*f* to 1.3*f* asymptote or peak at *f*	**B1** **B1**
			Only some students manage to score full marks. *You will need to recall the shape of the graph correctly.*	
	(d)		Correct shape: peaked line always below a peaked line A peak not as sharp and slightly less than frequency of peak in line A	**B1** **B1**
			Only some students manage to score full marks.	

6	**(a)**		An alternating voltage applied to the primary coil produces a changing magnetic flux in the core. An e.m.f. is only induced in the secondary coil when this magnetic flux linking it is changing.	**B1** **B1**

			Many answers lacked details e.g. did not state where the changing flux is created/experienced and the location where is e.m.f. is induced.		
	(b)		Either $(V_p)_0 = 220$ $(V_p)_{rms} = \frac{220}{\sqrt{2}}$ = 155.6 $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ $\frac{155.6}{V_s} = \frac{2700}{450}$ V_s = 25.9 ≈ 26 V	Or $(V_p)_0 = 220$ $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ $\frac{220}{V_s} = \frac{2700}{450}$ V_s = 36.67 $(V_p)_{rms} = \frac{36.67}{\sqrt{2}}$ = 25.9 ≈ 26 V	**C1** **C1** **A1**
			Generally well done. A minority of students included the trigonometric function in the working which made the calculation confusing and usually inconclusive.		
	(c)		The power dissipated as heat in the heating coil is given by $P = I^2R$. Hence, the power dissipated (heating power) in the coil is directly proportional to the square of instantaneous current. This means that regardless of whether current is flowing in either direction, there will still be power dissipated in the heating coil, cause heating. OR The average current is zero because the current flows one direction for half a cycle and in the opposite direction for the second half of the cycle. The heating effect directly proportional to the square of the non-zero current in each half cycle. Instantaneous current not zero (most of the time). OR rms current is not zero. Average power is thus not zero.		**B1** **B1** **(B1)** **(B1)** **(B1)** **(B1)**
			Poorly done in general. Many answers did not reconcile how the average current being zero can still lead to power being dissipated in the resistor.		

7	(a)	The emission line spectrum consists of bright coloured lines against a black / dark background. The absorption line spectrum consists of dark lines on a continuous coloured background. Do not accept "rainbow" in replacement of coloured background/coloured lines. *Award marks only when the two spectral lines are compared as the question asked for the difference rather than for their individual description.*		B1
		Some mixed up the descriptions distinguishing between the two different line spectra. *Some stated black lines against white background and vice-versa (probably due to the notes printed in black and white).*		
	(b)	(i)	The energy transition between levels is related to the emission of photon by $\Delta E = \frac{hc}{\lambda}$. $\Delta E = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(400\times10^{-9})}$ $= 4.97\times10^{-19}$ J $= 3.11$ eV In the case of the 400 nm violet light which is the smallest wavelength (most energetic photon) in the visible spectrum, a minimum energy transition of 3.11 eV is required for visible light emission. This is less than the smallest energy transition involving the energy level -13.6 eV (that is from n=2 and n=1) which is -3.40 – (-13.6) = 10.2 eV. Therefore, transition to the energy level -13.6 eV cannot emit wavelength in the visible spectrum. Alternative explanation: The smallest energy transition involving the energy level -13.6 eV is 10.2 eV. Since the wavelength emitted is inversely proportional to the energy transition, the corresponding wavelength released from transitions to -13.6 eV would be shorter than 400nm.	C1 A1 B1 B1 (B1) (B1)
			Most were able to derive the energy of the violet light photon (3.1 eV). *However, the explanation to the visible light waves not being emitted with respect to the ground state (-13.6 eV) was not clear.* *Rather than comparing violet light photon energy (3.1 eV) to the energy transition 10.2 eV as being too large, many merely stated that 3.11 eV does not match any transitions between the energy levels.*	
		(ii) 1.	Based on **(b)(i)**, the range of the energies of photons in the visible spectrum is between a minimum of 1.6 eV and a maximum of 3.11 eV. Thus, based on Fig. 7.1 only, there are 3 lines in the visible spectrum (transitions ending with n = 2).	B1
			Most were able to get the value.	
		(ii) 2.	The longest wavelength emitted by the hydrogen atom in the visible spectrum corresponds to the smallest energy transition from -1.51 eV to -3.40 eV $[(-1.51)-(-3.40)]\times(1.60\times10^{-19}) = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda}$ $\lambda = 6.58\times10^{-7}$m	C1 A1
			Some obtained wavelengths that were outside of the visible light range.	

	(c)	From Einstein's photoelectric equation Energy of incident photon = Work function + Max KE of electron emitted -3.40 – (-13.6) = 4.5 + Max KE Max KE = 5.69 eV	**C1** **A1**
		Mostly well done. However, some mixed up the signs. Example : 4.5 + 10.2 = 14.7 eV	
	(d)	The <u>largest energy transition</u> for the hydrogen atom <u>is 13.6eV</u> which <u>will release radiation up to the ultraviolet range only</u>. The hydrogen atom is too small in size (energy transition is insufficient) to release radiation in the X-ray region (typically 10keV) Must compare X-ray photons to hydrogen transition within the eV range.	**B1**
		The wavelength of X-ray is typically 10^{-10} m and the required energy transition is $\Delta E = \frac{hc}{\lambda}$ $\Delta E = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(1\times10^{-10})}$ $= 2.0\times10^{-15}$ J $= 12.4$ keV	

8	**(a)**	**(i)1.**	total energy stored $= 0.055 \times 34$ $= 1.87$ GJ	**C1** **A1**
		(i)2.	useful energy used to propel the car $= 1.870 \times 25\% (= 0.4675 \text{ GJ})$ range $= 0.4675 \times \left(\frac{100}{0.086}\right)$ $= 544$ km OR energy required to travel 100 km $= \frac{0.086}{25\%} (= 0.0344 \text{ GJ})$ range $= \frac{1.87}{0.0344} \times 100$ $= 544$ km OR range if car is 100% efficient $= \frac{1.87}{0.086} \times 100 (= 2174 \text{ km})$ actual range $= 2174 \times 25\%$ $= 544$ km Allow for range = 543 m (rounded down), as this is the max distance.	**C1** **C1** **A1** **(C1)** **(C1)** **(A1)** **(C1)** **(C1)** **(A1)**
		(i)3.	fuel efficiency $= \frac{544}{0.055}$ $= 9890 \text{ km m}^{-3}$	**C1** **A1**
			(a)(i) is mostly done well.	

		(ii)	required stored energy in battery $= \dfrac{0.4675}{77\%} (= 0.607\text{ GJ})$ required volume of battery $= \dfrac{0.607}{2.63}$ $= 0.23\text{ m}^3$ (*shown*) OR required energy per 100 km $= \dfrac{0.086}{77\%} (= 0.1117\text{ GJ})$ required volume of battery $= \dfrac{0.1117 \times \frac{544}{100}}{2.63}$ $= 0.23\text{ m}^3$ (*shown*) OR useful max energy density $= 2.63 \times 77\% (= 2.0251\text{ GJ kg}^{-1})$ required volume of battery $= \dfrac{0.4675}{2.0251}$ $= 0.23\text{ m}^3$ (*shown*)	**M1** **M1** **A0** **(M1)** **(M1)** **(A0)** **(M1)** **(M1)** **(A0)**
			Some students forgot to take into account the efficiency of the battery (77%).	
		(iii)	Volume of battery required is about/more than 4x that of petroleum for the same range. Electric cars would need to carry more volume/mass than ICE cars over the same distance for the same capacity of energy. OR For the same volume of battery and petroleum, the electric car battery can power the electric car for a smaller range. OR To travel the same distance, the volume/mass of battery must be larger than the volume/mass of fuel.	**B1** **(B1)**
			Poorly attempted. The term "Hence" requires students to talk about the volume as shown in previous part. Many just commented on energy density. Some mentioned the lower volume, but did not mentioned this was for the same range as that of the ICE car carrying same volume of fuel.	
	(b)	**(i)**	Li-NMC: average change in OCV $= \dfrac{4.00 - 3.45}{90 - 10} = 6.88 \times 10^{-3}$ V per 1% LFP: average change in OCV $= \dfrac{3.35 - 3.25}{90 - 10} = 1.88 \times 10^{-3}$ V per 1% Correct read off for all 4 data points (to ½ smallest division) (minimum read off correctly for 3 points) Correct answer for Li-NMC Correct answer for LFP	**C1** **A1** **A1**
			Mostly well done. Some mistakenly read values for the whole 100% range.	

		(ii)	The variation of OCV per 1% change in SOC is very low for LFP batteries compared to Li-NMC batteries. Hence it is more accurate to monitor the capacity of an Li-NMC battery using this method. OR A small change in OCV will have a larger change in SOC for Li-NMC batteries compared to LFP batteries. Hence it is more accurate to monitor the capacity of an Li-NMC battery using this method. OR A more precise scale is required to observe changes in OCV for an LFP battery than for an Li-NMC battery. Hence it is more accurate to monitor the capacity of an Li-NMC battery using this method.	**B1** **(B1)** **(B1)**
			Many students understood wrongly. If the change OCV per 1% is lower, it is harder to read. The percentage error in reading the change is bigger for smaller changes in OCV.	
			LHS: base unit of $F_D = \text{kg m s}^{-2}$ RHS: base units of $\frac{1}{2}\rho v^2 CA = (\text{kg m}^{-3})(\text{m s}^{-1})^2(\text{m}^2)$ $= \text{kg m s}^{-2}$ Since units of left side of the equation are equal to the units of right side of the equation, the equation is homogeneous. Correct expression of base units of F_D. Correct base unit substitution for each quantity of $\frac{1}{2}\rho v^2 CA$	**B1** **B1**
			Most students presented their answer poorly. Some assumed LHS and RHS are already equal at the get go (e.g., starting off with $\text{kg m s}^{-2} = (\text{kg m}^{-3})(\text{m s}^{-1})^2(\text{m}^2)$) *Some incorrectly wrote that the quantity = units (e.g., $F = \text{kg m s}^{-2}$)*	
		(ii)	At max power, the drag force = driving force (no net force/acceleration) $F_{drive} = F_{drag} = \frac{1}{2}(1.29)v^2(0.29)(1.62 \times 1.88)$ $P_{drive} = F_{drive} \times v$ $100 \times 10^3 = \frac{1}{2}(1.29)v^2(0.29)(1.62 \times 1.88) \times v$ $v^3 = \frac{2(100 \times 10^3)}{(1.29)(0.29)(1.62 \times 1.88)}$ $v = 56.0 \text{ m s}^{-1}$	**C1** **C1** **A1**
			Many students could not tell that at max velocity, there is no net force, so driving force = drag force. *Some identified the wrong dimension for the car's cross-sectional area, which should be perpendicular to the direction of motion (hence, breadth x width).*	

		(iii)	The driving force needs to be more than the drag force to accelerate. As it approaches the top speed, the drag force (viscous force) increases. Hence, the acceleration will be very low and it will take very long for the car to accelerate up to this top speed. OR Hence, the energy loss is higher at higher speeds and it will take very long for the car to reach the top speed (gain kinetic energy). OR Hence, at high speeds almost all of the power is used to overcome drag, so it will take a long time for the car to gain kinetic energy.	**B1** **B1** **(B1)** **(B1)**
			Poorly done. Most students gave general knowledge type answers (e.g., there are no roads long enough to attain the speed), which did not reference any physics concepts.	

YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG

INDEX NO

PHYSICS 9749/03

Paper 3 Longer Structured Questions **15 September 2025**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.
Section B
Answer **one** question only.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 3	
Section A	
1	/ 4
2	/ 9
3	/ 7
4	/ 10
5	/ 11
6	/ 11
7	/ 8
Section B	
8	/ 20
9	/ 20
Penalty	
Paper 3 Total	
	/80

This document consists of **26** printed pages and **2** blank pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle C^2\rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1 One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically. The diameter *d* of the wire and the load *F* are measured as

$$d = 0.40 \pm 0.02\text{mm},$$

$$F = 25.0 \pm 0.5\text{N}.$$

The stress σ in the wire is calculated by using the expression

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

Determine the value of σ and its associated uncertainty.

$\sigma + \Delta\sigma$ = ……………………………. ± ………………….. N m^{-2} [4]

[Total: 4]

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2 A particle A of mass 5*u* and velocity 2000 m s^{-1} collides head-on with another particle B of mass 32*u* and velocity 500 m s^{-1} as shown in Fig. 2.1. During the collision, the particles stay in contact for 2.5×10^{-12} s. After the collision, particle B moves rightwards with velocity 56 m s^{-1}.

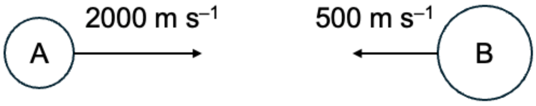

Fig. 2.1

(a) Determine the magnitude and direction of velocity of particle A after the collision.

magnitude of velocity = ……………………… m s^{-1}

direction = ………….……………… [3]

(b) For the time during collision,

(i) state and explain whether both particles could be stationary at the same time,

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………. [2]

(ii) calculate the average force *F* between the particles.

F = ……………………… N [2]

(c) By considering quantitatively the relative speeds of approach and of separation of the two particles, deduce whether the collision is elastic or inelastic.

………

…… [2]

[Total: 9]

3 **(a)** Define the moment of a force about a point.

....

.... [1]

(b) A uniform fishing rod AB of length 2.40 m and weight 5.2 N is shown in Fig. 3.1.

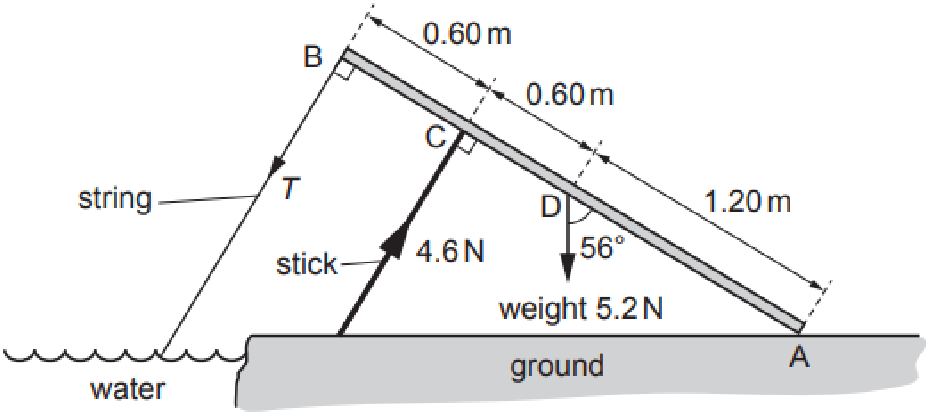

Fig. 3.1 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force of 4.6 N perpendicular to the rod at point C. The weight of the rod acts at point D. The tension *T* in the string is in a direction perpendicular to the rod.

The rod is in equilibrium and inclined at an angle of 56° to the vertical.

(i) By taking moments about end A of the rod, calculate the tension *T*.

T = ... N [2]

(ii) Determine the magnitude and the direction of the resultant force acting at the end A.

magnitude of the resultant force = ……………………… N

direction of the resultant force = ………………………° above the horizontal

[4]

[Total: 7]

4 A binary star consists of two stars A and B that orbits one another, as illustrated in Fig. 4.1.

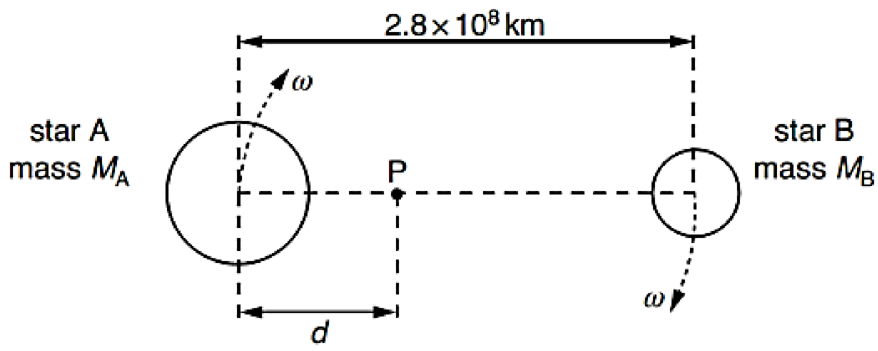

Fig. 4.1

The stars are in circular orbits with the centres of both orbits at point P, a distance d from the centre of star A.

(a) **(i)** Explain why the centripetal force acting on both stars has the same magnitude.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

………………………………………………………………………………………………… [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed ω of the stars.

ω = …………………… rad s^{-1} [2]

(b) The separation of the centres of the stars is 2.8 × 10^8 km.

The mass of star A is M_A. The mass of star B is M_B. The ratio $\frac{M_A}{M_B}$ is 3.0.

(i) Determine the distance *d*.

d = …………………… km [3]

(ii) Use the answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B.

M_B = …………………… kg [3]

[Total: 10]

5 **(a)** Define electric field strength.

………

……… [1]

(b) Two small solid metal spheres A and B are in a vacuum. They have equal radii and their centres are 15 cm apart as shown in Fig. 5.1. Sphere A has charge +3.0 pC and sphere B has charge +12 pC.

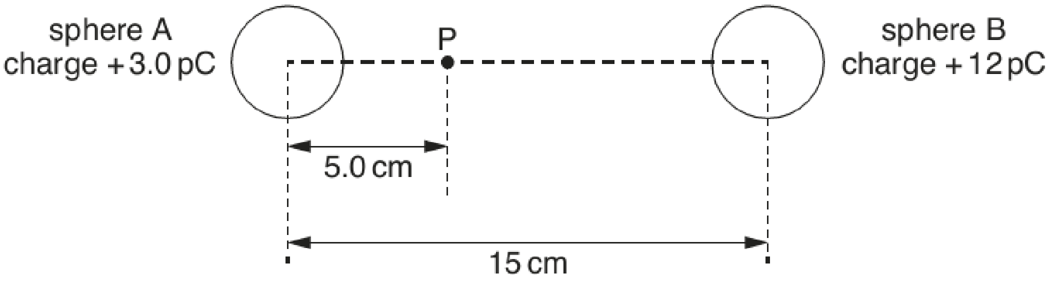

Fig. 5.1

Point P lies on the line joining the centres of the spheres and is a distance of 5.0 cm from the centre of sphere A.

(i) Suggest why the electric field strength in both spheres is zero.

……

……

………………………………………………………………………………………………………. [2]

(ii) Show that the electric field strength is zero at point P. Explain your working.

[3]

(iii) Calculate the electric potential at point P.

electric potential = …………………… V [2]

(iv) A silver-107 nucleus ($^{107}_{47}\text{Ag}$) has speed *v* when it is a long distance from point P.

Use your answer in **(b)(iii)** to calculate the minimum value of speed *v* such that the nucleus can reach point P. Explain your answer.

v = …………………… m s^{-1} [3]

[Total: 11]

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6 **(a)** A cell of e.m.f. 1.5 V and internal resistance 0.25 Ω is connected in series with a metal wire that has resistance 6.0 Ω, as shown in Fig. 6.1. The resulting current I passes through the metal wire for a time of 5.0 minutes.

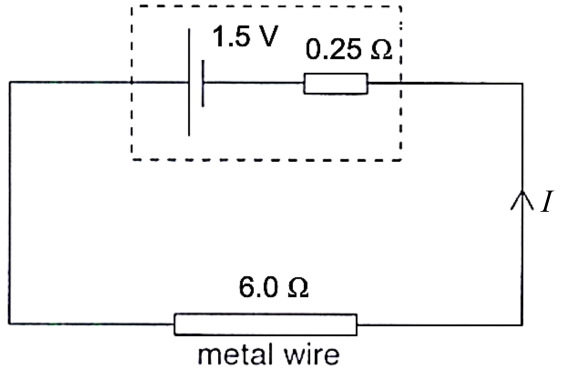


Fig. 6.1

(i) Calculate current I passing through the metal wire.

I = …………………… A [2]

(ii) Calculate the total energy transferred to the metal wire.

energy = …………………… J [2]

(iii) A second similar cell is now connected in series with the cell in **(a)** and the metal wire. This causes the current in the metal wire to increase.

By considering the atomic structure of a metal conductor, explain why the resistance of the metal wire increases.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(b) An ideal cell of e.m.f. 3.0 V is connected in series with a fixed resistor of resistance 1.0 kΩ and a thermistor, as shown in Fig. 6.2.

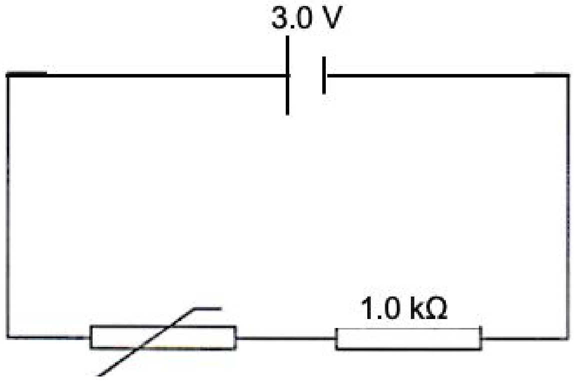


Fig. 6.2

The thermistor has resistance 10 kΩ at 0 °C and 100 Ω at 150 °C, and the internal resistance of the cell may be considered negligible.

(i) Define potential difference.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………… [1]

(ii) On the same set of axes in Fig. 6.3, sketch the following graphs:

1. The potential difference (p.d.) across the thermistor vs temperature of the thermistor. Label the graph as **T**.
2. The p.d. across the 1.0 kΩ resistor vs temperature of the thermistor. Label the graph as **R**.

[2]

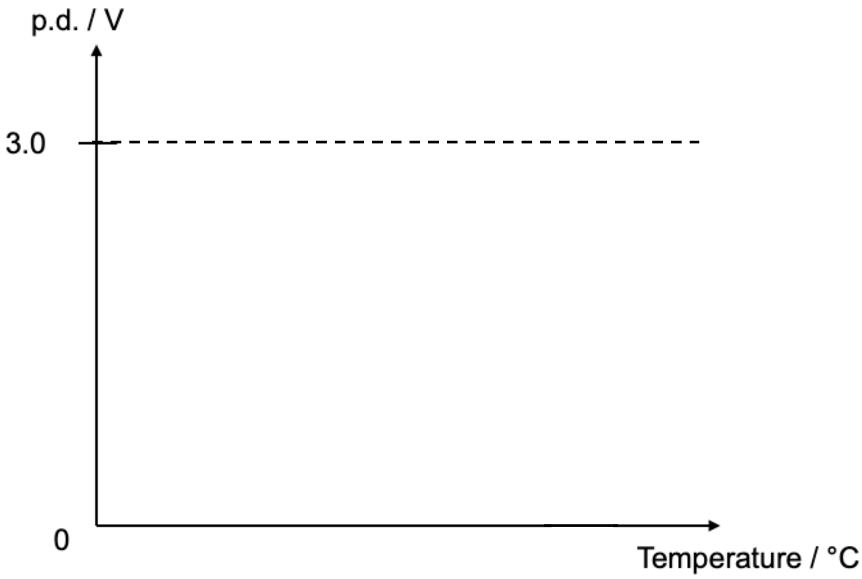


Fig. 6.3

(iii) In one application of the circuit in Fig. 6.2, the user wishes for the potential difference across the fixed resistor to range from 1.2 V at 0 °C to 2.4 V at 150 °C.

Determine whether, by substituting a different fixed resistor in the circuit of Fig. 6.2, it is possible to achieve this range of potential differences.

……………………………………………………..…………………………………………

……………………………………………….………………………………..….. [3]

[Total: 11]

7 **(a)** **(i)** Smoke alarms are installed in buildings and homes to warn people of smoke, likely from fires. Once smoke is detected, the alarms will create very loud sounds.

Fig. 7.1 shows part of the inside of a smoke alarm, that contains an α-radiation source and a radiation detector.

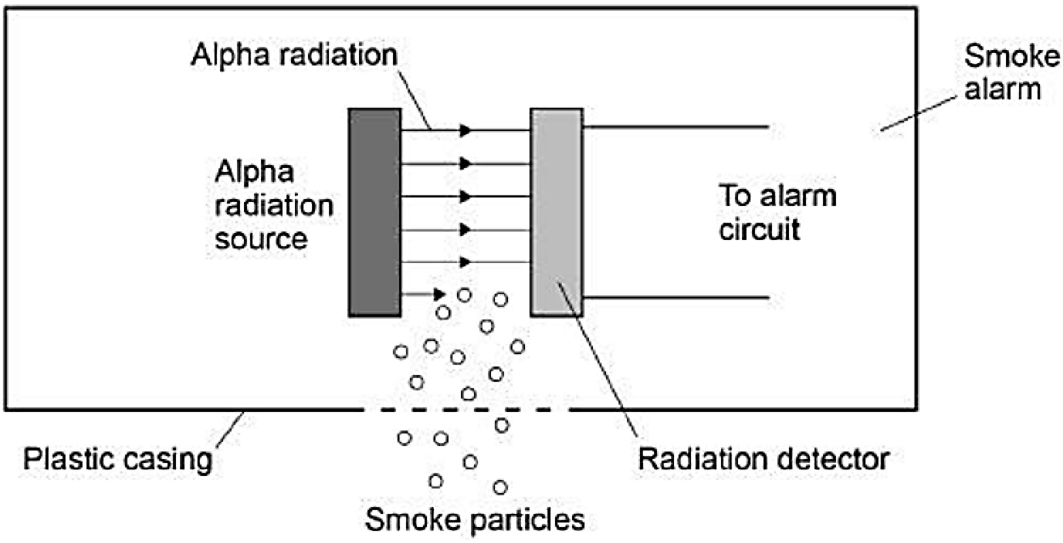


Fig. 7.1

When α-particles arrive at the detector, the smoke alarm stays off.

Suggest why the alarm turns on when smoke particles enter the plastic casing.

……..

……..

………………………………………………………………………………………………………. [2]

(ii) State and explain whether the source should have a long or short half-life when used in smoke alarms.

……...

……...

………………………………………………………………………………………………………. [2]

(b) **(i)** α-particles are released when Plutonium-239 decays to form an isotope of uranium, U.

Complete the equation below for the above decay.

$$^{239}_{\dots\dots}\text{Pu} \rightarrow {}^{\dots\dots}_{92}\text{U} + {}^{\dots\dots}_{\dots\dots}\alpha$$

[2]

(ii) The binding energies per nucleon of the three nuclides above are shown below.

Nuclide	Binding energy per nucleon / MeV
Plutonium-239	7.560
Isotope of uranium	7.591
α-particle	7.062

Determine the energy released when a Plutonium-239 nucleus decays.

energy released = ………………………. MeV [2]

[Total: 8]

Section B

Answer **one** question from this section in the spaces provided.

8 **(a)** State the meaning of the following terms associated with wave motion.

(i) *intensity* of a wave.

....

.... [1]

(ii) *plane polarisation* of a wave.

....

....

.... [2]

(b) A small loudspeaker is rated 2.5 W. The amplitude of an emitted sound wave from the loudspeaker of intensity 1.0 W m^{-2} is 4.0 μm.

Determine the amplitude of the sound wave at a distance of 2.0 m from the loudspeaker.

amplitude = ... μm [2]

(c) Two waves are shown in Fig. 8.1.

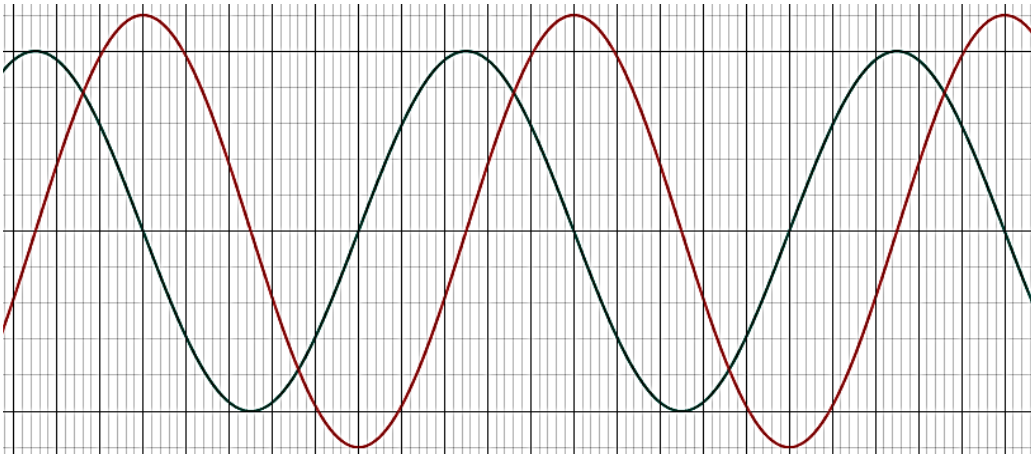


Fig. 8.1

(i) Deduce the phase difference between the two waves.

phase difference = ……………………° [2]

(ii) Explain why the two waves in Fig. 8.1 are coherent.

……………………………………………………………………………………………...

……………………………………………………………………………………………...

…………………………………………………………………………………………… [2]

(d) A two-source interference pattern is set up using light of wavelength 546 nm. The light passes through two slits 1.13 mm apart as shown in Fig. 8.2. A pattern of light is formed on a screen at a distance 1.25 m from the slits. A graph of the intensity of light in the pattern is shown in Fig. 8.2.

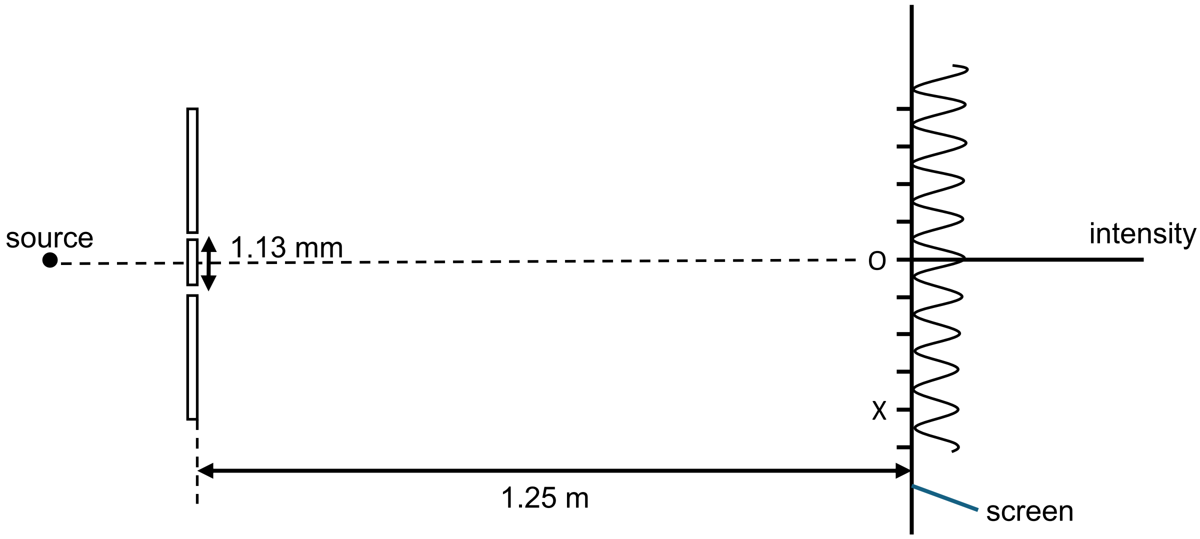


Fig. 8.2

(i) Calculate the distance OX.

OX = …………………… m [2]

(ii) Suggest how the appearance of the fringes changes when each of the following adjustments is made separately.

1. The width of both slits is reduced without altering their separation.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………... [1]

2. The screen is rotated so that it is no longer parallel to the plane of the two slits.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………... [2]

(e) A stationary microwave is formed between a microwave source at A and a reflector at B, as shown in Fig. 8.3.

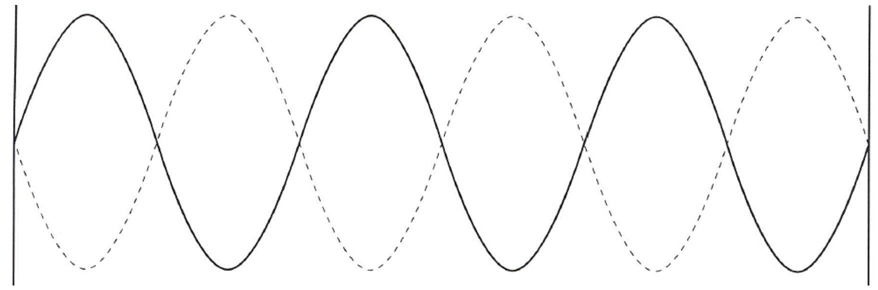


Fig. 8.3

The solid line represents the wave at time t = 0 and the dotted line represents the wave at time $t = \frac{T}{2}$, where T, the period of the wave, is 40 picoseconds.

(i) Calculate the distance between A and B.

distance = …………………… m [3]

(ii) Sketch, on Fig. 8.3, the shape of the wave when:

1. $t = \frac{T}{4}$. Label this wave shape **X**.

2. $t = \frac{7T}{8}$. Label this wave shape **Y**.

[3]

[Total: 20]

9 **(a)** **(i)** State Faraday's law of electromagnetic induction.

………………………………………………………………………………………………

……………………………………………………………………………………………... [1]

(ii) State Lenz's law of electromagnetic induction.

………………………………………………………………………………………………

……………………………………………………………………………………………... [1]

(b) A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 9.1.

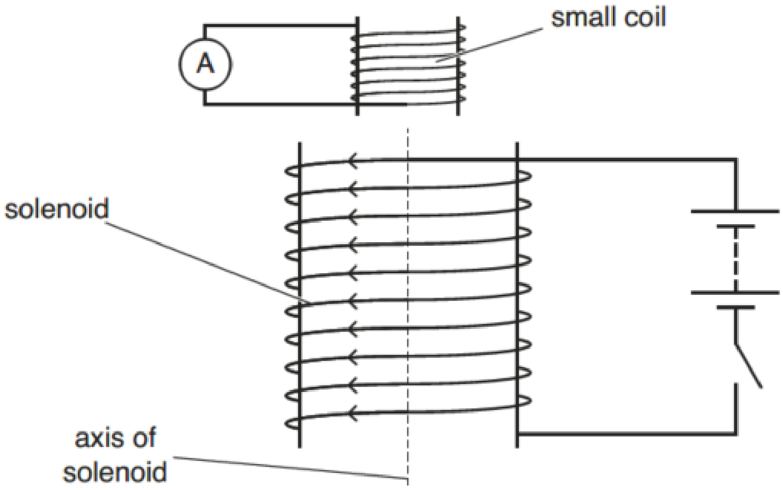


Fig. 9.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

(i) On Fig. 9.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid when the current in the solenoid is switched on. Label this arrow **P**. [1]

(ii) As the current in the solenoid is switched off, the magnetic flux density inside the solenoid is reduced from 7.5 mT to 0 mT in a time of 0.15 s, inducing an average e.m.f. of 3.6 mV across the solenoid.

1. Use Lenz's law of electromagnetic induction to explain the direction of the induced magnetic field due to the induced current in the small coil when the current is switched off.

On Fig. 9.1, mark the direction of this induced magnetic field with an arrow inside the small coil. Label this arrow **Q**.

……………………………………………………………………………………………...

……………………………………………………………………………………………...

……………………………………………………………………………………………...

……………………………………………………………………………………………... [3]

2. The battery is now replaced with a variable power supply, which is used to vary the magnetic flux density *B* in the small coil with time *t* as shown in Fig. 9.2.

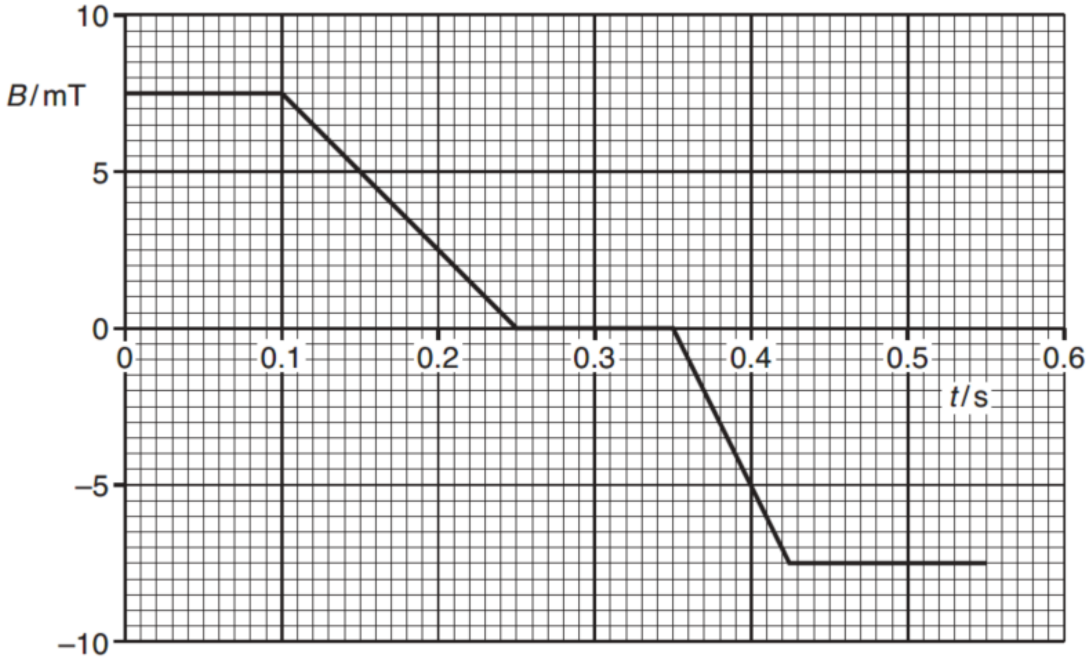


Fig. 9.2

On Fig 9.3, sketch the variation with time *t* of the e.m.f. *E* induced in the small coil.

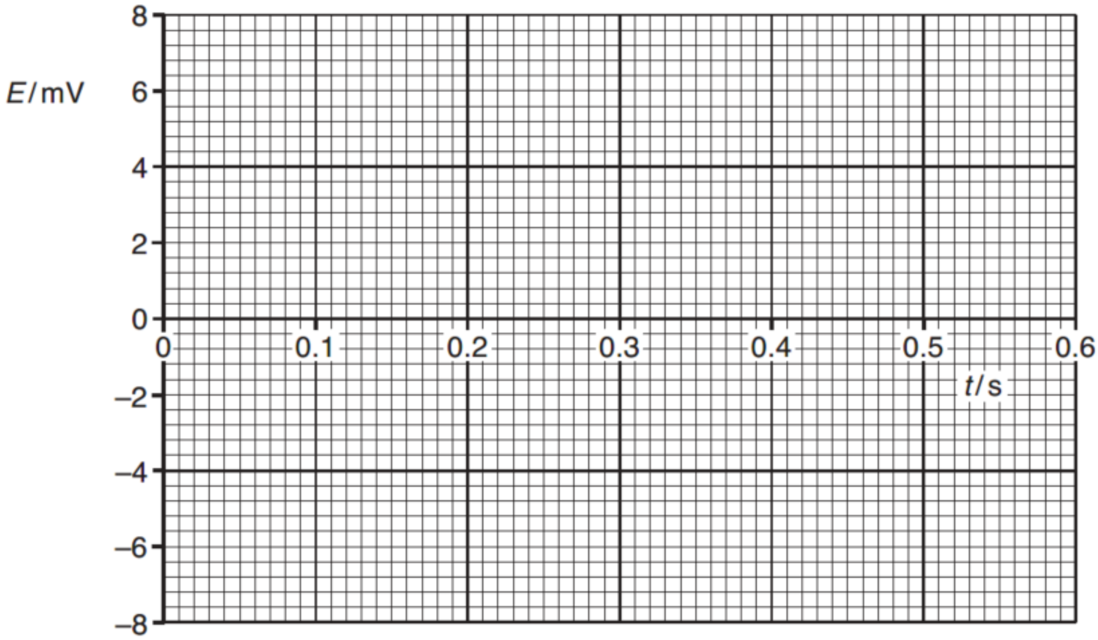


Fig. 9.3

[3]

(c) An electromagnetic braking system is connected to the wheels of a vehicle.

(i) In order to activate the electromagnetic braking system, a uniform magnetic field of flux density 0.017 T is produced by two similar flat coils, as shown in Fig. 9.4. The two flat coils are fixed so that their planes are parallel.

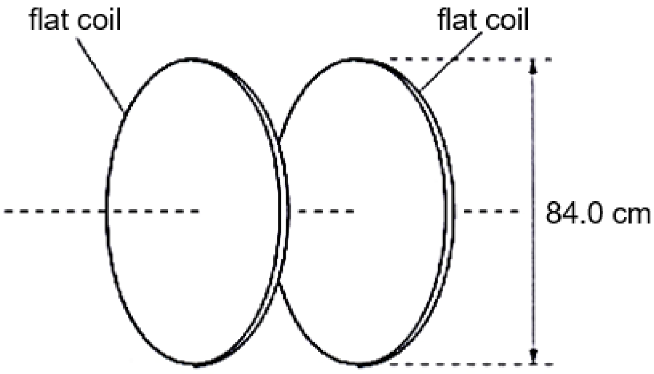


Fig. 9.4

The current I in both coils is 12 A.

The magnetic flux density B in the region between the two coils is uniform and given by the expression

$$B = 0.72\mu_o \frac{NI}{r}$$

where N is the number of turns on each of the flat coils of radius r and μ_0 is the permeability of free space.

Determine the number of turns N needed to produce a magnetic flux density of 0.017 T.

N = ………………...... [2]

(ii) A heavy aluminium disc is connected to the wheels of a vehicle. The magnetic field produced in **(c)(i)** is perpendicular to the plane of the rotation of the aluminium disc, as shown in Fig. 9.5. The disc has a diameter of 0.72 m.

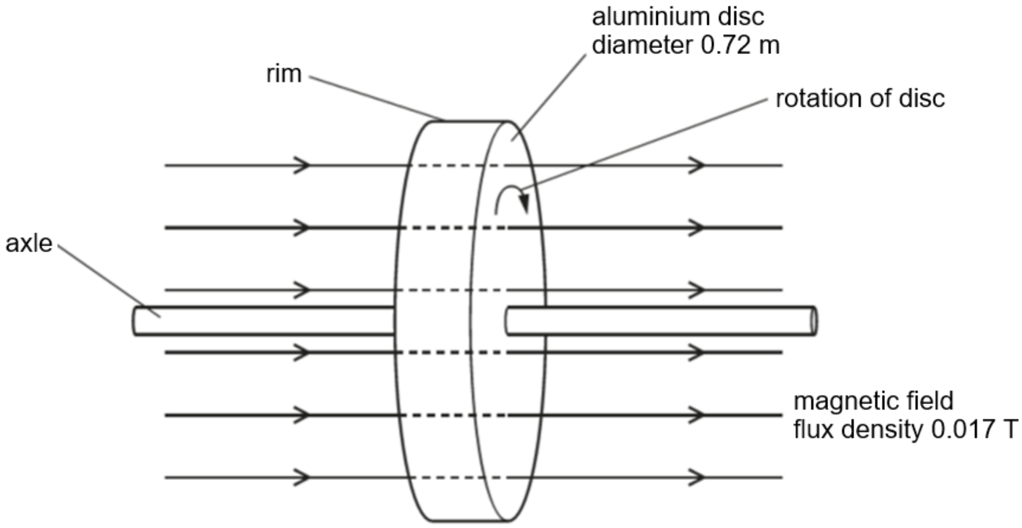


Fig. 9.5

An e.m.f. is induced between the centre and the rim of the rotating disc when a magnetic field of 0.017 T is directed into it. The rotation of the disc can be modelled as a radial wire OP between the axle and the rim cutting the magnetic field as shown in Fig. 9.6.

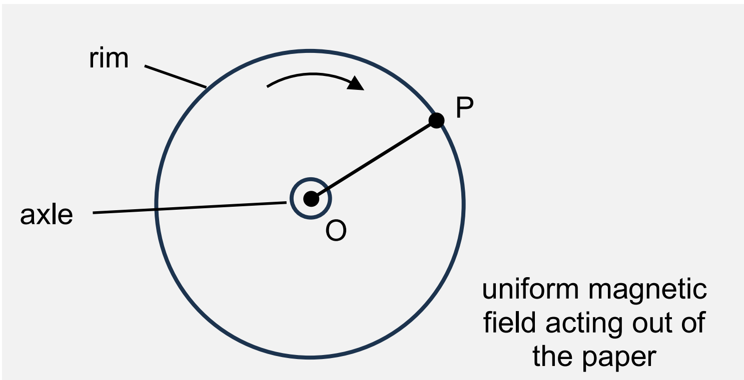


Fig. 9.6

1. Calculate the total magnetic flux cut by the radial wire when the disc rotates one round.

Give a unit for your answer.

magnetic flux = ………………... unit ……... [3]

2. The disc is rotating at a rate of 25 revolutions per second.

Calculate the magnitude of the electromotive force (e.m.f.) induced between the axle and the rim of the disc.

e.m.f. = ……………….. V [3]

3. The axle and the rim are connected to an external circuit that enables the energy of the rotation of the disc to be stored. The direction of rotation is shown in Fig. 9.6.

Use Lenz's law to determine whether the direction of current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………. [3]

[Total: 20]

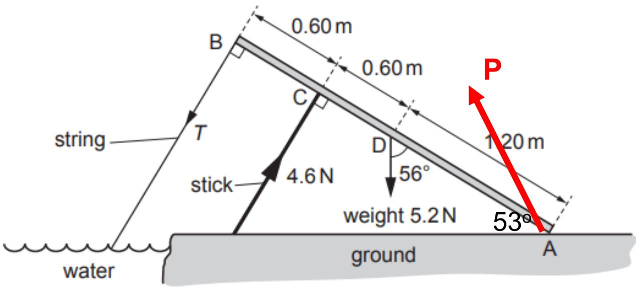
2025 YIJC JC2 Preliminary Examination
H2 Physics Paper 3 Solution

1			$\pm\dfrac{\Delta\sigma}{\sigma}=\pm\left[\dfrac{\Delta F}{F}+\dfrac{2\Delta d}{d}\right]$ $=\pm\left[\dfrac{0.5}{25.0}+\dfrac{2(0.02)}{0.4}\right]$ $(=\pm0.12)$	**C1**
			$\sigma=\dfrac{4(25)}{\pi(0.40\times10^{-3})^2}$ $(=1.98\times10^{8}\text{ N m}^{-2})$	**C1**
			$\pm\Delta\sigma=\pm0.12\times(1.98\times10^{6})$ $=0.2\times10^{8}\text{ N m}^{-2}\ (1sf)$	**C1**
			$\sigma\pm\Delta\sigma=(2.0\pm0.2)\times10^{8}\text{ N m}^{-2}$	**A1**
			Many students did not convert d's value from mm to m. *An even larger majority did not leave the absolute uncertainty to 1 s.f. and the value of σ was not expressed to the same d.p. as its uncertainty.*	

2	**(a)**	**(i)**	Taking rightwards as positive, $m_Au_A+m_Bu_B=m_Av_A+m_Bv_B$ $5u(2000)+32u(-500)=5uv_A+32u(56)$ $v_A=-1560\text{ m s}^{-1}\ (3sf)$ <u>Leftwards</u> (Simply stating 'leftwards' or 'rightwards' without justification by way of using a sign convention and the proper working will not be given credit. It must be based on a sign convention in the working and final answer's sign.)	**C1** **A1** **A1**
			Most candidates were able to write the COM equation correctly with the normal sign convention. However, a significant number of candidates were careless with the signs. Some even use the alternative form in terms of the change of momentum for A and B (eg loss of momentum of A = gain in momentum of B which is (ΔP_A = -ΔP_B). But in most cases, the signs were inserted wrong (eg (ΔP_A = ΔP_B).	
	(b)	**(i)**	The initial <u>net momentum of the system is non-zero (Left hand side = -6000u)</u> In a closed system, COM applies and hence the <u>net momentum during the collision is non-zero</u>. Hence it is <u>impossible for both trolleys to be stationary (as its total momentum would be zero)</u>	**M1** **A1**

			Those who got it right were few. There was confusion on the use of the sign convention again. *The main misconception was the notion that prior to the collision there was momentum or motion for each individual particle and therefore during the collision it cannot result in a zero momentum or zero motion. It is possible to have a zero momentum if the momentum of both approaching particles are equal and opposite.* *Some tried to justify for it using the rule of conservation of kinetic energy. Initially there was KE. But during collision, KE is zero. Thus, the two particles cannot be stationary at the same time.* *Candidates should determine the total initial momentum for this question in order to justify the case.*	
		(ii)	$F = \frac{\Delta p_B}{\Delta t} = \frac{32\left(1.66\times10^{-27}\right)\left[-500-56\right]}{2.5\times10^{-12}}$ Magnitude of $F = 1.18\times10^{-11}$ N	**C1** **A1**
			This was poorly done. The force of impact applies to the change of momentum happening on either particle (not on both). Due to N3L, the force of impact on A by B is the same and opposite to the force on B by A. Confusion arises again with the wrong signs (eg 500-56). Instead of the change of momentum for either A or B, the total momentum of the system was used. *Some arrived at F= 7.1 x 1015 N which is a huge value for such a microscopic collision. This should be a red flag. They forgot to consider the unified atomic mass u in the calculation.*	
	(c)		Relative speed of approach: $u_B - u_A = -500 - 2000 = -2500$ m s^{-1} Relative speed of approach: $v_A - v_B = -1560 - 56 = -1616$ m s^{-1} Both workings for the relative speeds are correct Since the relative speeds of approach and separation are **not** equal, it is an inelastic collision. (Proof by calculating the difference in the initial and final KE of the system is not accepted as the question specifically asked for proof using the above step).	**M1** **A1**
			This was poorly done mainly due to the wrong application of the sign convention for vector quantities (eg relative speed of approach = 2000 – 500 = 1500 m s^{-1}). *Some did not follow the question and instead use the differences in KE method instead.* *In the end, this question was not so much on the concept of COM but the wrong application of the same convention.*	

3	**(a)**	The moment of a force about a point is the product of the force and the perpendicular distance between the line of action of the force to the point.		**B1**
		Most students managed to recall the definition correctly, though some students still confuse with the principle of moments definition.		
	(b)	**(i)**	Taking moments about point A Total anticlockwise moments = Total clockwise moments (T × 2.4) + (5.2sin56° × 1.2) = (4.6 × 1.8) T = 1.3 N	**C1** **A1**
			Most students managed to calculate tension correctly.	

		(ii)	Let the force on point A be P **Resolving forces in x-direction,** $\Sigma F_x = 0$ $P_x + 4.6\cos56° – (1.29)\cos56° = 0$ $P_x = -1.85$ N **Resolving forces in y-direction,** $\Sigma F_y = 0$ $P_y + 4.6\sin56° – (1.29)\sin56° – 5.2 = 0$ $P_y = 2.46$ N Resultant force $P = \sqrt{P_y^2 + P_x^2} = \sqrt{2.46^2 + 1.85^2} = 3.1$ N $\tan\theta = \frac{P_y}{P_x} = \frac{2.46}{1.85} = 1.33$ θ = 53° above the negative x-direction  If one of the components calculated wrongly, max 2m awarded if resultant force **AND** θ is correctly calculated based on the wrong component value.	C1 C1 A1 A1
			Most students get at least one mark. *Less than half the number of students managed to get full credit for this question.* *Students are reminded to be careful in their calculations and present their answers systematically.* *Less than 5 students are able to solve using vector triangle method and get the correct answers.*	

4	**(a)**	**(i)**	(According to Newton's third law), the gravitational force acting on star A by star B has the same magnitude as the gravitational force acting on star B by star A. Since the gravitational forces acting on each star provides its centripetal force, the centripetal forces acting on both stars have the same magnitude.	**B1** **B1**
			This part was marked quite leniently. Answers that lacked details and given BOD included "gravitational force on both stars was equal". *Many still did not get the full score. Some included equations in their answers without defining the terms. Some stated Newton's 3rd Law without applying to the context (i.e., the gravitational force or A on B is equal to the gravitational force of B on A.) Other common mistake was to state that the higher mass of B is outweighed by the larger distance from P. This was inconclusive as no quantity analysis was given.* *The most problematic answers applied N3L to the centripetal force which is conceptually wrong. N3L should be applied to actual forces, and not resultant (or centripetal) force.*	

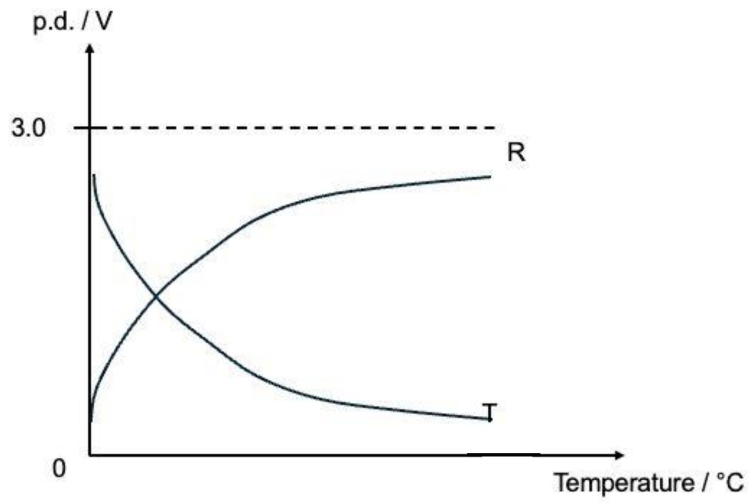
		(ii)	$\omega = \dfrac{2\pi}{T}$ $= \dfrac{2\pi}{4 \times 265 \times 24 \times 60 \times 60}$ $= 4.98 \times 10^{-8} = 5.0 \times 10^{-8}\ (2sf)$	**C1** **A1**
			Mostly well done. Some careless mistakes in calculating the final answer even though the substitution was correct.	
	(b)	**(i)**	$F_{c\text{ of A}} = M_A d\omega^2$ $F_{c\text{ on B}} = M_B\left(2.8 \times 10^8 - d\right)\omega^2$ *(Correct expression for either F_c.)* Since $F_{c\text{ of A}} = F_{c\text{ on B}}$, $M_A d\omega^2 = M_B\left(2.8 \times 10^8 - d\right)\omega^2$ $\dfrac{d}{2.8 \times 10^8 - d} = \dfrac{M_A}{M_B} = 3$ $d = 7.0 \times 10^7$ km	**C1** **C1** **A1**
			A lot of students wrongly assumed that the gravitational potential at P of both planets are the same magnitude. Some unnecessarily equated the gravitational force but substituted the wrong value of distance between the planets' centres.	
		(ii)	$F_{c\text{ of A}} = M_A d\omega^2$ $= M_A\left(7.0 \times 10^7 \times 10^3\right)\left(4.98 \times 10^{-8}\right)^2$ $F_{G\text{ on A}} = \dfrac{GM_AM_B}{r^2}$ $= \dfrac{GM_AM_B}{\left(2.8 \times 10^8 \times 10^3\right)^2}$ gravitational force provides the centripetal force $F_G = F_c$ $\dfrac{GM_AM_B}{\left(2.8 \times 10^8 \times 10^3\right)^2} = M_A\left(7.0 \times 10^7 \times 10^3\right)\left(4.98 \times 10^{-8}\right)^2$ $M_B = 2.04 \times 10^{29}\text{ kg} = 2.0 \times 10^{29}\text{ kg}\ (2\text{sf})$	**C1** **C1** **A1**

			OR $F_{c\text{ of B}} = M_B\left(2.8\times10^8\times10^3 - d\right)\omega^2$ $= M_B\left(2.8\times10^8\times10^3 - 7.0\times10^7\times10^3\right)\left(4.98\times10^{-8}\right)^2$	**(C1)**
			$F_{G\text{ on B}} = \dfrac{GM_AM_B}{r^2}$ $= \dfrac{G\left(\frac{1}{3}M_B\right)M_B}{\left(2.8\times10^8\times10^3\right)^2}$	**(C1)**
			gravitational force provides the centripetal force $F_G = F_c$ $\dfrac{G\left(\frac{1}{3}M_B\right)M_B}{\left(2.8\times10^8\times10^3\right)^2} = M_B\left(2.8\times10^8\times10^3 - 7.0\times10^7\times10^3\right)\left(4.98\times10^{-8}\right)^2$ $M_B = 2.04\times10^{29}\text{ kg} = 2.0\times10^{29}\text{ kg (2sf)}$	**(A1)**
			A good number of students could not solve this question. The most common mistake for those that attempted was to assume (wrongly) the distance r in the equation $\frac{GMm}{r^2} = mr\omega^2$ was the same for both sides. ***The distance r in the gravitational force is the distance between centres of the masses, but the distance r is the distance between the mass and the centre of the orbit, which is P.***	

5	**(a)**		Electric field strength is the electric force per unit positive charge.	**B1**
			Most students who lose the mark did not mention "positive". *Students are reminded to review their definitions prior to the examinations.*	
	(b)	**(i)**	The mobile charges (in the metal sphere) would move in an electric field. The charges would move until the net electric force or net electric field is zero.	**B1** **B1**
			More than half the number of students misunderstood the question. *The question is about why the electric field in (within) each sphere is zero, not between the 2 spheres.*	
		(ii)	At P, $E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$ $E_A = \frac{1}{4\pi\epsilon_0}\frac{3.0\times10^{-12}}{(5.0\times10^{-2})^2} = 10.79\text{ N C}^{-1}$ $E_B = \frac{1}{4\pi\epsilon_0}\frac{12.0\times10^{-12}}{(10.0\times10^{-2})^2} = 10.79\text{ N C}^{-1}$ Since E_A and E_B have the equal magnitude and opposite in direction, (the net electric field strength at point P is zero.) (Final A1 can BOD if mathematical equation is used in lieu and there is evidence that the candidate understands that *E* is a vector.)	 **M1** **M1** **A1**
			Some students lost marks due to power of ten (POT) calculation in the working such as 5 cm or 3.0 x 10^{-9} C in the substitution. *Most students who scored 2 marks did not mention why the 2 values must subtract/cancel each other. A short explanation such as the 2 fields are in opposite direction, or electric field is a vector quantity is expected.*	

		(iii)	$V_{net} = V_A + V_B$ $V_{net} = \frac{1}{4\pi\epsilon_0}\left[\frac{3.0\times10^{-12}}{5.0\times10^{-2}} + \frac{12.0\times10^{-12}}{10.0\times10^{-2}}\right]$ V_{net} = 1.618 ≈ 1.6 V	**C1** **A1**
			The most common wrong answer is 0.54 V as students subtract the 2 values instead of add.	
		(iv)	Using conservation of energy, $EPE_1 + KE_1 = EPE_2 + KE_2$ For the minimum speed so that the nucleus can reach point P, the final KE is 0. Since the nucleus starts at a long distance from point P, its initial EPE is zero. $0 + \frac{1}{2} mv^2 = qV + 0$ $\frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2 = 47 \times 1.60 \times 10^{-19} \times 1.62$ $v = 1.17 \times 10^4 \approx 1.2 \times 10^4$ m s^{-1}	**C1** **C1** **A1**
			It is satisfying to see some students to get full credit for this question. *About half the number of students get at least one mark for the conservation of energy statement.*	

6	**(a)**	**(i)**	$I = \frac{E}{R+r}$ $I = \frac{1.5}{6.0+0.25}$ $I = 0.24$ A	**C1** **A1**
			Mostly done correctly. Some ignored the internal resistance.	
		(ii)	$E = I^2Rt$ $E = 0.24^2(6.0)(5\times60)$ $E = 104$ J Allowed for ECF	**C1** **A1**
			Mostly done correctly. Some used VIt but substituted 1.5V instead of the terminal p.d. *Curiously, a significant number of candidates used Q = It to find the energy transferred.*	
		(iii)	Higher current (due to increased emf) causes the wire to <u>heat up, increasing the lattice ions vibration</u> resulting in <u>more frequent collisions with electrons. This scattering effect causes the current flow to be impeded (impede does not mean that the current decreases)</u> hence increasing the resistance of the wire.	**B1**
			There are still many lingering misconceptions when explaining the rise in resistance of the wire as a result of the voltage increase. The following are the errors. • *Wrong: Current decreases due to the frequent collisions. They justified it by using Ohm's law, R increase , I decrease. The current actually increases but not as much as the corresponding increase in the voltage. The ratio of V/I is increased and so R increased* • *Wrong:With increased p.d. or current, there will be more electrons generated or flowing. The number density of the free electrons is the same. It is the rate of flow of electrons that is changed not the number.* • *Wrong: The drift velocity decreases. The drift velocity increases because the current increases.* • *The explanation fell short of the full treatment. Most mentioned the lattice ions vibration is increased but did not explain how this will affect the electron flow due to the frequent collisions made. A scattering effect on the electrons will impede their flow – overall the resistance of the wire increases.*	

	(b)	**(i)**	The potential difference (p.d.) *V* between two points of a circuit is the electrical **energy converted per unit charge** into other forms of energy when charges move between the two points. *No mark awarded for stating 'energy transferred to a unit charge'.*	**B1**
			The explanation for the definition of the potential difference was mostly correct. However, some fell short of using the phrase 'per unit charge'. Some were not very specific about the energy transferred. Some simply stated V is defined as the product of the current and the resistance.	
		(ii)	 B1: Trend of T (exponential decrease with temperature) B1: Trend of R should mirror T If any of the graphs touch 0V or 3V, award maximum of 1 mark	 **B1** **B1**
			Many were able to interpret the NTC thermistor as a semiconductor that has decreasing R with increasing temperature. Using the principle of potential divider, they were able to deduce that the potetial difference across it follow the same trend. However, the relationship between the p.d. for R and T was unclear.	

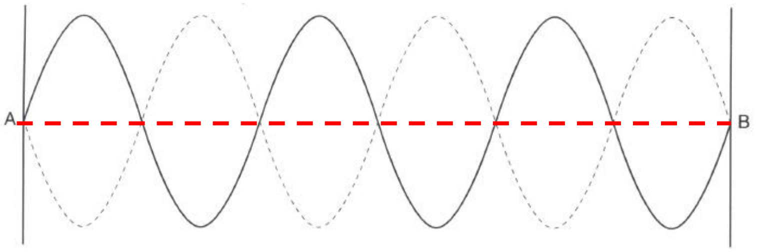
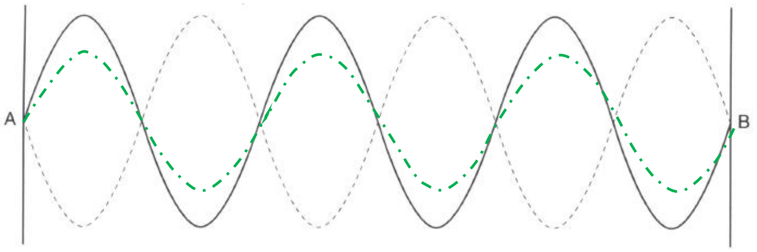
		(iii)	For V across fixed resistor to be 1.2 V at 0 °C, we assume it to have a resistance of *X*. $\frac{X}{X+10000}(3.0)=1.2$ $X=6700\ \Omega$ Using the same value of *X* at 150 °C: $V=\frac{X}{X+100}(3.0)$ $V=\frac{6700}{6700+100}(3.0)$ $V=2.96\text{ V}\quad(\neq 2.4\text{ V})$ Hence, there is no single fixed resistance value that allows for the requirement to work.	**Alternative** For V across fixed resistor to be 1.2 V at 0 °C, we assume it to have a resistance of *X*. $\frac{X}{X+10000}(3.0)=1.2$ $X=6700\ \Omega$ Finding new *X'* at 150 °C where V across fixed resistance is 2.4 V $\frac{X'}{X'+100}(3.0)=2.4$ $X'=400\Omega$ Hence, there is no single fixed resistance value that allows for the requirement to work.	**C1** **C1** **A1**
			Poorly done. The potential divider principle was not properly used leading to confusion on the quantity to be determined.		

7	**(a)**	**(i)**	smoke <u>absorbs / stops / block α-particles</u> as it has <u>weak penetrating ability</u>	**B1** **B1**
			When describing the effect smoke particles had on the alpha-particles, many students used vague words such as collide/hamper/hinder or incorrect words such as deflect. *There was hardly any mention of the weak penetrating ability of the alpha-particles.*	
		(ii)	The <u>count-rate detected</u> by the detector <u>is constant</u> over a long duration. The source should have a <u>long half-life</u>. OR The <u>count-rate does not drop to low levels in a short period of time</u>. The source should have a <u>long half-life</u>. No marks if no attempt of explaining long half-life. No marks if wrong physics in the explanation of long half-life.	**B1** **B1** **(B1)** **(B1)**
			Some students stated that long half-life is preferred because the alarm can be used for a longer time. Students are reminded to provide physics reasons as far as possible before discussing economical or functional reasons.	
	(b)	**(i)**	$^{239}_{\underline{94}}\text{U} \rightarrow {}^{\underline{235}}_{92}\text{U} + {}^{\underline{4}}_{\underline{2}}\alpha$ **All correct: 2** **One wrong: 1** **≥2 wrong: 0**	**B2**

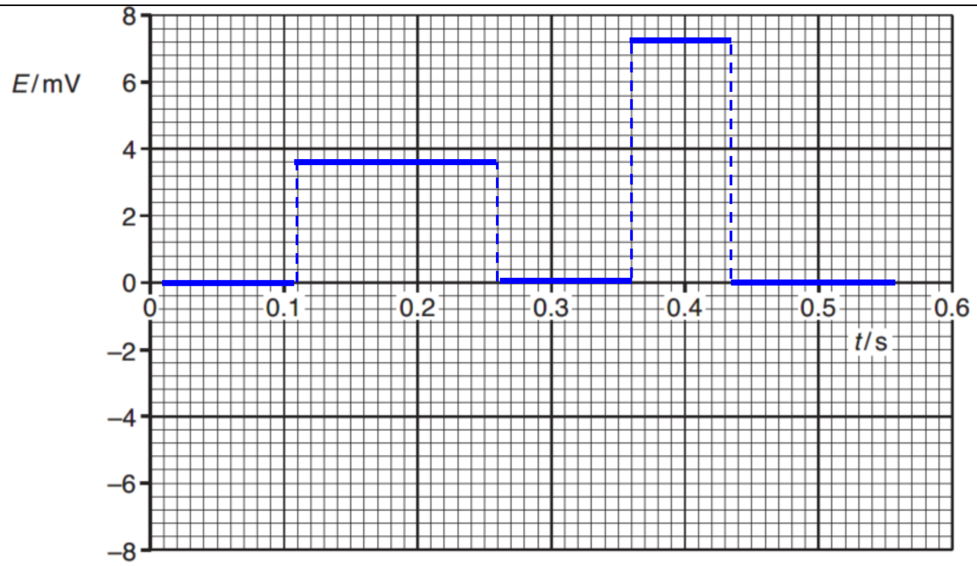
			Generally well-done. A minority of students did not know the A and Z value for an alpha-particle.	
		(ii)	Net energy released = (7.591 × 235) + (7.062 × 4) – (7.560 × 239) = 5.293 MeV (accept 2, 3 or 4 sf here)	C1 A1
			Although this was generally well-done, there was still a substantial number of students who incorrectly thought that they had to multiply c2 or u to the difference in BE. Some students also wrongly calculated the difference in BE/A.	

8	(a)	(i)	It is the rate at which energy is received per unit area perpendicular to the direction of propagation of the energy.	B1
			Poorly done. Many wrongly relate the definition of intensity to its amplitude. Some who has some understanding of intensity wrongly use cross-sectional area or did not state that it is per unit surface area.	
		(ii)	Plane polarisation of a wave refers to the limiting of the oscillation or vibration to one direction or on a single plane that is perpendicular to the direction of the energy transfer.	B1 B1
			Poorly done. Many did not indicate that the oscillation is restricted to one plane.	
	(b)		$Int = \frac{P}{A} \rightarrow I = \frac{2.5}{4\pi r^2}$ At distance r = 2.0 m away, $I = \frac{2.5}{4\pi(2)^2} \rightarrow I$ = 0.0497 W m^{-2} Using $I = k A^2$, where k is constant and A is the amplitude of the wave, (1): 1.0 = k (4 μm)^2 (2): 0.0497 = k $(A)^2$ $\frac{(2)}{(1)} : \frac{0.0497}{1} = \frac{A^2}{(4\mu m)^2}$ A = 0.892 μm Award C1 for either I = P/4Pi r^2 OR I proportional to A^2.	C1 A1
			Poorly done. Some manage to find the proportional constant for the relationship between intensity and amplitude. But many didn't use the available data to determine the intensity of the wave at 2 m or did not understand that the area is the surface area of a sphere ($4\pi r^2$).	
	(c)	(i)	Either: $\Delta\phi = \frac{\Delta x}{\lambda} \times 360°$ $= \frac{12.5 \text{ small boxes}}{50 \text{ small boxes}} \times 360°$ $= 90°$ (Accept phase difference = 270°) Or: The maximum displacement of the first graph corresponds to the zero displacement of the second graph. The phase difference is 90. (Accept phase difference = 270°)	C1 A1
			Average. Many could determine or deduce the phase difference from the graph, though some struggled with the calculation method.	

		(ii)	The two waves have the same wavelength / period despite different amplitudes. The two waves have a constant phase difference at all times.	**B1** **B1**
			Average. Many correctly stated that coherent waves require constant phase difference, though some incorrectly believed waves must be "in phase". Many failed to mention the additional requirement of same wavelength/frequency.	
	(d)	**(i)**	$\lambda = \frac{ax}{D} \rightarrow x = \frac{\lambda D}{a}$ $x = \frac{(546\times10^{-9})(1.25)}{(1.13\times10^{-3})}$ x = 6.04 × 10^{-4} m OX = 4 x = 0.00242 m = 2.42 mm = 2.42 × 10^{-3} m	 **C1** **A1**
			Average. Many correctly identified this as Young's double slit and calculated OX = 4x. Common errors included using diffraction grating formulae instead, or incorrectly stating OX = x or using wrong multiples of x.	
		(ii) 1.	(When the width of the slits is reduced, the amount of light passing through decreases.) There is an overall decrease in the intensity of the maxima. Or The contrast between the maxima and minima is reduced. The spacing of the bright fringes remains unchanged.	 **B1**
			Poorly done. Many students wrongly stated there would be no change in appearance, failing to consider that reducing slit width decreases brightness of maxima due to less light passing through. Some wrongly thought fringe separation would be affected by slit width.	
		(ii) 2.	For the part of the screen further away from the double slits, the fringe separation increases. For the part of the screen nearer to double slits, the fringe separation decreases.	**B1** **B1**
			Poorly done. Many did not understand what rotating the screen meant and incorrectly concluded that interference would cease entirely. Some recognised that the distance from slits to screen would vary across the rotated screen, but incorrectly explained that this would affect brightness rather than fringe separation.	
	(e)	**(i)**	$f = \frac{1}{T} \rightarrow f = \frac{1}{40\times10^{-12}}$ = 2.5 × 10^{10} Hz Since speed of microwave (light) = c = 3.0 × 10^8 m s^{-1} $c = f\lambda$ 3.0 × 10^8 = 2.5 × 10^{10} λ λ = 0.0120 m Counting the number of inter-nodal loops, the distance between A and B is 3λ. AB = 3λ = 3 × 0.0120 = 0.0360 m	 **C1** **C1** **A1**
			Poorly done. Many recognised that distance AB equals 3λ but couldn't calculate it because they failed to realise microwaves travel at the speed of light. Several students left this part unattempt, showing no understanding of the concept.	

		(ii) 1.	 1 mark for the horizontal line joining AB.	**B1**
			Poorly done. Many students incorrectly treated this as a progressive wave, drawing it shifting horizontally rather than recognising it as a stationary wave.	
		(ii) 2.	 Over the distance of AB, 1 mark for the displacement more than midway between zero and maximum. 1 mark for all the correct nodal points.	**B1** **B1**
			Poorly done. Many students incorrectly treated this as a progressive wave, drawing it shifting horizontally rather than recognising it as a stationary wave. Some who recognised it as a stationary wave failed to show that the displacement at t = 7T/8 is greater than at the midway point.	

9	**(a)**	**(i)**	*Faraday's law states that the magnitude of the induced e.m.f. is directly proportional to the rate of change of the magnetic flux linkage.*	**B1**
			Average. Many students recalled this definition correctly, though some omitted the directly proportional relationship and simply stated that changing magnetic flux linkage causes an e.m.f. Another common error was stating "flux" instead of "flux linkage".	
		(ii)	Lenz's law states that the direction/polarity of the induced e.m.f (tends to) causes an effect to oppose the change that produces it.	**B1**
			Poorly done. Many students failed to mention key concepts of polarity/direction and induced e.m.f. Students need to understand that induced e.m.f. only produces current in a closed circuit. The crucial idea that the induced effect opposes the change that produces it was often missing.	
	(b)	**(i)**	The direction of the magnetic field inside the solenoid is downward (labelled P).	**B1**
			Mostly well done.	
		(ii)	As the current in the solenoid is switched off, the magnetic flux linkage experienced by the small coil is decreasing. According to Lenz's Law, the small coil produces a downwards magnetic field (in the opposite direction) to oppose this decrease. On Fig. 9.3, an arrow should be drawn inside (or just above) the small coil pointing in the same direction to P, and labelled Q.	**B1** **B1** **B1**
			Challenging. Students struggled to apply Lenz's law correctly and state that the induced e.m.f. creates a downward magnetic field to oppose the decreasing magnetic flux linkage. Many wrongly state that the direction of magnetic field in small coil B is opposite to the direction of the magnetic field in P.	

		(iii)	 Zero for 0 to 0.10 s, 0.25 to 0.35 s and 0.425 to 0.55 s and non-zero outside these ranges two horizontal steps with the same polarity correct values (1st step 3.6 mV and 2nd step 7.2 mV)	**B1** **B1** **B1**
			Challenging. Most students only earned the first mark by recognising that changing magnetic field induces e.m.f., otherwise e.m.f. is zero. Many failed to realise that the magnetic field changes from 0.1-0.25s and 0.35-0.425s have the same gradient, resulting in the same polarity of e.m.f. This could also be deduced using Faraday's law by examining the gradient. Many also missed that the magnitude of induced e.m.f. differs because the gradients of the B-t graph are different.	
	(c)	**(i)**	$B = 0.72\mu_0 \frac{NI}{r}$ $0.017 = 0.72 \times 4\pi \times 10^{-7} \times \frac{N \times 12}{0.420}$ N = 657.6 ≈ 660	 **C1** **A1**
			Mostly well done, with a few making the error in the current and the radius of coil.	
		(ii)	magnetic flux = $BA \cos \theta$ = $0.017 \times \pi \times 0.36^2$ = 0.00692 ≈ 6.9×10^{-3} Wb The unit of magnetic flux is Wb (weber).	 **C1** **A1** **B1**
			Average. Most understood the magnetic flux cutting concept and calculated correctly using given values. However, some incorrectly included the number of coil turns, which is unrelated to the rotating disc, while others left this unattempted.	
		(iii)	time for one revolution = 1/25 s e.m.f. = rate of cutting flux or $\Delta\Phi/\Delta t$ = 0.00692×25 = 0.173 ≈ 0.17 V	**C1** **C1** **A1**
			Poorly done. Many didn't know how to proceed even after computing the total magnetic flux cut by the disc. Some incorrectly included the number of coil turns, which is unrelated to the rotating disc.	

		(iv)	Either According to Lenz's law, the induced current produces a braking torque that opposes the rotation of the disc.	Or According to lenz's law, the induced current will be in a direction to oppose the change of flux linkage / reduce the cutting of flux.	**B1**
			The braking torque is due to the magnetic force acting on the induced current by the magnetic field.	The wire/wheel must experience a braking force/torque that would result in a slower rotation in order to reduce the rate of change of flux linkage.	**B1**
			Using Fleming's Left-Hand Rule, the force is opposite to the direction of rotation, which indicates that the current flows from the rim to the axle.	Hence, by Fleming's left hand rule, the current must flow from rim to axle.	**B1**
			No marks awarded if no attempt of explanation even if direction of current is correct. No marks awarded if wrong physics presented in the explanation.		
			Poorly done. Most students failed to recognise that the disc's rotation causes flux cutting. To oppose this change, the induced current must oppose the disc's rotation.		

YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CG		INDEX NO	

PHYSICS 9749/04

Paper 4 Practical **28 August 2025**

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the apparatus list.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Answer **all** questions.

You will be allowed a maximum of one hour with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working, where appropriate, in the spaces provided.

Give details of the practical shift and laboratory, where appropriate, in the boxes provided.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 9
2	/13
3	/21
4	/12
Total	/55

1 In this experiment, you will investigate the oscillations of a rod.

(a) **(i)** The length of the rod is L, as shown in Fig. 1.1

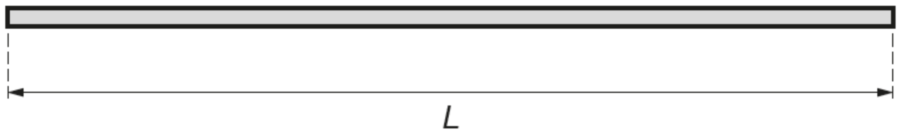


Fig. 1.1

Measure and record L.

L = ……………….………….

(ii) The mass of the rod is M.

Measure and record M.

M = ………..………………….

[1]

(iii) Calculate S, where

$$S = \frac{ML^2}{12}$$

S = ……….…………….. [1]

(b) **(i)** Wrap one end of the copper wire tightly three times around the centre of the rod, as shown in Fig. 1.2.

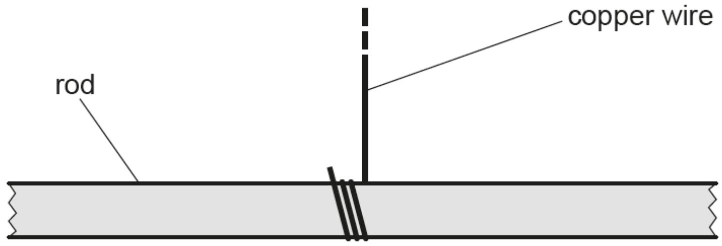


Fig. 1.2

Slide a 50 g slotted mass onto each end of the rod.

Record the mass *m* on **one** end of the rod.

m = ……………………………… g

Adjust the positions of the masses so that they are equally spaced from the centre of the rod and their centres are approximately 3 cm apart, as shown in Fig. 1.3. You may need to use some of the Blu-tack to keep the masses in position.

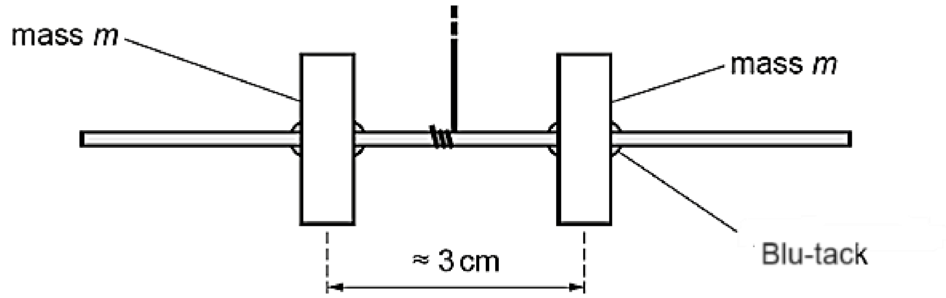


Fig. 1.3

(ii) Set up the apparatus as shown in Fig. 1.4.

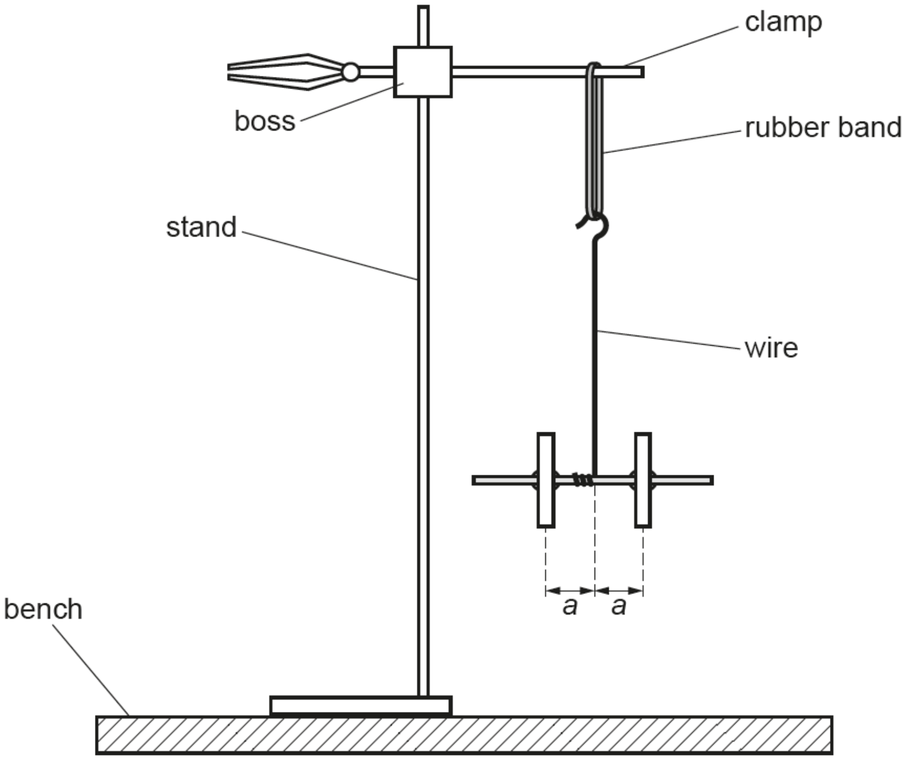


Fig. 1.4

Make a hook in the wire and place the hook on the rubber band.

The distance between the centre of each mass and the wire is *a*.

Adjust the position of the masses until the rod is parallel to the bench and each mass is the same distance *a* from the wire.

Measure and record *a*.

a = ... [1]

(c) Rotate the rod horizontally through 90°.

Release the rod. The rod will oscillate.

Take measurements to determine the period *T* of these oscillations.

T = ... [2]

(d) It is suggested that the relationship between T, S, a and m is

$$T^2 = k\,(S + a^2 m)$$

where k is a constant.

Using your data, calculate k.

k = ... [1]

(e) **(i)** Suggest two significant sources of uncertainty in this experiment.

1. ....

....

2. ....

....

[2]

(ii) Suggest an improvement that could be made to the experiment to reduce one of the uncertainties identified in **(e)(i)**.

You may suggest the use of other apparatus or a different procedure.

....

....

....

[1]

[Total: 9]

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2 In this experiment, you will determine the resistivity of a metal.

(a) Set up the circuit as shown in Fig. 2.1. The resistance wire is taped onto a metre rule.

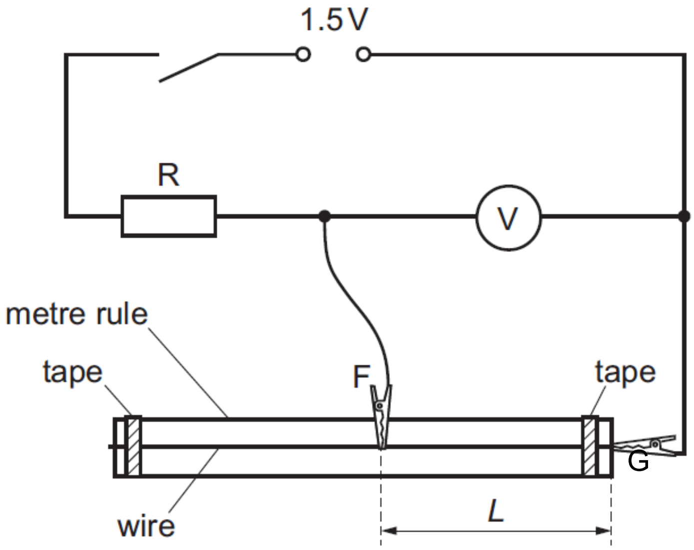

Fig. 2.1

The distance between the two crocodile clips F and G is *L*.

The reading on the voltmeter is *V*.

Adjust the position of the crocodile clip F so that *L* is approximately 45 cm.

Close the switch.

Record the value of *L* and the voltmeter reading *V*.

L = ...

V = ...

[1]

(b) Vary L by adjusting the position of F. For each position of F, measure L and V.

Present your results clearly in a table.

[4]

(c) L and V are related by the expression

$$\frac{1}{V} = \frac{J}{L} + K$$

where J and K are constants.

Plot a suitable graph to determine the values of J and K.

J = ……………………………………..

K = …………………………………….

[6]

(d) Theory suggests that

$$J = \frac{\pi d^2 K R}{4\rho}$$

where R is 33 Ω, d is the diameter of the resistance wire and ρ is the resistivity of the metal in the resistance wire.

Determine a value of ρ.

ρ = ... Ω m [2]

[Total: 13]

3 In this experiment, you will investigate the equilibrium of a metre rule.

(a) (i) You have been provided with a metre rule and a pair of attached springs. Secure the string attached to the two springs at the 1.0 cm mark of the rule.
The distance between one end of the metre rule and the string is *L*, as shown in Fig. 3.1.

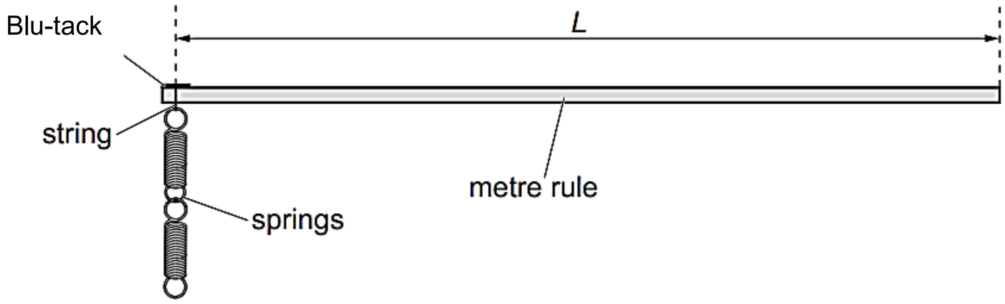

Fig. 3.1

Measure and record *L*.

L = ... [1]

(ii) Calculate *L* / *n* where *n* = 3.

L / *n* = ... [1]

(b) (i) Set up the apparatus as shown in Fig. 3.2.

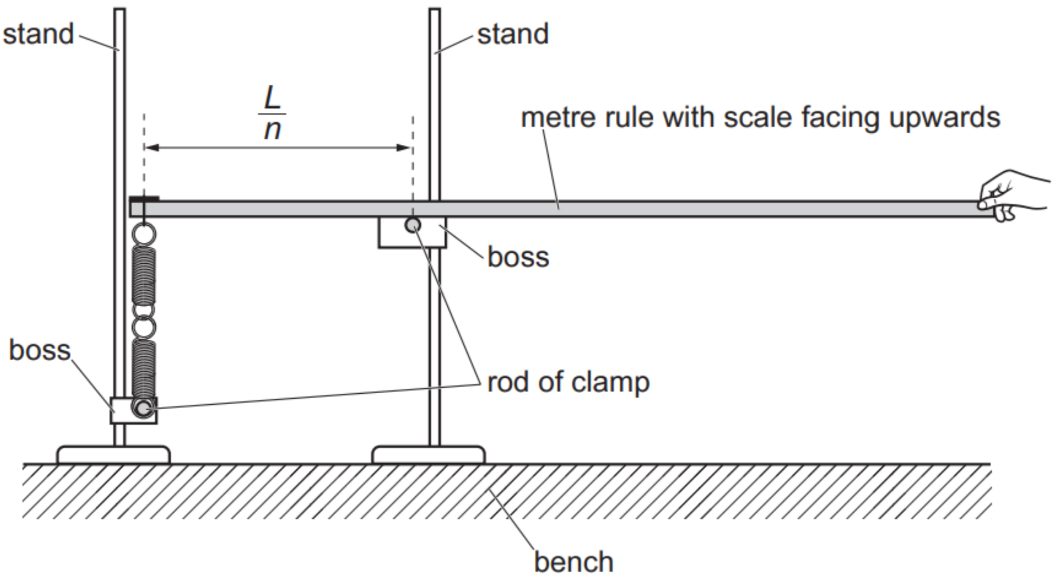

Fig. 3.2

Adjust the apparatus until the horizontal distance between the centres of the rods of the clamps is equal to your value of *L/n* .

Adjust the heights of the bosses so that the rule is horizontal and the springs are vertical and unstretched when the rule is held in position.

Gradually release the rule by lowering your hand. The rule will tilt.

The angle between the rule and the horizontal is θ, as shown in Fig. 3.3.

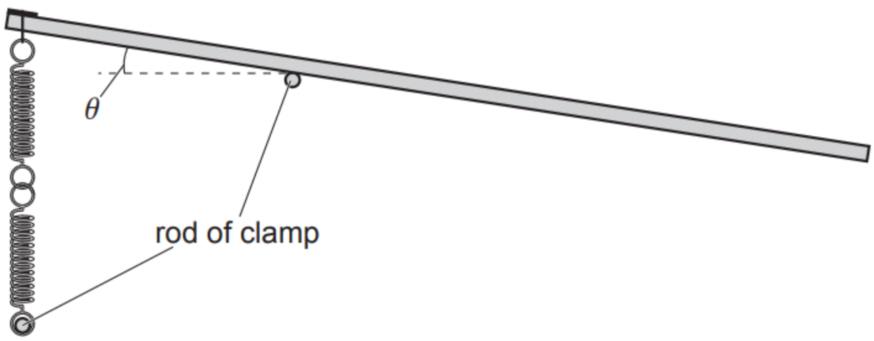

Fig. 3.3

Measure and record θ.

θ = ...° [2]

(ii) Estimate the percentage uncertainty in your value of θ. Show your working.

percentage uncertainty = ... [1]

(iii) Calculate sin θ.

sin θ = ... [1]

(c) (i) Calculate L / n where n = 3.5.

L / n = ...

Repeat **(b)(i)** and **(b)(iii)** using this value of L / n .

θ = ... °

sin θ = ...

[2]

(ii) Justify the number of significant figures that you have given for your value of sin θ in **(b)(iii)** and **(c)(i)**.

....

....

.... [1]

(d) It is suggested that the relationship between θ and n is

$$\sin\theta = C\left(\frac{n^2}{2} - n\right)$$

where C is a constant.

(i) Using your data, calculate two values of C.

first value of C = ...

second value of C = ...

[1]

(ii) With reference to part **(b)(ii)**, explain whether your results support the suggested relationship.

....

....

....

....[1]

(e) There are ways to determine the weight of a long object if a mass balance is not available. One suggested method is to support the object at some part along its long edge while the other end is resting on a horizontal surface.

Fig. 3.4 is an example of such a set up whereby the long object is a metre rule.

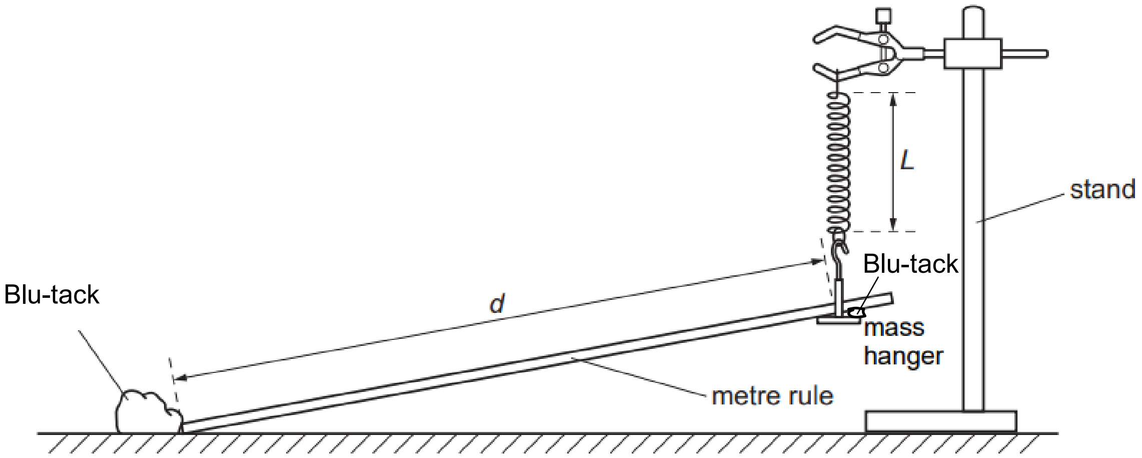

Fig. 3.4

A metre rule supported by a mass hanger that is suspended from a vertical spring, where d is the distance from the lower end of the rule to the mass hanger and L is the length of the coiled section of the spring.

It is suggested that L and d are related by the following equation:

$$L = \frac{Wd_o}{2kd} + c$$

where W is the weight of the metre rule, d_o is the length of the metre rule, k is the spring constant of value 25 N m^{-1} and c is a constant.

Plan an investigation to show that the relationship is valid and to determine W.

Your account should include:

- your experimental procedure
- how you would use your results to show that the relationship is valid
- how you would determine W.

....

....

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....[4]

(f) Complete the table in Fig. 3.5 by taking measurements according to your plan in **(e)**. Use the grid on the next page to determine the value of *W*.

d / m	*L* / m	
0.550		
0.700		
0.800		
0.950		

Fig. 3.5

W = ... N

[5]

(g) Suggest a problem with the measurement of *L* for very small values of *d*.

....

....

....

....

.... [1]

[Total: 21]

4 A DVD is type of compact disc that can store large amounts of data, especially audiovisual material of high resolution. The reflective layer on DVDs has a microscopic pattern of grooves that act like a diffraction grating.

A student is investigating the reflection of light from a DVD, as shown in Fig. 4.1.

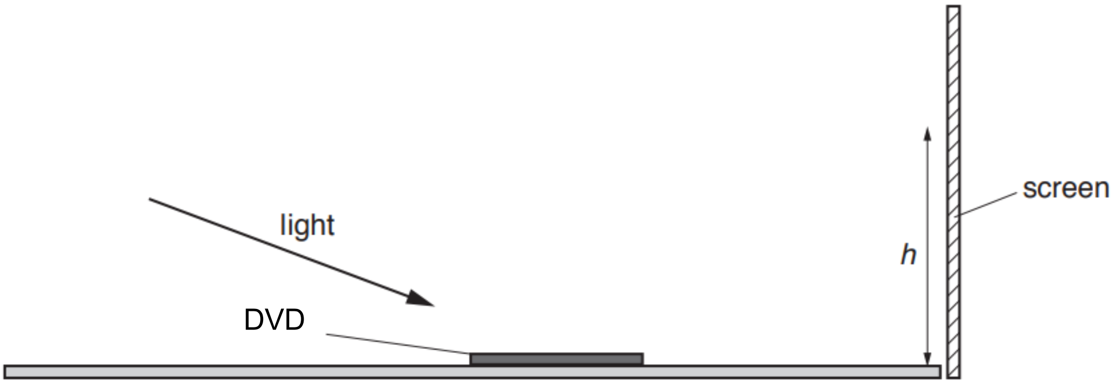

Fig. 4.1

The student observes on the screen a pattern of maxima and minima which is similar to that produced by a diffraction grating.

The distance h is measured to one of the maxima.

It is suggested that the relationship between h, the wavelength λ of the incident light and its incident angle θ (in rad) is

$$h = r\lambda^{p}\theta^{q}$$

where r, p and q are constants.

Design a laboratory experiment to determine the values of p and q.

Assume that you have a number of laser pointers of different wavelengths but the values of the wavelengths are not given.

Draw a diagram to show the arrangement of your apparatus.

You should pay particular attention to:

- the equipment you would use
- the procedure to be followed
- the control of variables
- how the wavelength of the incident light is determined
- any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

....[12]

[Total:12]

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YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CG		INDEX NO	

PHYSICS 9749/04

Paper 4 Practical

28 August 2025

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the apparatus list.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Answer **all** questions.

You will be allowed a maximum of one hour with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working, where appropriate, in the spaces provided.

Give details of the practical shift and laboratory, where appropriate, in the boxes provided.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	**/ 9**
2	**/13**
3	**/21**
4	**/12**
Total	**/55**

1 In this experiment, you will investigate the oscillations of a rod.

(a) **(i)** The length of the rod is L, as shown in Fig. 1.1

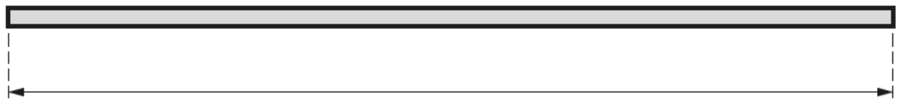


Fig. 1.1

Measure and record L.

L = 10.0 cm

(ii) The mass of the rod is M.

Measure and record M.

(2.22 + 2.25 + 2.23) / 3

M = 2.23 g

[1]

L – Precision: nearest 0.1 cm or 0.001 m. Accuracy: 9.5 cm to 10.5 cm M – Repeat reading. Precision: nearest 0.1 g or 0.01 g. Accuracy: 2.0 g to 2.5 g [1]

(iii) Calculate S, where

$$S = \frac{ML^2}{12}$$

$$S = \frac{\left(2.23\times10^{-3}\right)\left(10.0\times10^{-2}\right)^2}{12} = 1.86\times10^{-6}\,\text{kg m}^2$$

Correct calculation. Correct precision: correct sf based on L and M. Correct units (kg m^2 or kg cm^2 or 18.6 g cm^2) [1]

S = 1.86×10^{-6} kg m^2

[1]

(b) **(i)** Wrap one end of the copper wire tightly three times around the centre of the rod, as shown in Fig. 1.2.

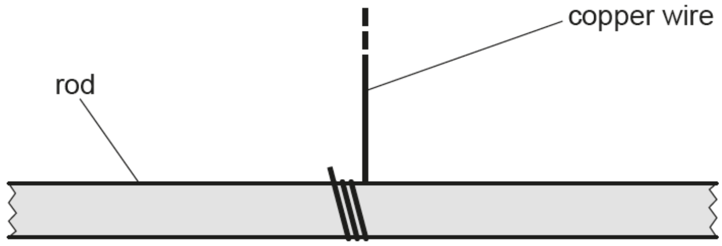


Fig. 1.2

Slide a 50 g slotted mass onto each end of the rod.

Record the mass *m* on **one** end of the rod.

m = ... g 50

Adjust the positions of the masses so that they are equally spaced from the centre of the rod and their centres are approximately 3 cm apart, as shown in Fig. 1.3. Use some of the Blu-tack to keep the masses in position.

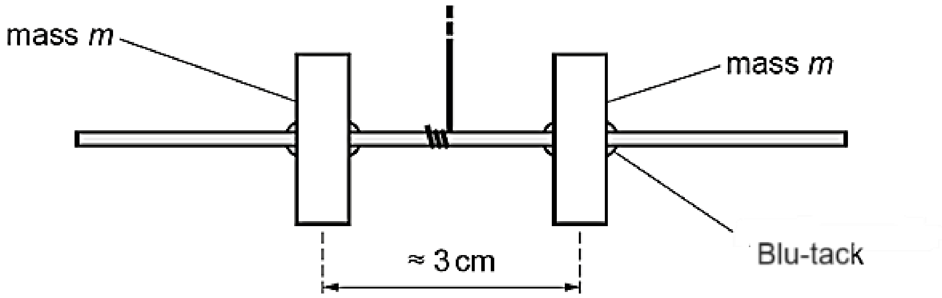


Fig. 1.3

(ii) Set up the apparatus as shown in Fig. 1.4.

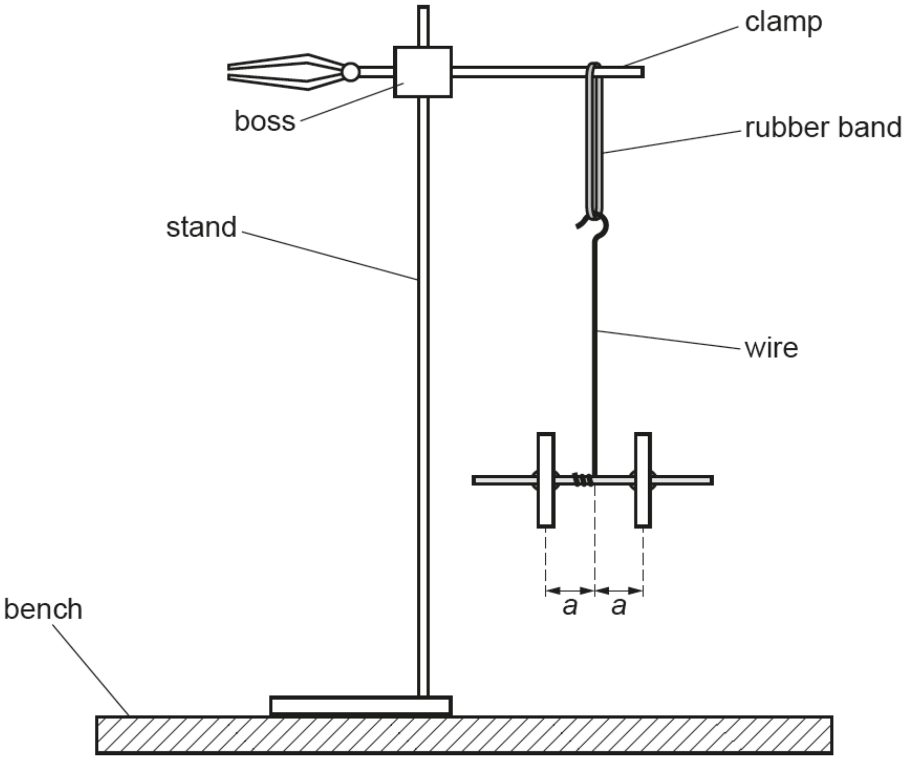


Fig. 1.4

Make a hook in the wire and place the hook on the rubber band.

Adjust the position of the masses until the rod is parallel to the bench and each mass is the same distance *a* from the wire.

The distance between the centre of each mass and the wire is *a*.

Measure and record *a*.

a_1 = 1.5 cm, a_2= 1.5 cm

Average *a* = 1.5 cm

a = 1.5 cm

[1]

Repeated readings of *a*. **OR** Measure separation *d* and divide by 2.

AND
Precision: to nearest 0.1 cm

[1]

(c) Rotate the rod horizontally through 90°.

Release the rod. The rod will oscillate about the vertical axis.

Take measurements to determine the period T of these oscillations.

Time for 10 oscillations = 41.48 s , 41.50 s

Average period T = (41.48+41.50)/(2×10) = 4.149 s

Raw total time for N oscillation is more than 20s
Repeated readings
Precision of raw time: nearest 0.1 s or 0.01s
Accuracy: T = 3.8 s to 4s.8 s [1]

Correct calculation
Precision: Correct sf (3 or 4sf) for calculated data based on raw data (t) [1]

T = 4.149 s [2]

(d) It is suggested that the relationship between T, S, a and m is

$$T^2 = k\,(S + a^2 m)$$

where k is a constant.

Using your data, calculate k.

$$(4.149)^2 = k\,[(1.86\times10^{-6}) + (1.5\times10^{-2})^2(0.050)]$$

$$k = 1.3\times10^{6}\ \text{s}^2\ \text{kg}^{-1}\ \text{m}^{-2}$$

Correct calculation
Correct precision: 2 sf
Correct SI units (or 0.13 $\text{s}^2\ \text{g}^{-1}\ \text{cm}^{-2}$) [1]

k = $1.3\times10^{6}\ \text{s}^2\ \text{kg}^{-1}\ \text{m}^{-2}$ [1]

(e) **(i)** Suggest two significant sources of uncertainty in this experiment.

1. The placement of the slotted masses may not be symmetrical about the copper wire which can result in the dumbbell being slightly lopsided. This in turn can affect the oscillations and the accuracy of the measurement of a.

2. Due to the substantial thickness of the slotted mass and the separation of their centres being relatively small, the percentage uncertainty of the separation can be significant.

3. The inclusion of the Blu-tac poses an additional mass to the value of m. This may affect the accuracy of the value of k.

4. Because the setup is rather lightweight, the oscillations can be affected easily by the wind. This will have an impact on the period. (accept with valid reason) (if stated error due wind only then no mark is given) [2]

Any two of the above or other suggestions that are reasonable and valid. [2]

(ii) Suggest an improvement that could be made to the experiment to reduce one of the uncertainties identified in **(e)(i)**.

You may suggest the use of other apparatus or a different procedure.

- For (1) and (2), we can improve by doing following:
- We can measure the thickness of the slotted mass using a vernier caliper and divided it by 2. Making a centre mark on the mass will help to make the measurement of the separation of the centres more accurate. This in turn can allow the wire to be positioned more accurately at the halfway mark while ensuring the dumbbell is level.
- (3) measure the mass of the Blu-tack after the experiment and add to the value of *m*.
- (4) The experiment can be carried out within a wind shield.

[1]

Suggestion that addresses one of the uncertainties identified in (e)(i) and is reasonable and valid. [1]

[Total: 9]

2 In this experiment, you will determine the resistivity of a metal.

(a) Set up the circuit as shown in Fig. 2.1. The resistance wire is taped onto a metre rule.

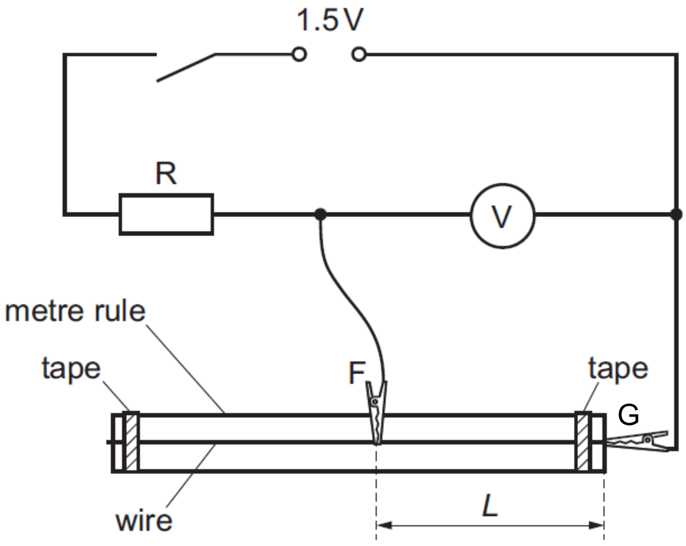


Fig. 2.1

The distance between the two crocodile clips F and G is *L*.

The reading on the voltmeter is *V*.

Adjust the position of the crocodile clip F so that *L* is approximately 45 cm.

Close the switch.

Record the value of *L* and the voltmeter reading *V*

L – Precision: 0.1 cm or 0.001m

V – Precision: 0.001 V (multimeter set to 2000mV).
Accuracy: 0.240 V – 0.400 V

[1]

(Repeated readings not required here.)

L = 45.0 cm

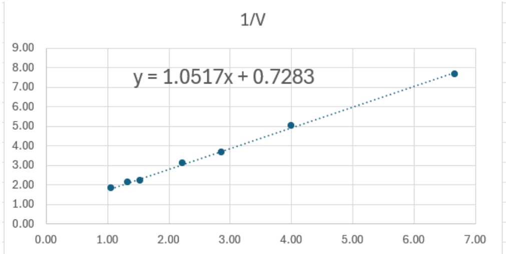
V = 0.322 V

[1]

(b) Vary L by adjusting the position of F. For each position of F, measure L and V.

Present your results clearly in a table.

L / m	V / V	$\frac{1}{L}$ / m^{-1}	$\frac{1}{V}$ / V^{-1}
0.150	0.130	6.67	7.69
0.250	0.198	4.00	5.05
0.350	0.272	2.86	3.68
0.450	0.322	2.22	3.11
0.650	0.448	1.54	2.23
0.750	0.466	1.33	2.15
0.950	0.546	1.05	1.83



At least 6 sets of readings of L and V without assistance. [1]

Range of L is at least 70.0 cm
Precision of raw data. L is 0.001 m and V is 0.001 V [1]

Each column heading must contain a quantity and corresponding correct unit. [1]
Do not accept units in the form 1/m or 1/V.
Do not accept if there are no calculated values in the table.

Correct calculated values. (Waive for one miscalculation.)
Number of s.f. for cal. data to follow that of raw data (allow for 1 extra s.f.) [1]

[4]

(c) V and L are related by the expression

$$\frac{1}{V} = \frac{J}{L} + K$$

where J and K are constants.

Plot a suitable graph to determine the values of J and K.

Plotting a graph of 1/V against 1/L gives a gradient of J and a y-intercept of K

J = gradient = $\frac{(7.00 - 1.75)}{(6.00 - 1.00)} = 1.05 \text{ m } V^{-1}$

J = 1.05 m V^{-1}

Reading from graph
K = y-intercept = 0.70 V^{-1}

By calculation
y=mx+c
7.00 = (1.05)(6.00) + c
K = c = 0.700 V^{-1}

K = 0.700 V^{-1}

Evidence of correct linearisation (plot correct y and x axis) [1]

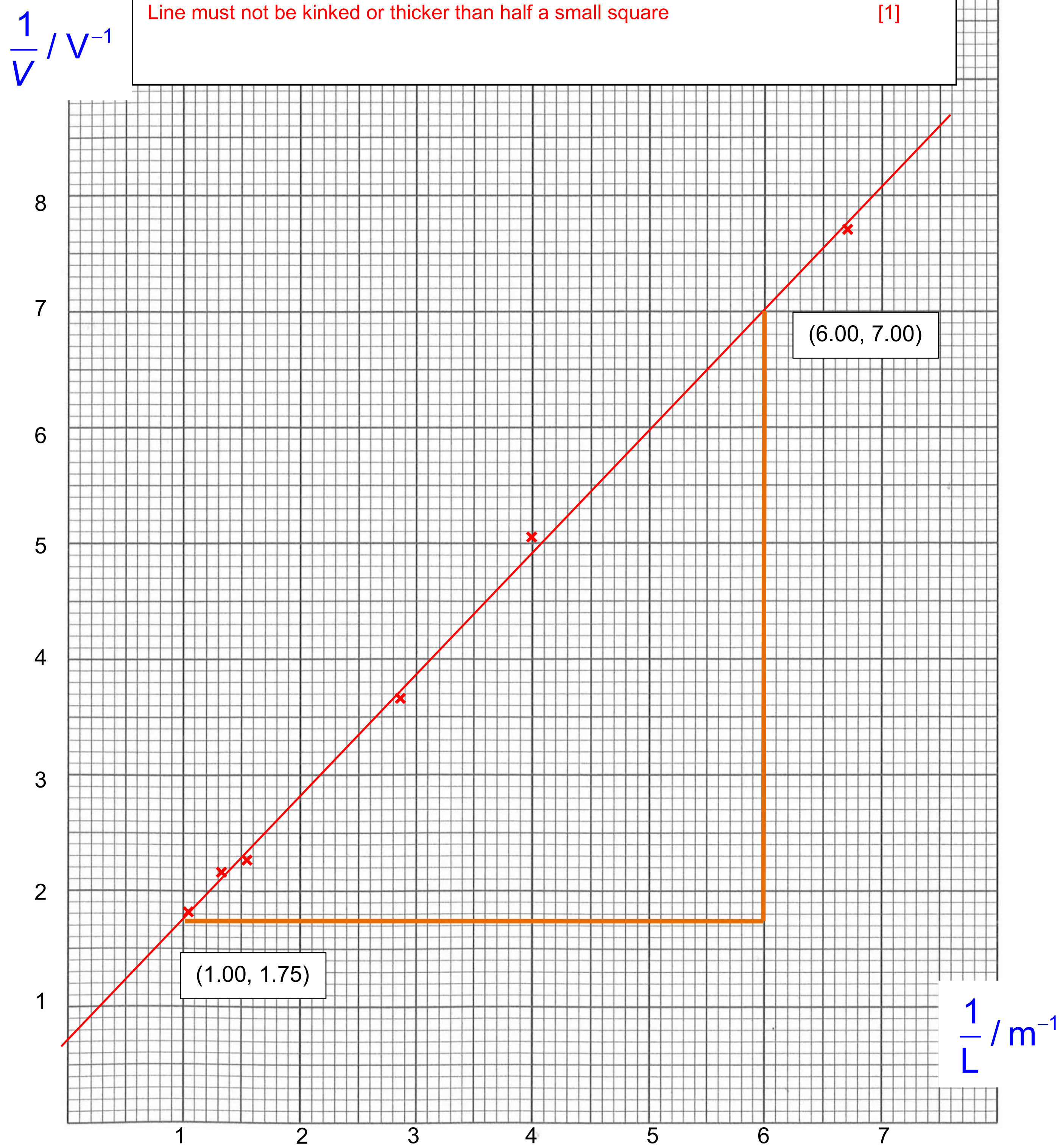
Hypotenuse of gradient triangle at least half the length of drawn line.
Read-offs accurate to half a small square in both x and y directions.
Gradient correctly calculated and expressed in 3 s.f. [1]

Correct calculation for finding the y-intercept OR correctly read from graph accurate to ½ small square.
Values of J and K are in 3sf.
Correct units for J (m V^{-1} or cm V^{-1}) and K (V^{-1}) [1]

Sensible choice of scale for axis, (eg 1:1, 1:2, 1.25, 1:4, 1:5). No awkward scales (eg 3:10).
Plotted graph occupies at least ½ graph paper in both x and y direction. (4 sq by 6 sq)
Scales must be labelled with qty that is plotted.
Scale markings should be no more than 2 large squares apart [1]

Accuracy of points plotted (any 3) to ½ small square.
Allow one anomalous point only if clearly indicated (i.e., circled or labelled). [1]

Line of best fit. Judge by balance of all points on the grid. Must have even distributions of points on either side of the line.
Line must not be kinked or thicker than half a small square [1]



(d) Theory suggests that

$$J = \frac{\pi d^2 KR}{4\rho}$$

where R is 33 Ω , d is the diameter of the resistance wire and ρ is the resistivity of the metal in the resistance wire.

Determine a value of ρ.

Average d = (0.27 + 0.27)/2 = 0.27 mm

$$1.05 = \frac{\pi\left(0.27\times10^{-3}\right)^2(0.700)(33)}{4\rho}$$

$\rho = 1.3\times10^{-6}$ Ωm

d – Repeated readings Precision: to nearest 0.01 mm. Accuracy: 0.25 mm– 0.30 mm [1] ρ - Correct calculation. Precision: Correct sf (2sf) for calculated data based on raw data (d) [1]

ρ = 1.3×10^{-6} Ωm .... Ω m [2]

[Total: 13]

3 In this experiment, you will investigate the equilibrium of a metre rule.

(a) (i) You have been provided with a metre rule and a pair of attached springs. Secure the string attached to the two springs at the 1.0 cm mark of the rule.
The distance between one end of the metre rule and the string is L, as shown in Fig. 3.1.

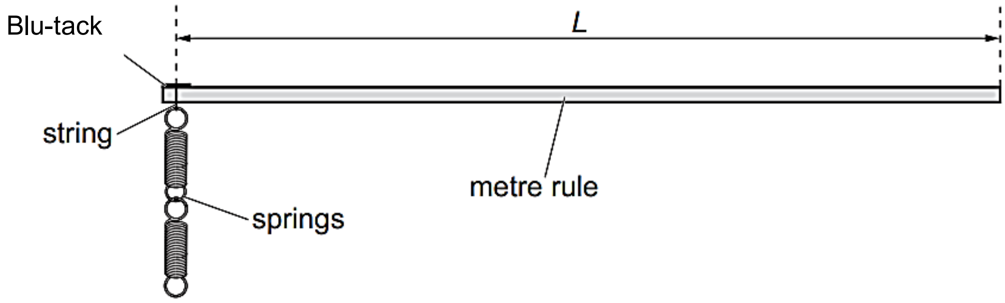


Fig. 3.1

Measure and record L.

L – Precision: to 1 mm or 0.1 cm or 0.001 m.
Accuracy: 98.5 cm to 99.5 cm [1]

L = 99.0 cm [1]

(ii) Calculate $\frac{L}{n}$ where $n = 3$.

L/n – Correctly calculated. Precision: Correct sf (3sf) for calculated data based on raw data (L) [1]

$\frac{L}{n}$ = 33.0 cm [1]

(b) (i) Set up the apparatus as shown in Fig. 3.2.

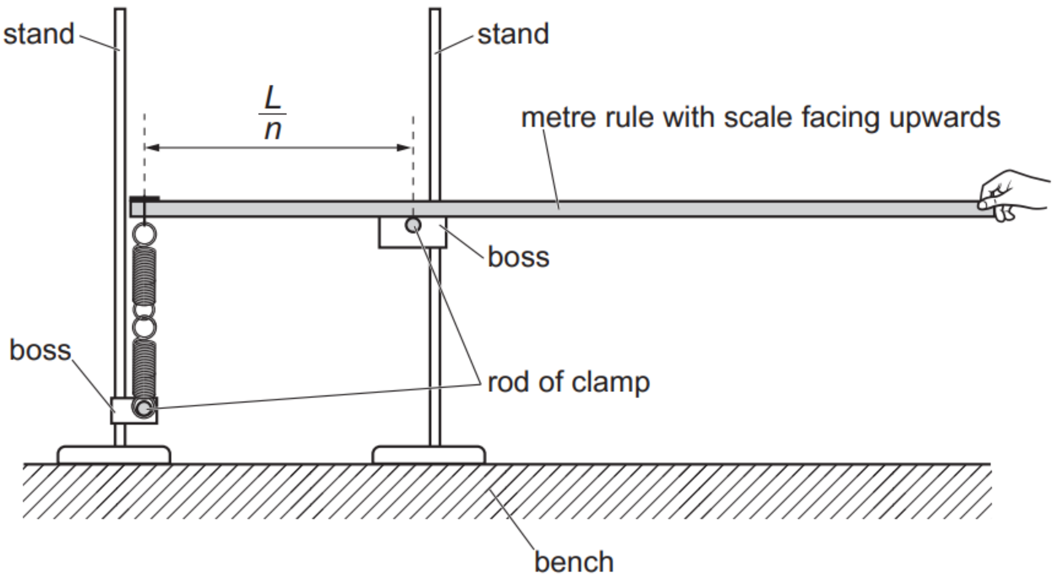


Fig. 3.2

Adjust the apparatus until the horizontal distance between the centres of the rods of the clamps is equal to your value of *L/n* .

Adjust the heights of the bosses so that the rule is horizontal and the springs are vertical and unstretched when the rule is held in position.

Gradually release the rule by lowering your hand. The rule will tilt.

The angle between the rule and the horizontal is θ, as shown in Fig. 3.3.

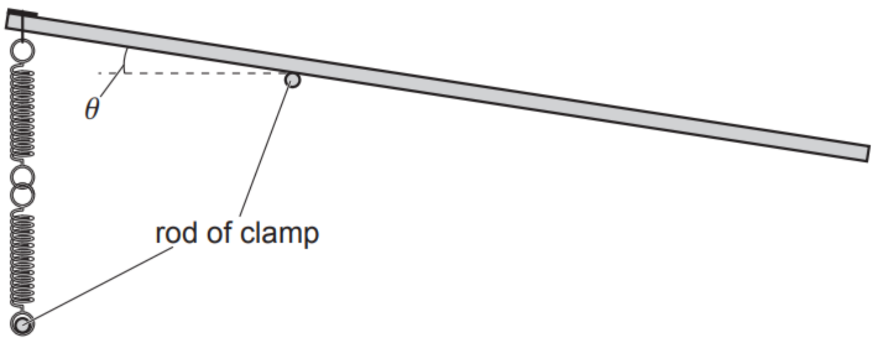


Fig. 3.3

Measure and record θ.

θ - Repeated measurement. [1]

Correct calculation of average value. Precision: to nearest degree. Accuracy: 2° – 8° [1]

Ave value of θ = (4° + 5°) ÷ 2 = 5°

θ = ...5............° [2]

(ii) Estimate the percentage uncertainty in your value of θ. Show your working.

$\Delta\theta$ - 2° to 4°
Correct calculation of percentage uncertainty. Precision: to 2 s.f. [1]

($\Delta\theta$ should be less than or equal to value of θ.)

2°/5° × 100% = 40%

percentage uncertainty = ...40%............ [1]

(iii) Calculate sin θ.

sin θ - Correct calculation.
Precision: follows the s.f. of θ or +1 s.f.. [1]

sin θ = 0.087 [1]

(c) (i) Calculate L / n where n = 3.5.

L / n = 28.3 cm

Repeat **(b)(i)** and **(b)(iii)** using this value of L/n.

Ave value of θ = (8° + 8°) ÷ 2 = 8°

L / n and sin θ calculated correctly, Precision: Correct sf (3sf) for calculated data based on raw data (θ and L). [1]

Value of θ is larger than in **(b)(i)** [1]

θ = 8 °

sin θ = 0.14

[2]

(ii) Justify the number of significant figures that you have given for your value of sin θ in **(b)(iii)** and **(c)(i)**.

The number of s.f. follows the s.f. of θ, which is 1 sf plus 1 to distinguish the two values. [1]

[1]

(d) It is suggested that the relationship between θ and n is

$$\sin\theta = C\left(\frac{n^2}{2} - n\right)$$

where C is a constant.

C – Correct calculation.
Precision: Correct sf (2sf) for calculated data based on raw data (θ).
Correct units (no units). [1]

(i) Using your data, calculate two values of C.

C_1 = 0.087 / (3^2/2 – 3)
= 0.058

C_2 = 0.14 / (3.5^2/2 – 3.5)
= 0.053

first value of C = 0.058

second value of C = 0.053

[1]

(ii) With reference to part **(b)(ii)**, explain whether your results support the suggested relationship.

Percentage difference = 100% × (0.058 – 0.053)/0.053
= 9.4 %

Since percentage difference is less than percentage uncertainty in (b)(ii), the results support the suggested relationship.

....[1]

Calculation of percentage difference
AND

If percentage difference > percentage uncertainty, results do not support suggested relationship
OR
If percentage difference <= percentage uncertainty, results support suggested relationship

[1]

(e) There are ways to determine the weight of a long object if a mass balance is not available. One suggested method is to support the object at some part along its long edge while the other end is resting on a horizontal surface.

Fig. 3.4 is an example of such a set up whereby the long object is a metre rule.

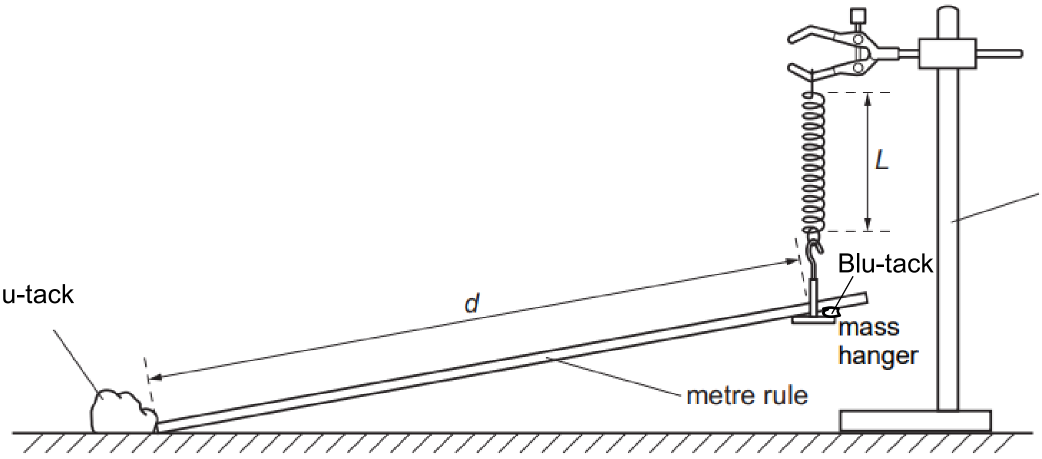


Fig. 3.4

A metre rule supported by a mass hanger that is suspended from a vertical spring, whereby *d* is the distance from the lower end of the rule to the mass hanger and *L* is the length of the coiled section of the spring.

It is suggested that *L* and *d* are related by the following equation:

$$L = \frac{Wd_o}{2kd} + c$$

where *W* is the weight of the metre rule, d_o is the length of the metre rule, *k* is the spring constant of value 25 N m^{-1} and *c* is a constant.

Plan an investigation to show that the relationship is valid and to determine *W*.

Your account should include:

- your experimental procedure
- how you would use your results to show that the relationship is valid
- how you would determine *W*.

M1	Basic procedure : ☐ *d* is varied, *d* and d_o are read off, *L* is measured using rule	1
A1	☐ graph of *L* against *1/d* is plotted	1
A2	☐ If linear graph is obtained, relationship is valid	1
A3	☐ *W* is obtained from gradient × $2k/d_0$	1

1. Set up the apparatus as shown in Fig. 3.4.
2. Read off from the metre rule the value of d_o.
3. Read off from the metre rule the value of *d*.
4. For this value of *d*, measure *L* using a rule.
5. Repeat steps 3-4 for five other values of *d*.
6. For each value of *d*, calculate corresponding value of 1/*d*.
7. Plot a graph of *L* vs 1/*d*.
8. If a linear graph is obtained, the given relationship is valid.
9. *W* is obtained from gradient × 2*k* ÷ d_o

[4]

(f) Complete the table of Fig. 3.5 below by taking measurements according to your plan in **(e)**. Use the grid on the next page to determine the value of *W*.

d / m	*L* / m	1/*d* / m^{-1}
0.550	0.087	1.82
0.700	0.080	1.43
0.800	0.076	1.25
0.950	0.072	1.05

Fig. 3.5

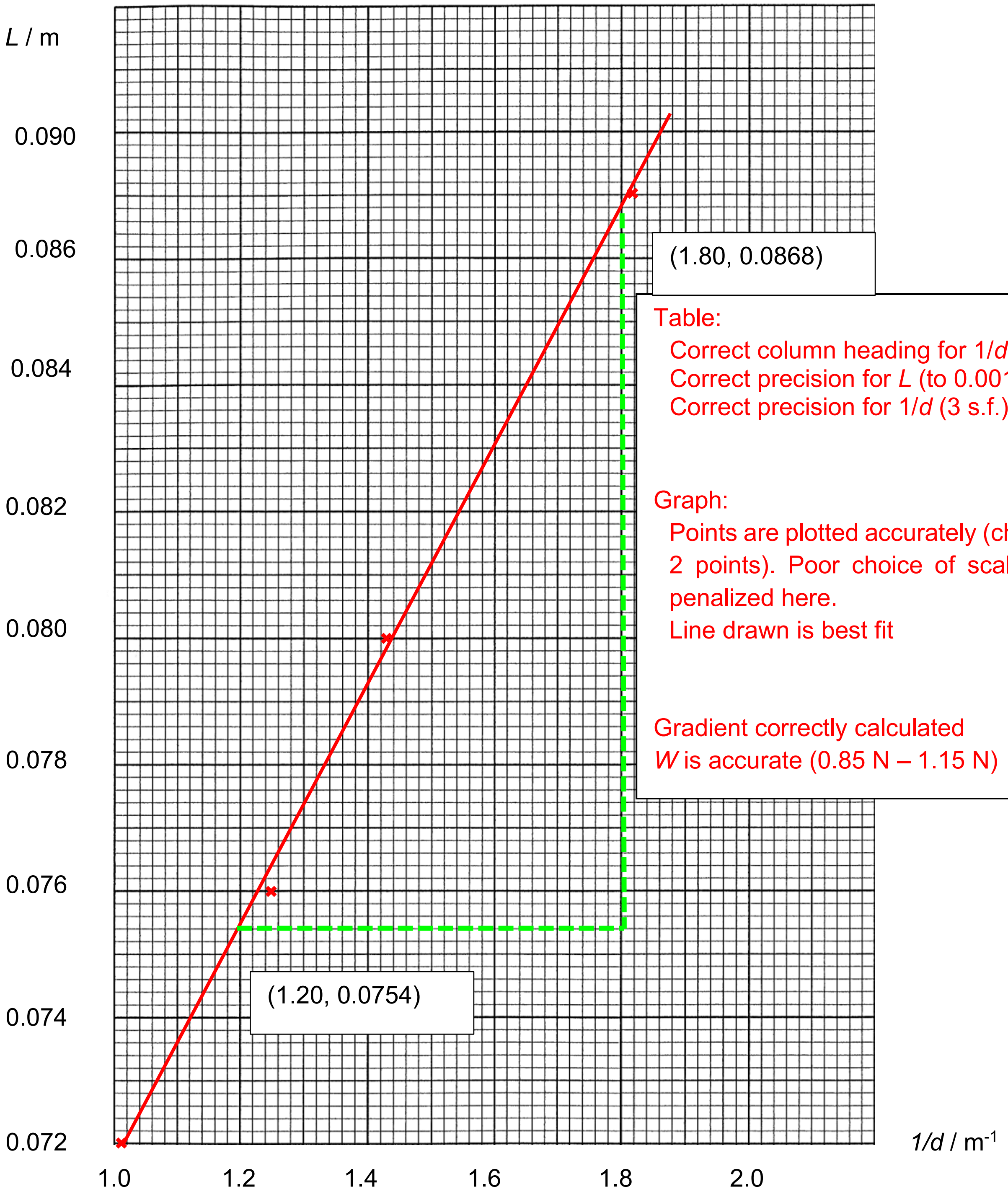


Table:

Correct column heading for 1/*d*
Correct precision for *L* (to 0.001 m)
Correct precision for 1/*d* (3 s.f.) [1]

Graph:

Points are plotted accurately (check 2 points). Poor choice of scale is penalized here. [1]
Line drawn is best fit [1]

Gradient correctly calculated [1]
W is accurate (0.85 N – 1.15 N) [1]

Gradient = (0.0868-0.0754)/(1.80-1.20) = 0.0190 m^2

Thus 0.0190 = *W* (1.000) ÷ (2 × 25)
⇒ *W* = 0.0190 × (2 × 25) ÷ 1.000
= 0.95 N

W = ………………………… N [5]

(g) Suggest a problem with the measurement of *L* for very small values of *d*.

For very small values of *d*, the values of *L* could be so large that the elastic limit of the spring is exceeded / spring is deformed / limit of proportionality of the spring is exceeded. [1]

....[1]

[Total: 21]

4 A DVD is a type of compact disc that can store large amounts of data, especially audiovisual material of high resolution. The reflective layer on DVDs has a microscopic pattern of grooves that act like a diffraction grating.

A student is investigating the reflection of light from a DVD, as shown in Fig. 4.1.

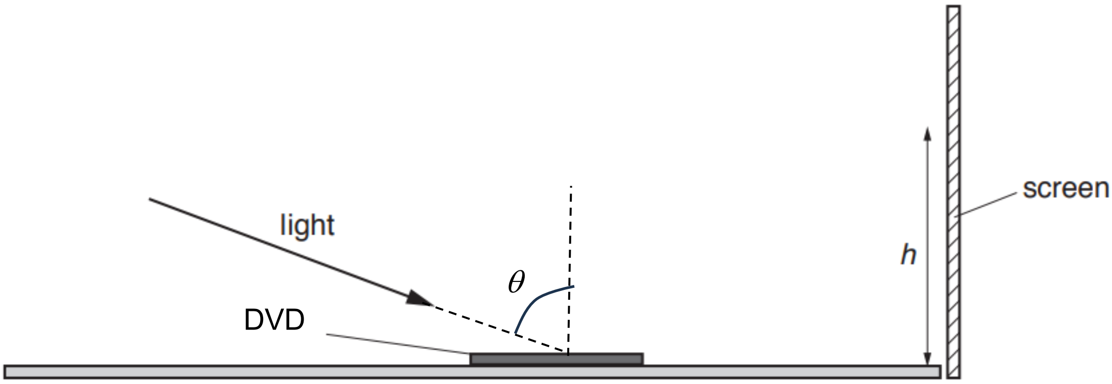


Fig. 4.1

The student observes on the screen a pattern of maxima and minima which is similar to that produced by a diffraction grating.

The distance h is measured to one of the maxima.

It is suggested that the relationship between h, the wavelength λ of the incident light and its incident angle θ (in rad) is

$$h = r\lambda^{p}\theta^{q}$$

where r, p and q are constants.

Design a laboratory experiment to determine the values of p and q.

Assume that you have a number of laser pointers of different wavelengths but the values of the wavelengths are not given.

Draw a diagram to show the arrangement of your apparatus.

You should pay particular attention to:

- the equipment you would use
- the procedure to be followed
- the control of variables
- how the wavelength of the incident light is determined
- any precautions that should be taken to improve the accuracy and safety of the experiment.

[Total:12]

Question 4 (Planning)

Suggested Marking Scheme

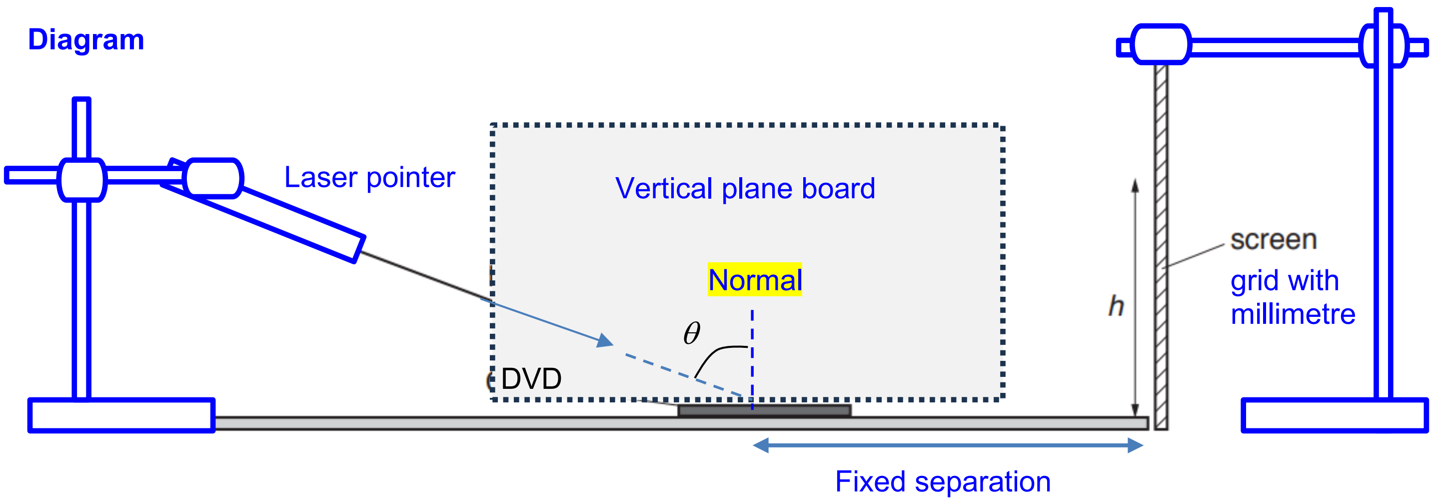
Symbol		Marks
D	Defining the problem	2
M	Procedure / Methods of data collection	5
R	Reliability precautions	2
A	Method of analysis	2
S	Safety precautions	1
	Total	12

Marking Scheme

	Defining the problem (max 2 marks)		**Marks**
D1	☐ The distance/height *h* is the dependent variable. ☐ The wavelength λ of the incident light (ray) and the incident angle θ are the independent variables.	1	
D2	☐ At least one controlled variable: 1. Fixed the distance between the screen and the point where the light (ray) is incident on the DVD. 2. *n*, the order of the maximum	1	
	Procedure / Methods of data collection (max 5 marks)		
M1	Labelled diagram of workable arrangement including: ☐ Laser source/pointer ☐ Laser pointer held by retort clamp ☐ Screen held by wall/retort stand (Reject setup which has no label and which lack essential parts. No ‘floating’ apparatus allowed)	1	
M2	Method to determine λ : ☐ Pass the laser beam through a separate set-up, eg Young’s double-slit (just state, no need to draw) or diffraction expt. ☐ The wavelength λ is obtained by $\lambda = ax/D$ where *a* is the slit separation of the double-slit, *x* and *D* are measured using a metre rule.	1	
M3	☐ Instrument to measure *h* : metre rule	1	
M4	☐ Instrument to measure θ : protractor ☐ Convert θ from degrees to radians	1	
M5	☐ Evidence of experiment carried out with *h* and λ, to find *p*. Here, θ is fixed. **AND** ☐ Evidence of experiment carried out with *h* and θ., to find *q*. Here, λ is fixed.	1	
	Reliability precautions (max 2 marks)		
R1 **R2**	Any 2 of below: • Perform experiment in a dim or dark room so that the maxima and minima of the light on the screen are due solely to the laser source.	2	

	• Keep the distance between the screen and the point where the light (ray) is incident on the DVD fixed by fixing the screen position and fixing the point of incidence. • To measure the angle of incidence θ more accurately, place a piece of white paper/cardboard as background. Using a set square, draw a line perpendicular to the plane of the DVD. Direct the laser ray at the point of intersection of the drawn line and the DVD plane. • The light beam may not be visible and so measuring the angle of incidence would be difficult. Use a smoke screen or angle the laser beam slightly relative the planar surface for the beam so as to make the beam visible. • Measure h to the same order of maximum, say n = 1. The order of maxima for n=0 is where the angle of incidence and the angle of reflection is the same. Thus, we can take reference from this maximum. • Ensure that the screen is perpendicular to the DVD plane by use of a set square so that h is more accurate • Details on measuring h (base to the top) then take average		
	Method of analysis (max 2 marks)		
A1	Two graphs are plotted. Experiment 1 (fixed θ) log h vs log λ is plotted. The gradient of best-fit line gives value of p	1	
A2	Experiment 2 (fixed λ) log h vs log θ is plotted. The gradient of best-fit line gives value of q	1	
	Safety precautions (max 1 mark)		
S1	Safety precaution linked to exposure of eyes to (intense) light, e.g. ~~-~~wear dark glasses or wear shaded/tinted goggles to protect eyes from the intense light.	1	
	Total	12	

Diagram



Variables

The dependent variable is *h*, the distance from the edge of the screen to the first maxima on the screen.

The independent variables are the wavelength λ of the incident light (beam/ray) and the incident angle θ.

The controlled variables are (a) the distance between the screen and the point where the light is incident on the DVD and (b) the order of the maxima

Procedure

1) Set up the apparatus as shown.

Experiment A:

2) Switch on the laser pointer and direct the beam towards a specific point on the DVD.
3) Read off the distance *h*, from the millimetre scale (OR measure *h* using a metre rule).
4) Determine the wavelength λ of the laser light by passing it through a Young's double slit arrangement.
5) The wavelength λ is obtained by the formula $\lambda = ax/D$ where *a* is obtained from the specifications of the double-slit, *x* and *D* are measured using a metre rule.
6) Repeat steps 3 – 5 by varying the wavelength using different laser pointers but directing the beam to the same point on the DVD.

Experiment B:

7) Repeat step 2.
8) Measure the angle θ using a protractor.
9) Convert the angle to radians.
10) Repeat step 3.
11) Repeat steps 7-10 by varying the height of the laser pointer but directing the beam to the same point on the DVD. The wavelength of the beam is unchanged.

Analysis

From experiment A (fixed θ), a graph of log h vs log λ is plotted. The gradient of best-fit line gives value of p.

From experiment B (fixed λ), a graph of log h vs log θ is plotted. The gradient of best-fit line gives value of q.

Reliability precautions

- Keep the distance between the screen and the point where the light (ray) is incident on the DVD fixed by fixing the screen position and fixing the point of incidence
- Measure h to the same order of maximum, say $n = 1$.
- Ensure that the screen is perpendicular to the DVD plane by use of a set square so that h is more accurate
- Perform experiment in a dark room so that the maxima and minima are due solely to the laser source
- Use a smoke screen or tilt the laser beam slightly to the vertical plane containing the beam. This will make the beam visible so that the angle can be measured.
- Details on measuring h (e.g. measure to the top and bottom of the maximum and then take average)
- To fix the point of incident on the DVD more precisely, place a piece of white cardboard as background. Draw a line perpendicular to the plane of the DVD. Direct the laser ray at the point of intersection of the drawn line and the DVD plane.

Safety Precautions

- Wear dark glasses to protect eyes from exposure to the intense light