MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9749/01

Paper 1 Multiple Choice **20 September 2018**

1 hour

Additional Materials: Optical Mark Sheet (OMS)

Candidate Name: ______________________

Class	Reg No

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
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In the Index Number section, shade your index number using the first two spaces (e.g. index number 5 should be entered as "05"). Ignore the remaining numbers and letters.

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

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_0	=	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
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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	=	$-Gm/r$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translation kinetic energy 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	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_o{}^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\frac{\mu_0 I}{2\pi d}$
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radioactive decay	x	=	$x_0 \exp(-\lambda t)$
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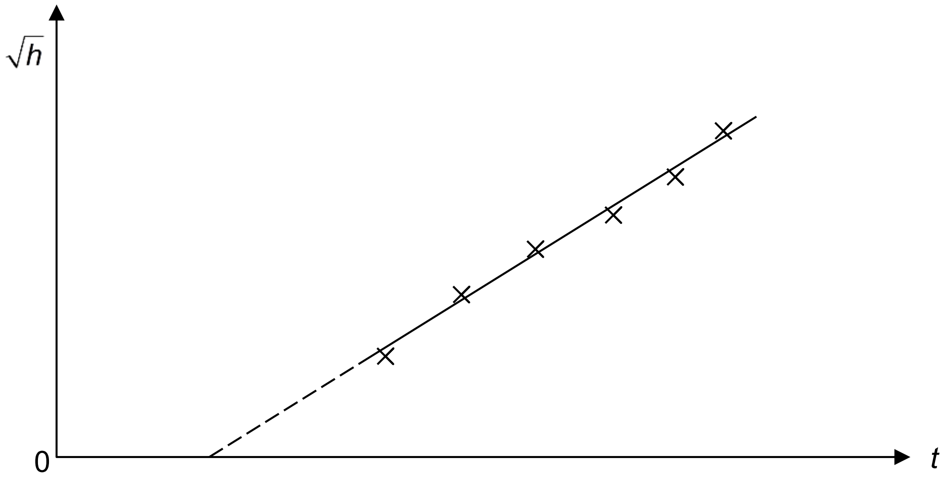

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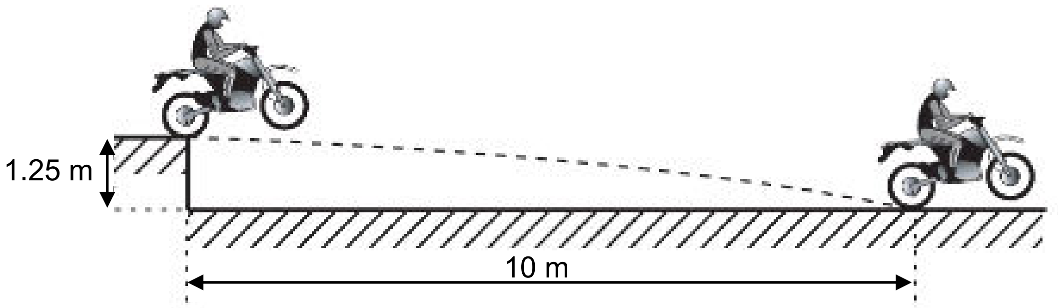
2 The experimental measurement of the heat capacity of a solid as a function of temperature T is found to fit the following expression

$$C = \alpha T^3 + \beta T$$

What are the possible base units of α and β?

	units of α	units of β
A	kg m^2 s^{-1} K^{-4}	kg m^2 s^{-1} K^{-1}
B	kg^2 m s^{-2} K^{-3}	kg^2 m s^{-2} K^{-2}
C	kg m^2 s^{-2} K^{-4}	kg m^2 s^{-2} K^{-2}
D	kg^2 m s^{-2} K^{-3}	kg^2 m s^{-2} K^{-1}

3 A motorcycle stunt-rider moving horizontally takes off from a point 1.25 m above the ground, landing 10 m away as shown in the diagram.



What was the speed at take-off?

A 5 m s^{-1} **B** 10 m s^{-1} **C** 15 m s^{-1} **D** 20 m s^{-1}

4 A body of mass 3.0 kg is thrown with a velocity of 20 m s^{-1} at an angle of 60° above horizontal. It reaches the maximum height after 1.8 s. Air resistance is negligible.

What is the rate of change of momentum of the body at the maximum height?

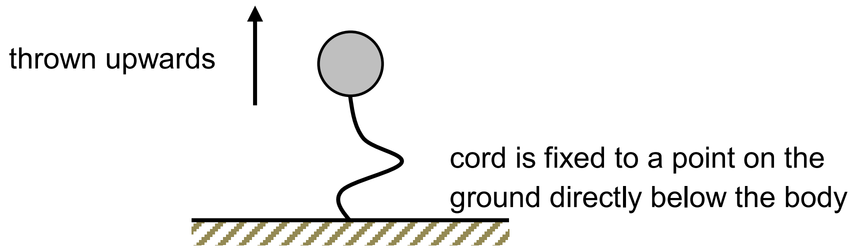
A zero **B** 17 kg m s^{-2} **C** 29 kg m s^{-2} **D** 33 kg m s^{-2}

5 A body P of mass 2.0 kg and moving with velocity +3.0 m s^{-1} makes a head-on inelastic collision with a stationary body Q of mass 4.0 kg.

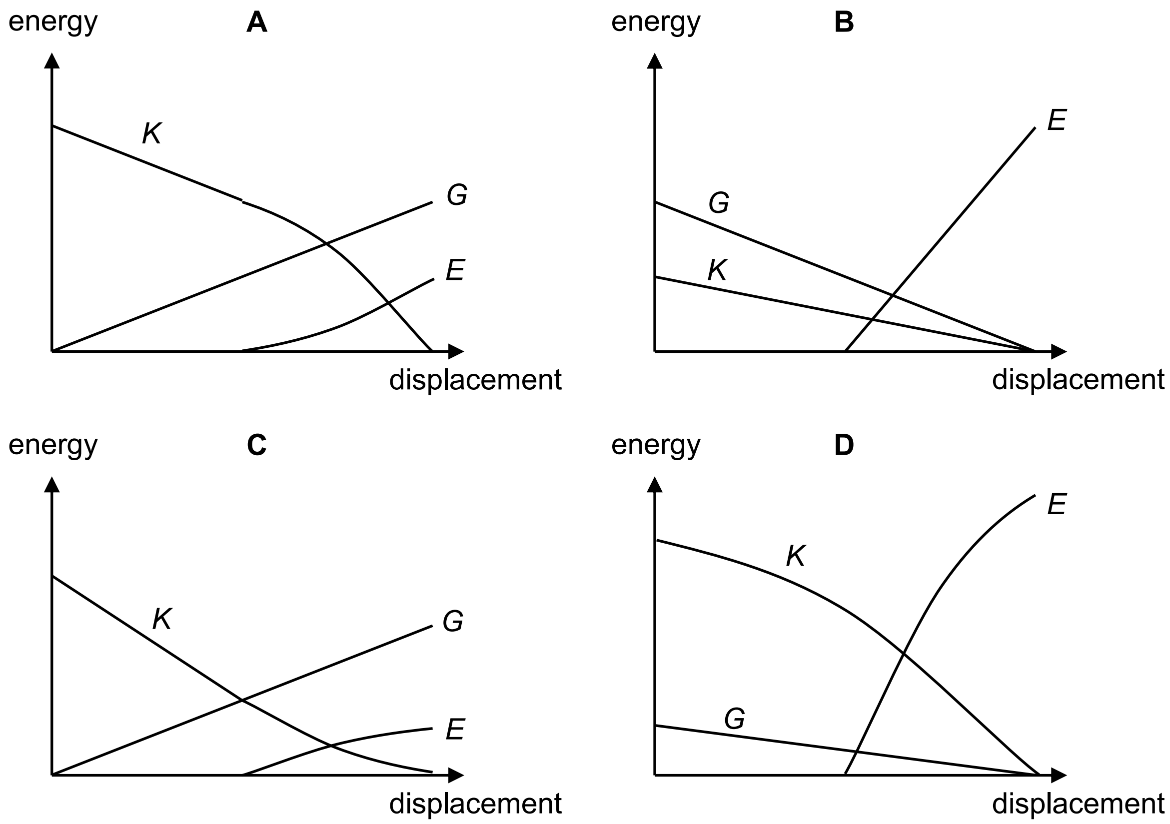
Which of the following could be the velocities of P and Q after the collision?

	velocity of P after collision	velocity of Q after collision
A	+0.5 m s^{-1}	+0.5 m s^{-1}
B	+0.0 m s^{-1}	+3.0 m s^{-1}
C	–1.0 m s^{-1}	+2.0 m s^{-1}
D	–0.6 m s^{-1}	+1.8 m s^{-1}

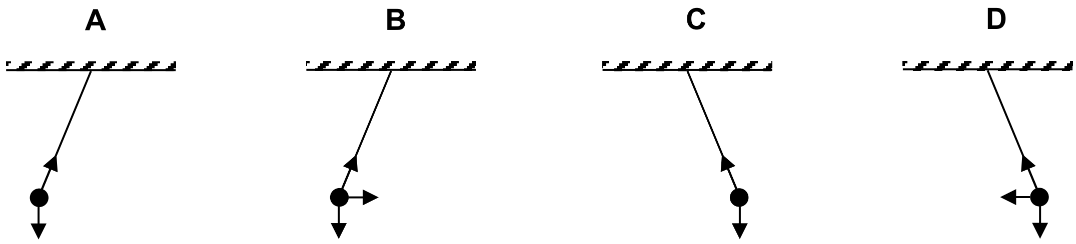
6 The diagram shows a body attached to an elastic cord being thrown vertically upwards. Initially the cord is unstretched but after a while it becomes stretched. The cord obeys Hooke's law and air resistance is ignored.



Which of the following shows the variation with displacement of the kinetic energy K, gravitational potential energy G and elastic potential energy E?



7 A passenger is sitting in a railway carriage facing in the direction in which the train is travelling. A pendulum hangs down in front of him from the carriage roof. The train travels along a circular arc bending to the left. Which one of the following diagrams shows the position of the pendulum as seen by the passenger, and the directions of the forces acting on it?



8 In two widely-separated planetary systems whose suns have masses S_1 and S_2, planet P_1 of mass M_1 (orbiting sun S_1) and planet P_2 of mass M_2 (orbiting sun S_2) are observed to have circular orbits of equal radii. If P_1 completes an orbit in half the time taken by P_2, it may be deduced that

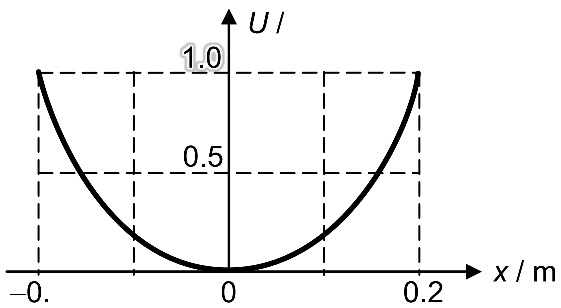
A $S_1 = S_2$ and $M_1 = 0.25\ M_2$

B $S_1 = 4S_2$ only

C $S_1 = 4S_2$ and $M_1 = M_2$

D $S_1 = 0.25\ S_2$ only

9 A particle of mass 4.0 kg moves in simple harmonic motion. Its potential energy U varies with position x as shown in the figure below.



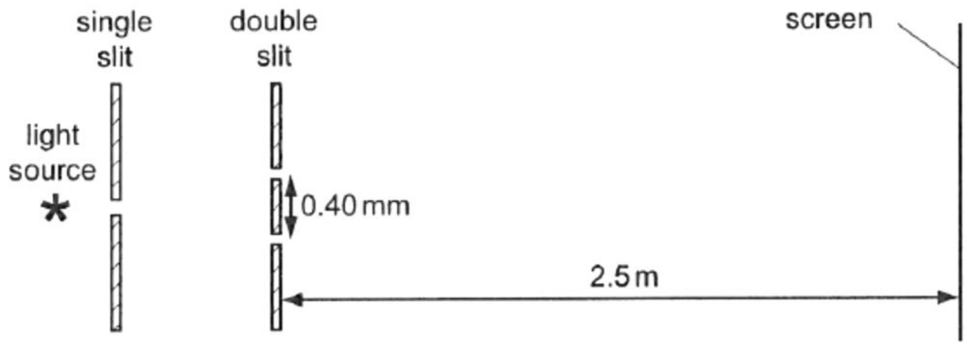
What is the period of oscillation of the mass?

A $\frac{2\pi}{25}$ s **B** $\frac{2\pi\sqrt{2}}{5}$ s **C** $\frac{8\pi}{25}$ s **D** $\frac{4\pi}{5}$ s

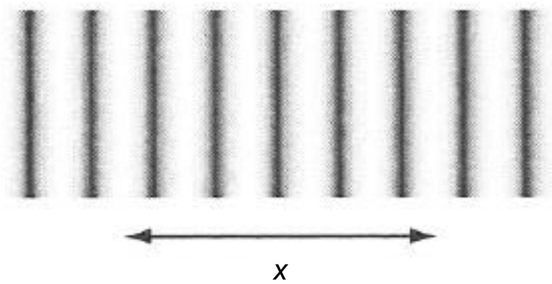
10 A toy car moving along a horizontal plane in simple harmonic motion starts from the amplitude at time t = 0 s. If the amplitude of its motion is 5.0 cm and frequency is 2.0 Hz, the magnitude of the acceleration of the toy car at 1.7 s is

A 0.25 m s^{-2} **B** 0.51 m s^{-2} **C** 6.4 m s^{-2} **D** 7.4 m s^{-2}

11 A two source interference experiment is set up as shown.



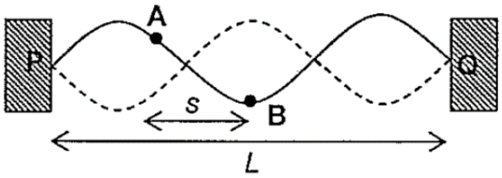
The source emits light of wavelength 600 nm. The interference pattern on the screen is shown below.



What is the distance *x*?

A 3.8×10^{-4} m **B** 1.9×10^{-3} m **C** 3.8×10^{-3} m **D** 1.9×10^{-2} m

12 A guitar string of length L is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown.



Two particles **A** and **B** on the string are separated by a distance s. The maximum kinetic energies of **A** and **B** are K_A and K_B respectively.

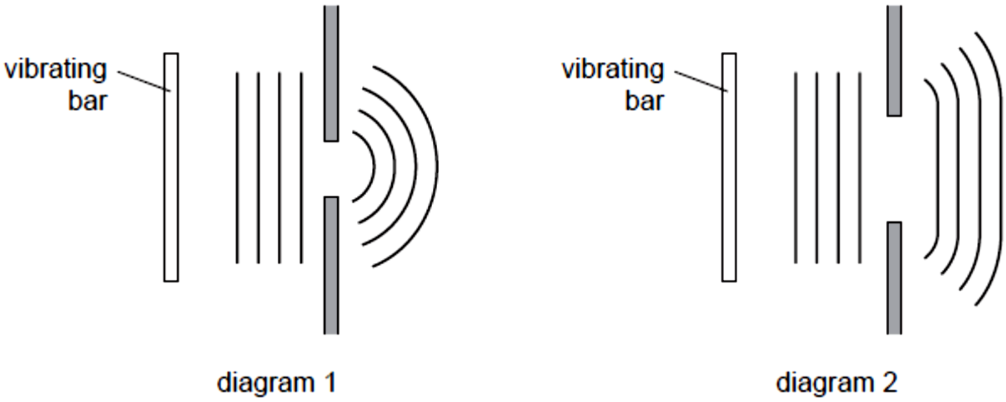
Which of the following gives the correct phase difference and maximum kinetic energies of the particles?

	Phase difference	Maximum kinetic energy
A	$\left(\frac{3s}{2L}\right)\times 360°$	$K_A < K_B$
B	$\left(\frac{3s}{2L}\right)\times 360°$	same
C	180°	$K_A < K_B$
D	180°	same

13 Diagram 1 shows a ripple tank experiment in which plane waves are diffracted through a narrow slit in a metal sheet.

Diagram 2 shows the same tank with a slit of greater width.

In each case, the pattern of the waves incident on the slit and the emergent pattern are shown.



Which action would cause the waves in diagram 1 to produce an emergent pattern closer to that shown in diagram 2?

A Increasing the frequency of vibration of the bar.

B Increasing the speed of the waves by making the water in the tank deeper.

C Reducing the amplitude of vibration of the bar.

D Reducing the length of the vibrating bar.

14 An ideal gas in a container of fixed volume 1.0 m^3 has a pressure of 3.0×10^5 Pa at a temperature of 200 K. The gas is heated until the temperature reaches 400 K. Some gas is released from the container during the heating to keep the pressure constant.

What volume does the gas released from the container occupy, if it is at atmospheric pressure of 1.0×10^5 Pa and at a room temperature of 300 K?

A 0.500 m^3 **B** 2.00 m^3 **C** 2.25 m^3 **D** 4.50 m^3

15 When a volatile liquid evaporates it cools down.

What is the reason for this cooling?

A All the molecules slow down.

B Fast molecules leave the surface so the mean speed of those left behind is reduced.

C Molecular collisions result in loss of kinetic energy of the molecules.

D The molecules collide with one another less frequently.

16 The molecules of an ideal gas at thermodynamic temperature T have a root-mean-square speed c.

The gas is heated to temperature $2T$.

What is the new root-mean-square speed of the molecules?

A $\sqrt{2}c$ **B** $2\sqrt{2}c$ **C** $2c$ **D** $4c$

17 Which one of the following statements about the electric potential at a point is correct?

A The potential is given by the rate of change of electric field strength with distance.

B The potential is equal to the work done per unit positive charge in moving a small point charge from infinity to that point.

C Two points in an electric field are at the same potential when a small positive charge placed along the line joining them remains stationary.

D An alternative unit for electric potential is J m^{-1}.

18 The electric potentials V are measured at distance x from P along a line PQ. The results are:

V / V	13	15	18	21	23
x / m	0.020	0.030	0.040	0.050	0.060

The electric field at *x* = 0.040 m is approximately

A 300 V m^{-1} towards Q

B 300 V m^{-1} towards P

C 450 V m^{-1} towards Q

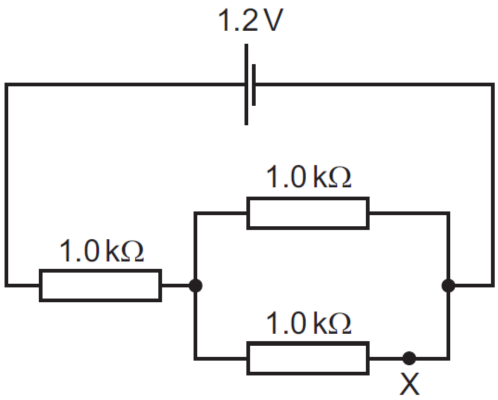
D 450 V m^{-1} towards P

19 A piece of wire of original length *L*, has a resistance of *R*. It is then melted and made into a new wire of length 1.7 *L*.

What is the resistance of the new wire?

A 0.59 *R* **B** *R* **C** 1.7 *R* **D** 2.9 *R*

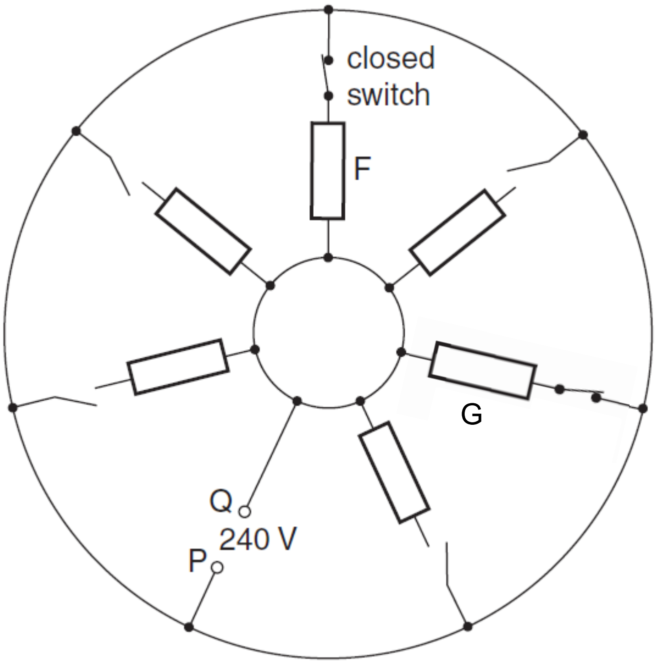
20 In the circuit below, 3 identical resistors of resistance 1.0 kΩ are connected to a cell of 1.2 V with negligible internal resistance as shown.



How many electrons pass through point X in a minute?

A 2.5×10^{15} **B** 1.5×10^{17} **C** 2.5×10^{18} **D** 1.5×10^{20}

21 Electrical sockets in a house are connected to a circuit called a ring main. The circuit is connected between P and Q to the 240 V power supply as shown.

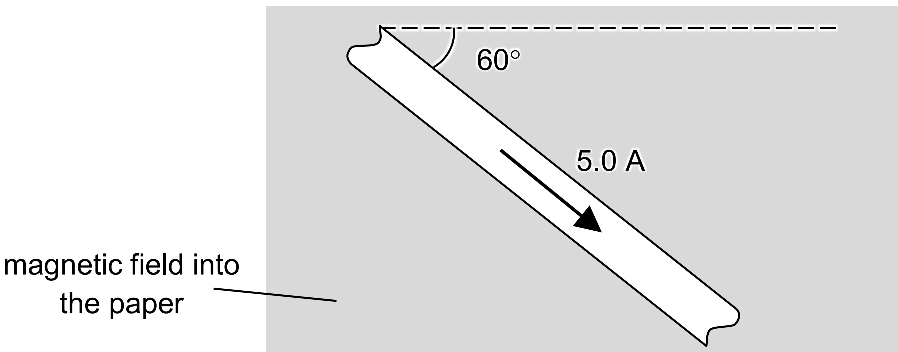


Two devices, F and G, are currently switched on. They have resistances of 1200 Ω and 1700 Ω respectively.

What is the current supplied by the power supply and total power dissipated by both devices?

	current / A	total power dissipated / W
A	0.083	20
B	0.083	82
C	0.34	20
D	0.34	82

22 A wire of length 3.0 cm is placed in the plane of the paper, along a line 60° clockwise from the *x*-axis. A magnetic field of flux density 0.040 T acts into the paper. The wire carries a current of 5.0 A.



What is the magnitude of the force which the field exerts on the wire?

A 0.0060 N **B** 0.0030 N **C** 0.0052 N **D** 0.0104 N

23 An electron is moving along the axis of a solenoid carrying a current.

Which of the following is a correct statement about the electromagnetic force acting on the electron?

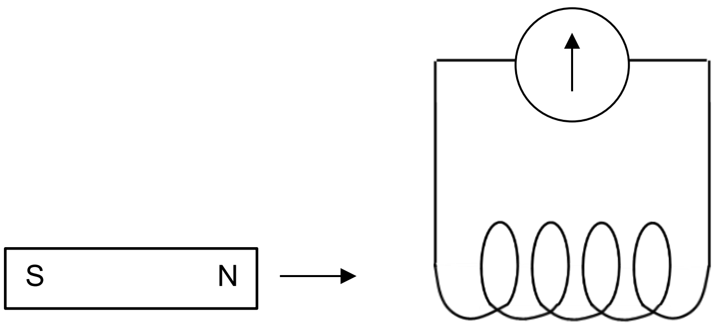
A No force acts on the electron.

B The force acts in the direction of motion.

C The force acts opposite to the direction of motion.

D The force causes the electron to move along a helical path.

24 The North pole of a bar magnet is pushed into the end of a coil of wire. The maximum movement of the meter needle is 10 units to the left.



The South pole of the magnet is then pushed into the other end of the coil at half the speed.

What is the maximum movement of the meter needle?

A less than 10 units to the left

B less than 10 units to the right

C more than 10 units to the left

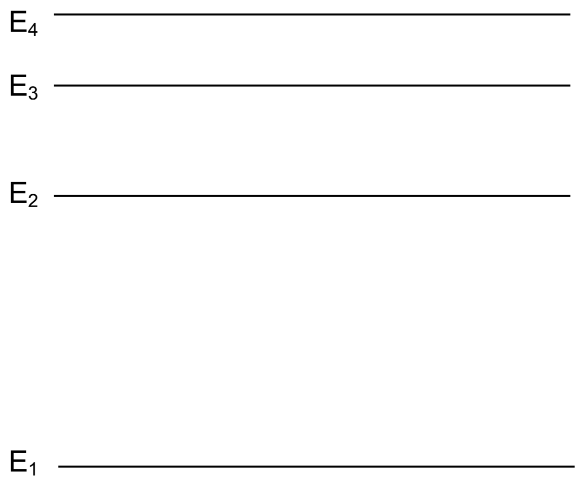
D more than 10 units to the right

25 The secondary coil of an ideal transformer delivers an r.m.s. current of 1.5 A to a load resistor of resistance 10 Ω. The r.m.s. current in the primary coil is 5 A.

What is the r.m.s. potential difference across the primary coil?

A 4.5 V **B** 6.4 V **C** 15 V **D** 50 V

26 The diagram represents in simplified form some of the energy levels of the hydrogen atom.



The transition of an electron from E_3 to E_2 is associated with the emission of red light.

Which transition could be associated with the emission of blue light?

A E_4 to E_1

B E_1 to E_4

C E_4 to E_2

D E_2 to E_4

27 An electron has a kinetic energy of 1.0 MeV. If its momentum is measured with an uncertainty of 1.0%, what is the uncertainty in its position?

A 7.7×10^{-10} m **B** 1.2×10^{-10} m **C** 2.9×10^{-12} m **D** 4.1×10^{-19} m

28 When the number of protons and the number of neutrons in a nuclide are both "magic numbers", it is more stable than expected. Such nuclides are termed "doubly magic".

The first few "magic numbers" are 2, 8, 20, 28, 50, 82, and 126.

How many of the following five nuclides are "doubly magic"?

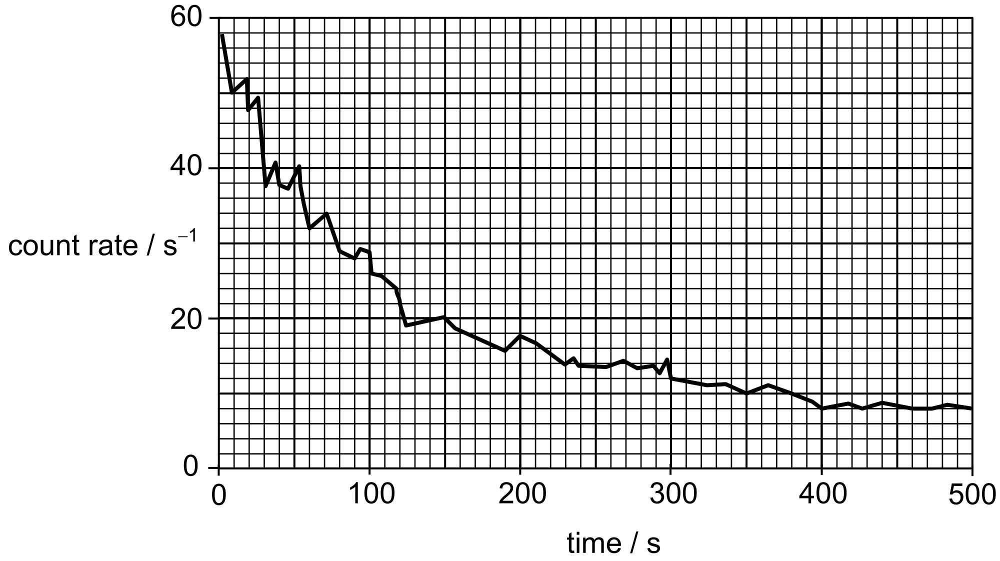
$^{28}_{8}O$	$^{40}_{20}Ca$	$^{56}_{26}Fe$	$^{50}_{28}Ni$	$^{126}_{50}Sn$

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

29 Radon-222, $^{222}_{86}Rn$ decays to Lead-210, $^{210}_{82}Pb$ via a series of three alpha and two beta decays through a series of intermediate nuclides. Which of the following cannot be one of the intermediate nuclides produced?

A $^{214}_{82}Pb$ **B** $^{214}_{83}Bi$ **C** $^{218}_{84}Po$ **D** $^{216}_{85}At$

30 An experiment is carried out in which the count rate is measured at a fixed distance from a sample of a certain radioactive material. The figure below shows the variation of count rate with time.



What is the approximate half-life of the material?

A 60 s **B** 80 s **C** 100 s **D** 120 s

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displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm \omega\sqrt{x_o^{\ 2} - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	X	=	$x_o \sin \omega t$
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radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

1	B	11	D	21	D
2	C	12	C	22	A
3	D	13	A	23	A
4	C	14	C	24	A
5	D	15	B	25	A
6	A	16	A	26	C
7	C	17	B	27	B
8	B	18	B	28	B
9	B	19	D	29	D
10	C	20	B	30	A

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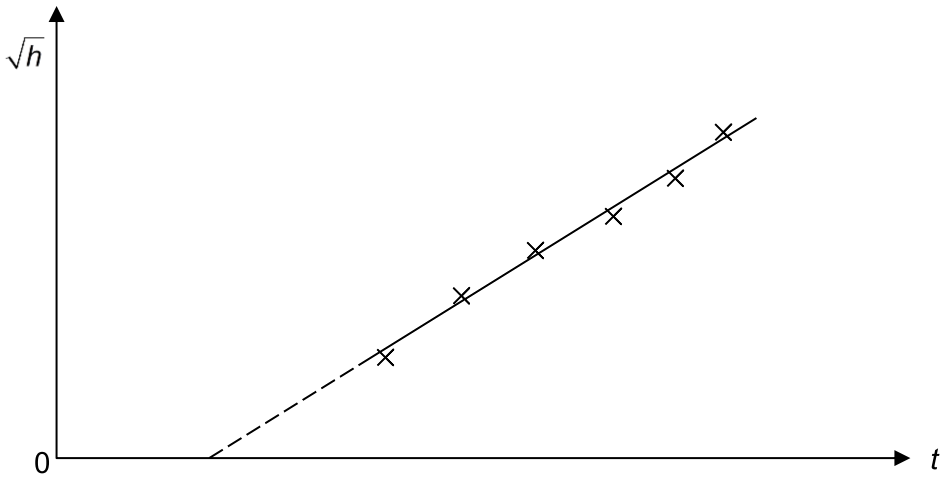

Which of the following statement is true?

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B The result is not accurate as the line does not pass through the origin

C Data is precise as there are equal number of data points on both sides of the line

D Data is precise as the data points do not deviate from the line

Ans: (B)
At time = 0, the height fallen should be zero since the ball is still at the starting point.

2 The experimental measurement of the heat capacity of a solid as a function of temperature *T* is found to fit the following expression

$$C = \alpha T^3 + \beta T$$

What are the possible base units of α and β?

units of α units of β

A	kg m^2 s^{-1} K^{-4}	kg m^2 s^{-1} K^{-1}
B	kg^2 m s^{-2} K^{-3}	kg^2 m s^{-2} K^{-2}
C	kg m^2 s^{-2} K^{-4}	kg m^2 s^{-2} K^{-2}
D	kg^2 m s^{-2} K^{-3}	kg^2 m s^{-2} K^{-1}

Ans: (C)

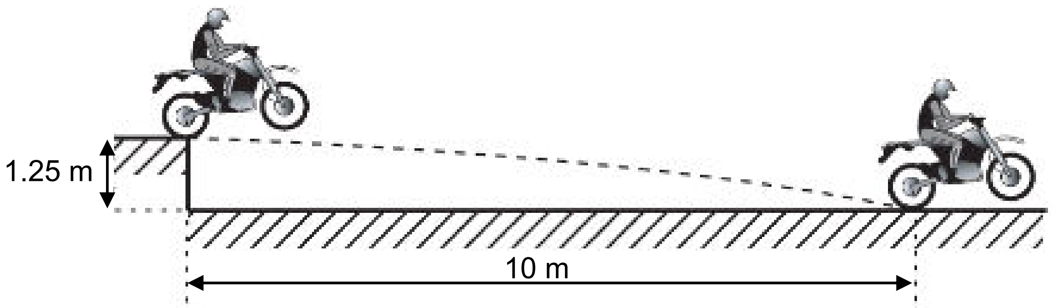
$C = \alpha T^3 + \beta T$

$\text{J K}^{-1} = [\alpha](\text{K}^3) = [\beta](\text{K})$

Using $E = \frac{1}{2}mv^2$ $\quad \text{J} = \text{kg m}^2\ \text{s}^{-2}$

$\text{kg m}^2\ \text{s}^{-2}\ \text{K}^{-1} = [\alpha](\text{K}^3) = [\beta](\text{K})$

3 A motorcycle stunt-rider moving horizontally takes off from a point 1.25 m above the ground, landing 10 m away as shown in the diagram.



What was the speed at take-off?

A 5 m s^{-1} **B** 10 m s^{-1} **C** 15 m s^{-1} **D** 20 m s^{-1}

Ans: D

$\downarrow s_y = u_y t + \frac{1}{2} a_y t^2 \Rightarrow 1.25 = 0 + \frac{1}{2}(9.81) t^2 \Rightarrow t = 0.50$ s

$\rightarrow s_x = u_x t \Rightarrow 10 = u_x (0.50) \Rightarrow u_x = 20$ m s^{-1}

4 A body of mass 3.0 kg is thrown with a velocity of 20 m s^{-1} at an angle of 60° above horizontal. It reaches the maximum height after 1.8 s. Air resistance is negligible.

What is the rate of change of momentum of the body at the maximum height?

A zero **B** 17 kg m s^{-2} **C** 29 kg m s^{-2} **D** 33 kg m s^{-2}

Ans: C

rate of change of momentum = net force = weight = 3.0 × 9.81 = 29 N

OR use $(mv_y - mu_y)/t = (0 - 3.0 \times 20 \sin 60°) / 1.8 = -29$ kg m s^{-2}

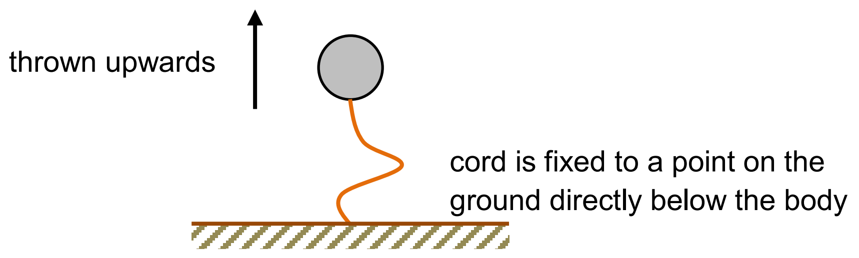
5 A body P of mass 2.0 kg and moving with velocity +3.0 m s^{-1} makes a head-on inelastic collision with a stationary body Q of mass 4.0 kg.

Which of the following could be the velocities of P and Q after the collision?

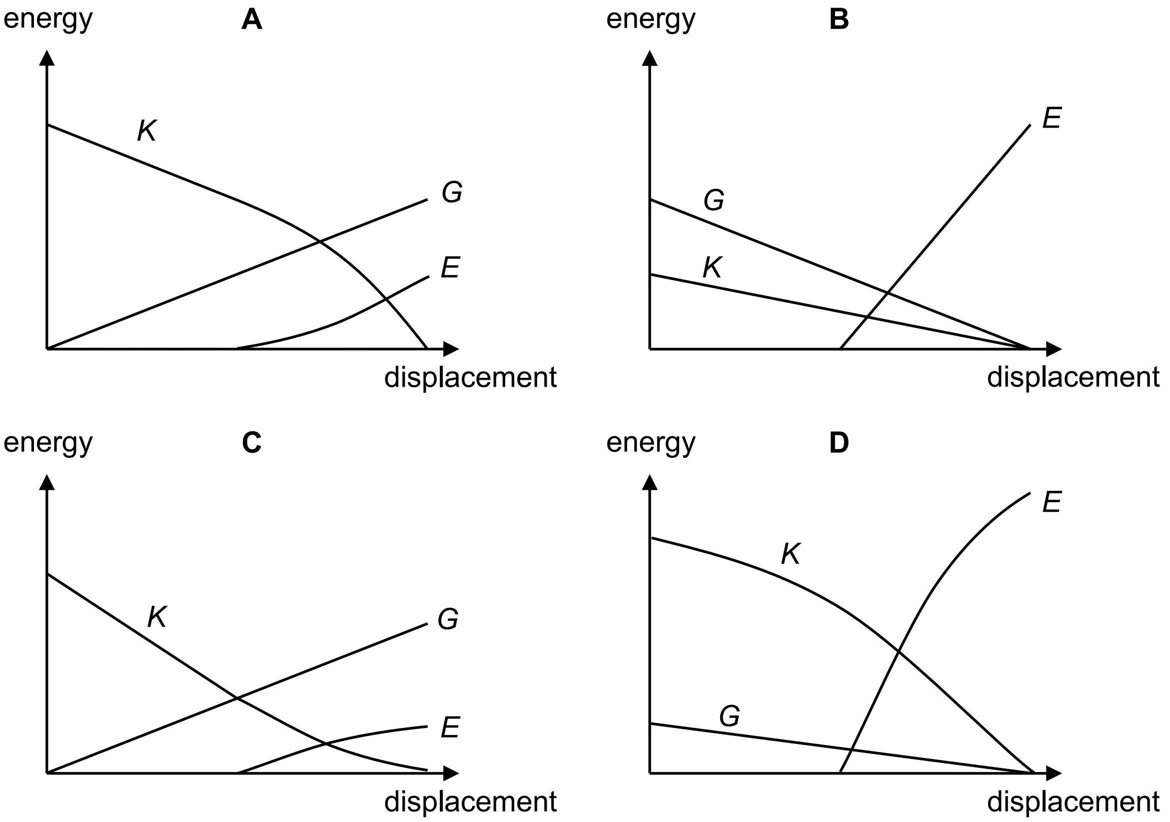
	velocity of P after collision	velocity of Q after collision
A	+0.5 m s^{-1}	+0.5 m s^{-1}
B	+0.0 m s^{-1}	+3.0 m s^{-1}
C	–1.0 m s^{-1}	+2.0 m s^{-1}
D	–0.6 m s^{-1}	+1.8 m s^{-1}

Ans: D
Initial momentum = 2.0 × 3.0 = +6.0 Ns
Final momentum = 2.0(–0.6) + 4.0(1.8) = –1.2 + 7.2 = +6.0 Ns
only D has momentum conserved but KE not conserved (or has lesser relative speed of separation than relative speed of approach)
Both momentum and KE are conserved for C (elastic collision)

6 The diagram shows a body attached to an elastic cord being thrown vertically upwards. Initially the cord is unstretched but after a while it becomes stretched. The cord obeys Hooke's law and air resistance is ignored.

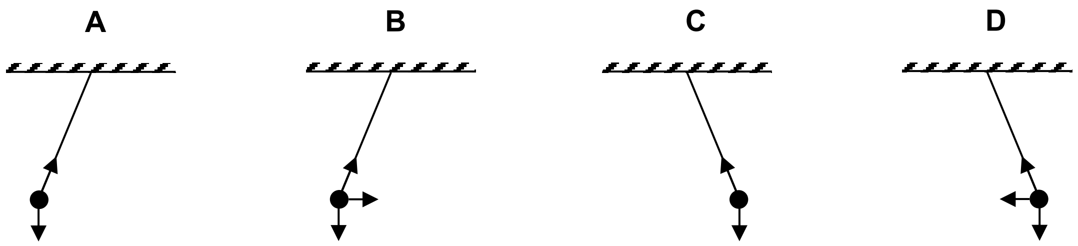


Which of the following shows the variation with displacement of the kinetic energy *K*, gravitational potential energy *G* and elastic potential energy *E*?



Ans: A
GPE increases linearly with displacement
EPE starts later, increases with extension squared (parabolic upwards)
KE decreases linearly with displacement at first (vs GPE), then decreases at greater and greater rate due to increasing EPE

7 A passenger is sitting in a railway carriage facing in the direction in which the train is travelling. A pendulum hangs down in front of him from the carriage roof. The train travels along a circular arc bending to the left. Which one of the following diagrams shows the position of the pendulum as seen by the passenger, and the directions of the forces acting on it?



Ans: C

8 In two widely-separated planetary systems whose suns have masses S_1 and S_2, planet P_1 of mass M_1 (orbiting sun S_1) and planet P_2 of mass M_2 (orbiting sun S_2) are observed to have circular orbits of equal radii. If P_1 completes an orbit in half the time taken by P_2, it may be deduced that

A $S_1 = S_2$ and $M_1 = 0.25\ M_2$

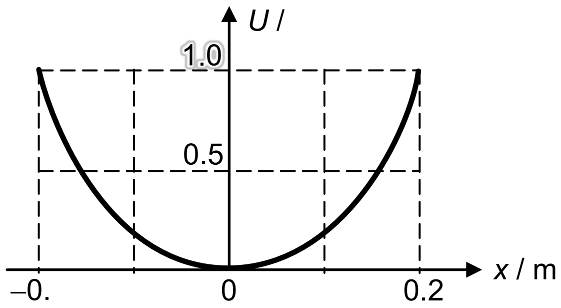
B $S_1 = 4S_2$ only

C $S_1 = 4S_2$ and $M_1 = M_2$

D $S_1 = 0.25\ S_2$ only

Ans: (B)

9 A particle of mass 4.0 kg moves in simple harmonic motion. Its potential energy *U* varies with position *x* as shown in the figure below.



What is the period of oscillation of the mass?

A $\dfrac{2\pi}{25}$ s **B** $\dfrac{2\pi\sqrt{2}}{5}$ s **C** $\dfrac{8\pi}{25}$ s **D** $\dfrac{4\pi}{5}$ s

Ans B

Total energy of system is constant.

Max PE = 1.0 J = Max KE = ½ m v_{max}^2

$$v_{max} = \frac{1}{\sqrt{2}}$$

$$v_{max} = \omega x_o = \frac{2\pi}{T} x_o$$

$$T = \left(\frac{2\pi}{v_{max}}\right) x_o$$

$$= 2\pi\left(\sqrt{2}\right)(0.2)$$

$$= \frac{2\pi\sqrt{2}}{5}$$

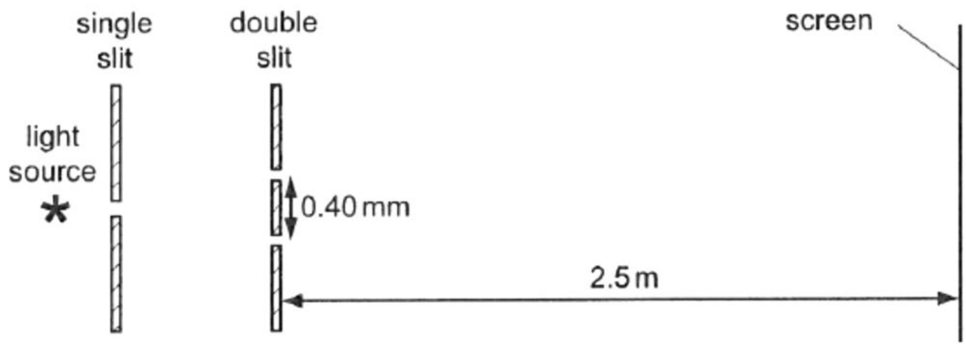
10 A toy car moving along a horizontal plane in simple harmonic motion starts from the amplitude at time *t* = 0 s. If the amplitude of its motion is 5.0 cm and frequency is 2.0 Hz, the magnitude of the acceleration of the toy car at 1.7 s is

A 0.25 m s^{-2} **B** 0.51 m s^{-2} **C** 6.4 m s^{-2} **D** 7.4 m s^{-2}

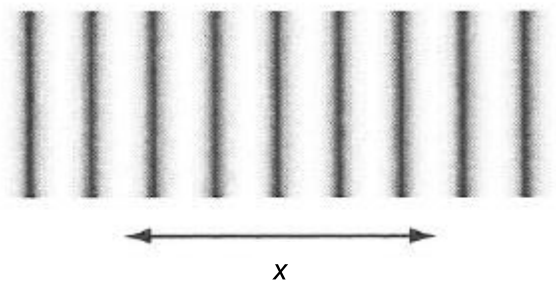
Ans C

$$x = x_o \cos(\omega t)$$
$$= 5.0\cos(2\pi(2)\times 1.7)$$
$$= -4.05 \text{ cm}$$
$$a = \left|\omega^2 x\right|$$
$$= (4\pi)^2 (4.05\times 10^{-2})$$
$$= 6.4 \text{ m s}^{-2}$$

11 A two source interference experiment is set up as shown.



The source emits light of wavelength 600 nm. The interference pattern on the screen is shown below.



What is the distance *x*?

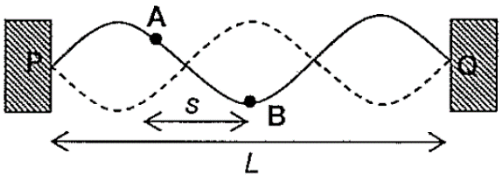
A 3.8×10^{-4} m **B** 1.9×10^{-3} m **C** 3.8×10^{-3} m **D** 1.9×10^{-2} m

Ans D

$$\Delta x = \frac{\lambda D}{a} = \frac{600\times 10^{-9}(2.5)}{0.40\times 10^{-3}} = 3.75\times 10^{-3} \text{ m}$$

$$x = 5\Delta x = 5(3.75\times 10^{-3}) = 1.9\times 10^{-2} \text{ m}$$

12 A guitar string of length *L* is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown.



Two particles **A** and **B** on the string are separated by a distance *s*. The maximum kinetic energies of **A** and **B** are K_A and K_B respectively.

Which of the following gives the correct phase difference and maximum kinetic energies of the particles?

	Phase difference	Maximum kinetic energy
A	$\left(\frac{3s}{2L}\right)\times 360°$	$K_A < K_B$
B	$\left(\frac{3s}{2L}\right)\times 360°$	same
C	180°	$K_A < K_B$
D	180°	same

Ans: C
Since particles A and B are at two sides of a node of a stationary wave, they are anti-phase. Hence phase difference is 180°
Maximum KE is proportional to amplitude. Since amplitude of A < amplitude of B,
$K_A < K_B$

13 Diagram 1 shows a ripple tank experiment in which plane waves are diffracted through a narrow slit in a metal sheet.

Diagram 2 shows the same tank with a slit of greater width.

In each case, the pattern of the waves incident on the slit and the emergent pattern are shown.

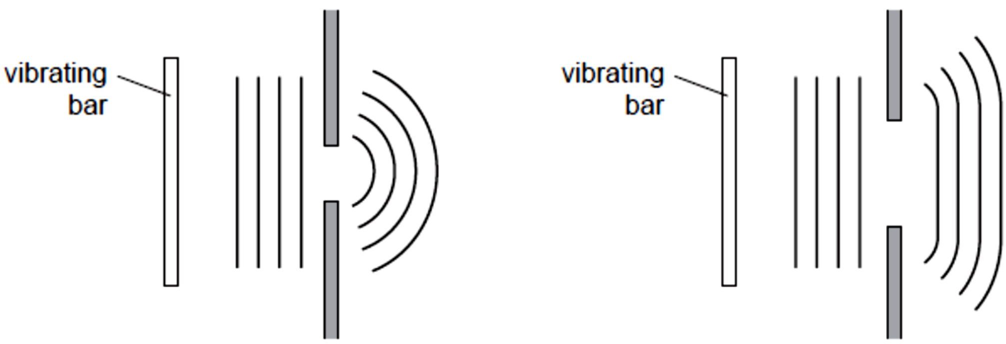


diagram 1   diagram 2

Which action would cause the waves in diagram 1 to produce an emergent pattern closer to that shown in diagram 2?

A Increasing the frequency of vibration of the bar.

B Increasing the speed of the waves by making the water in the tank deeper.

C Reducing the amplitude of vibration of the bar.

D Reducing the length of the vibrating bar.

Ans: A

14 An ideal gas in a container of fixed volume 1.0 m^3 has a pressure of 3.0 x 10^5 Pa at a temperature of 200 K. The gas is heated until the temperature reaches 400 K. Some gas is released from the container during the heating to keep the pressure constant.

What volume does the gas released from the container occupy, if it is at atmospheric pressure of 1.0 x 10^5 Pa and at a room temperature of 300 K?

A 0.500 m^3 **B** 2.00 m^3 **C** 2.25 m^3 **D** 4.50 m^3

Ans C

$$n_1 = \frac{p_1 V_1}{RT_1} = \frac{3.0\times10^5(1)}{8.31(200)} = 180.5 \text{ mol}$$

$$n_2 = \frac{p_2 V_2}{RT_2} = \frac{3.0\times10^5(1)}{8.31(400)} = 90.25 \text{ mol}$$

$$n_{released} = n_1 - n_2 = 90.25 \text{ mol}$$

$$V_{released} = \frac{n_{released}RT}{p} = \frac{90.25(8.31)(300)}{1.0\times10^5} = 2.25 \text{ m}^3$$

15 When a volatile liquid evaporates it cools down.

What is the reason for this cooling?

A All the molecules slow down.

B Fast molecules leave the surface so the mean speed of those left behind is reduced.

C Molecular collisions result in loss of kinetic energy of the molecules.

D The molecules collide with one another less frequently.

Ans B

16 The molecules of an ideal gas at thermodynamic temperature *T* have a root-mean-square speed *c*.

The gas is heated to temperature 2*T*.

What is the new root-mean-square speed of the molecules?

A $\sqrt{2}c$ **B** $2\sqrt{2}c$ **C** $2c$ **D** $4c$

Ans A

$$\frac{1}{2}m(c)^2 = \frac{3}{2}kT$$
$$c \propto \sqrt{T}$$
$$\frac{c_{new}}{c} = \sqrt{\frac{2T}{T}}$$
$$c_{new} = \sqrt{2}c$$

17 Which one of the following statements about the electric potential at a point is correct?

A The potential is given by the rate of change of electric field strength with distance.

B The potential is equal to the work done per unit positive charge in moving a small point charge from infinity to that point.

C Two points in an electric field are at the same potential when a small positive charge placed along the line joining them remains stationary.

D An alternative unit for electric potential is V m^{-1}.

Ans: B

18 The electric potentials V are measured at distance x from P along a line PQ.

The results are:

V / V	13	15	18	21	23
x / m	0.020	0.030	0.040	0.050	0.060

The electric field at x = 0.040 m is approximately

A 300 V m^{-1} towards Q

B 300 V m^{-1} towards P

C 450 V m^{-1} towards Q

D 450 V m^{-1} towards P

Ans: B

19 A piece of wire of original length *L*, has a resistance of *R*. It is then melted and made into a new wire of length 1.7 *L*.

What is the resistance of the new wire?

A 0.59 *R* **B** *R* **C** 1.7 *R* **D** 2.9 *R*

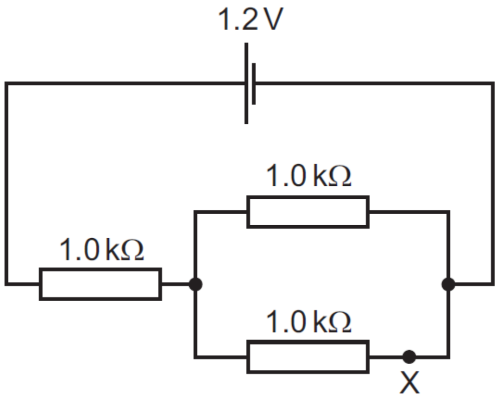
Ans: D
Since volume remains constant,

$$A_{old}L_{old} = A_{new}L_{new}$$

$$A_{new} = \frac{L}{1.7L}A_{old} = 0.59A_{old}$$

$$R_{new} = \rho\frac{L_{new}}{A_{new}} = \rho\frac{1.7L}{0.59A_{old}} = \frac{1.7}{0.59}R = 2.9R$$

20 In the circuit below, 3 identical resistors of resistance 1.0 kΩ are connected to a cell of 1.2 V with negligible internal resistance as shown.



How many electrons pass through point X in a minute?

A 2.5×10^{15} **B** 1.5×10^{17} **C** 2.5×10^{18} **D** 1.5×10^{20}

Ans: B

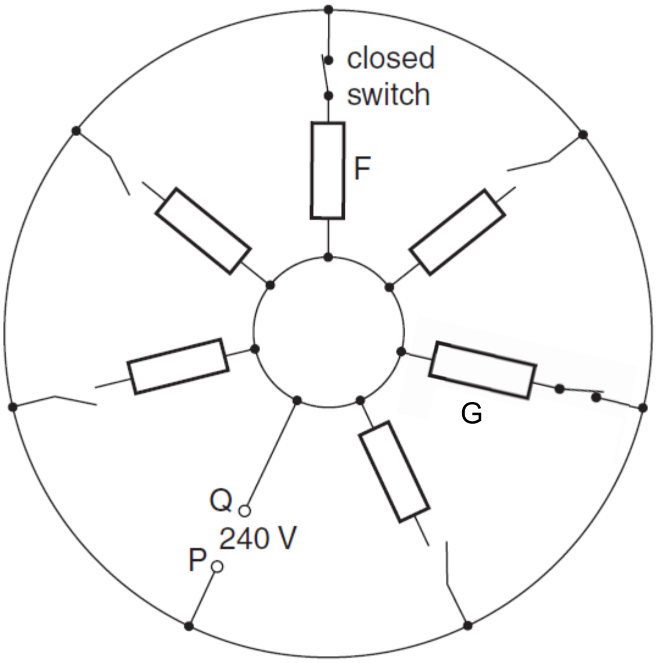
$$V_{parallel} = \frac{0.5}{1.5}(1.2) = 0.4\text{ V}$$

$$I = \frac{0.4}{1000} = 0.0004\text{ A}$$

$$\frac{N_e}{t} = \frac{0.0004}{1.6\times10^{-19}} = 2.5\times10^{15}$$

$$N_e = 2.5\times10^{15}\times60 = 1.5\times10^{17}$$

21 Electrical sockets in a house are connected to a circuit called a ring main. The circuit is connected between P and Q to the 240 V power supply as shown.



Two devices, F and G, are currently switched on. They have resistances of 1200 Ω and 1700 Ω respectively.

What is the current supplied by the power supply and total power dissipated by both devices?

	current / A	total power dissipated / W
A	0.083	20
B	0.083	82
C	0.34	20
D	0.34	82

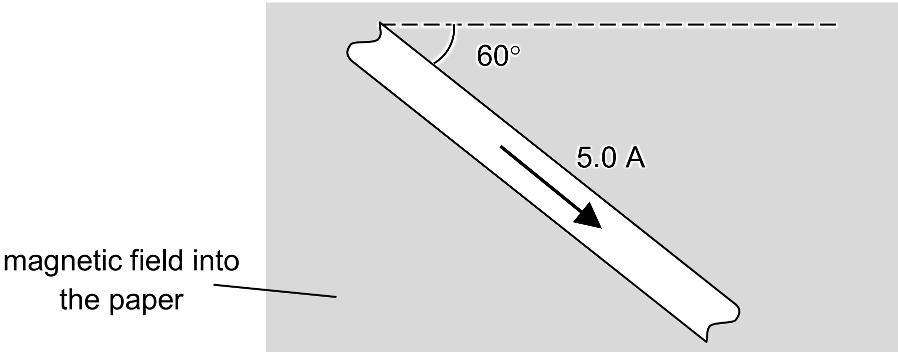
Ans: D
F and G are connected in parallel to the power supply.

$$R_{effective} = \left(\frac{1}{1200} + \frac{1}{1700}\right)^{-1} = 703\ \Omega$$

$$I = \frac{240}{703} = 0.34\ \text{A}$$

$$P_{total} = \frac{240^2}{1200} + \frac{240^2}{1700} = 82\ \text{W}$$

22 A wire of length 3.0 cm is placed in the plane of the paper, along a line 60° clockwise from the *x*-axis. A magnetic field of flux density 0.040 T acts into the paper. The wire carries a current of 5.0 A.



What is the magnitude of the force which the field exerts on the wire?

A 0.0060 N **B** 0.0030 N **C** 0.0052 N **D** 0.0104 N

Ans: (A)
F = BIL = (0.040)(5.0)(0.030) = 0.0060 N
The angle does not play a part.

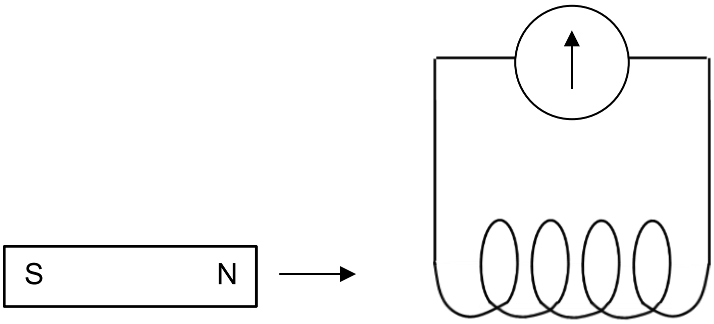
23 An electron is moving along the axis of a solenoid carrying a current.

Which of the following is a correct statement about the electromagnetic force acting on the electron?

A No force acts on the electron.
B The force acts in the direction of motion.
C The force acts opposite to the direction of motion.
D The force causes the electron to move along a helical path.

Ans: (A)
Magnetic field is along the axis. Since velocity of electron is parallel to magnetic field, no electromagnetic force acts on the electron.

24 The North pole of a bar magnet is pushed into the end of a coil of wire. The maximum movement of the meter needle is 10 units to the left.



The South pole of the magnet is then pushed into the other end of the coil at half the speed.

What is the maximum movement of the meter needle?

A less than 10 units to the left

B less than 10 units to the right

C more than 10 units to the left

D more than 10 units to the right

Ans: A

Applying Lenz's law, a North will be induced on the left side of the coil when the North pole is pushed into the left end; A South pole will be induced on the right side when South is pushed into the right end. Polarity of the induced B-field in the coil is the same for both cases.

Since speed is halved, rate of change of magnetic flux linkage in the coil is less and a lower (e.m.f. and hence) current is induced.

25 The secondary coil of an ideal transformer delivers an r.m.s. current of 1.5 A to a load resistor of resistance 10 Ω. The r.m.s. current in the primary coil is 5 A.

What is the r.m.s. potential difference across the primary coil?

A 4.5 V **B** 6.4 V **C** 15 V **D** 50 V

Ans: A

$P = I^2R = 1.5^2 \times 10 = 22.5$ W

$V_s = \frac{P}{I_s} = \frac{22.5}{5} = 4.5$ V

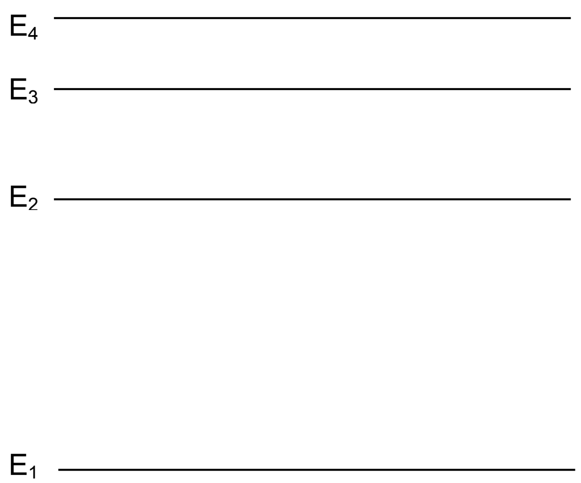
alt: $V_s = RI = 10 \times 1.5 = 15$ V

$\frac{V_p}{V_s} = \frac{I_s}{I_p}$

$V_p = \frac{1.5}{5} \times 15$

$= 4.5$ V

26 The diagram represents in simplified form some of the energy levels of the hydrogen atom.



The transition of an electron from E_3 to E_2 is associated with the emission of red light.

Which transition could be associated with the emission of blue light?

A E_4 to E_1 **B** E_1 to E_4

C E_4 to E_2 **D** E_2 to E_4

Ans: C

$\lambda_{red} \approx 700$ nm, $\lambda_{blue} \approx 400$ nm, $E = \dfrac{hc}{\lambda}$ hence the energy transition for blue light should be about 1.75 x that of red light.

Transition is from a higher energy level to lower energy level for emission of light.

27 An electron has a kinetic energy of 1.0 MeV. If its momentum is measured with an uncertainty of 1.0%, what is the uncertainty in its position?

A 7.7×10^{-10} m **B** 1.2×10^{-10} m **C** 2.9×10^{-12} m **D** 4.1×10^{-19} m

Ans: (B)

$$E = \frac{p^2}{2m}$$

$$p = \sqrt{2mE} = \sqrt{2\left(9.11\times10^{-31}\right)\left(1.0\times10^{6}\times1.6\times10^{-19}\right)}$$

$$= 5.399\times10^{-22} \text{ kg m s}^{-1}$$

$$\Delta x \cdot \Delta p \gtrsim h$$

$$\Delta x > \frac{h}{\%\Delta p} = \frac{6.63\times10^{-34}}{0.01\times5.399\times10^{-22}} = 1.2\times10^{-10} \text{ m}$$

28 When the number of protons and the number of neutrons in a nuclide are both "magic numbers", it is more stable than expected. Such nuclides are termed "doubly magic".

The first few "magic numbers" are 2, 8, 20, 28, 50, 82, and 126.

How many of the following five nuclides are "doubly magic"?

$^{28}_{8}O$	$^{40}_{20}Ca$	$^{56}_{26}Fe$	$^{50}_{28}Ni$	$^{126}_{50}Sn$

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

Ans: (B)

$^{28}_{8}O$: 8 protons, 20 neutrons (doubly magic)

$^{40}_{20}Ca$: 20 protons, 20 neutrons (doubly magic)

$^{56}_{26}Fe$: 26 protons, 30 neutrons (not)

$^{50}_{28}Ni$: 28 protons, 22 neutrons (not)

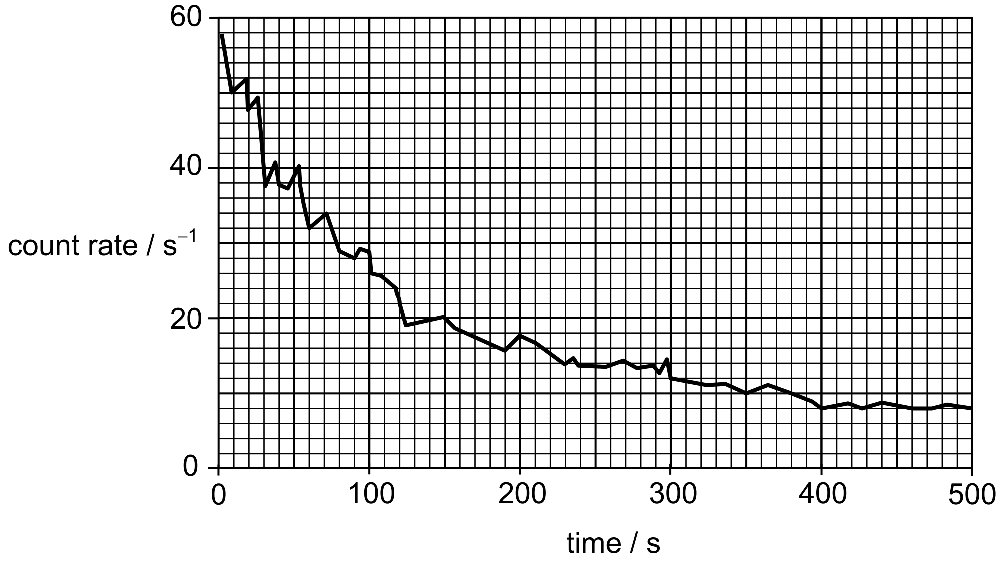
$^{126}_{50}Sn$: 50 protons, 76 neutrons (not)

29 Radon-222, $^{222}_{86}Rn$ decays to Lead-210, $^{210}_{82}Pb$ via a series of three alpha and two beta decays through a series of intermediate nuclides. Which of the following cannot be one of the intermediate nuclides produced?

A $^{214}_{82}Pb$ **B** $^{214}_{83}Bi$ **C** $^{218}_{84}Po$ **D** $^{216}_{85}At$

Ans: D
Alpha decays cause nucleon number to decrease by 4 each time.
Beta decays do not affect nucleon number.
Possible nuclides can only have nucleon numbers of 218, 214, 210.
(Sufficient to only consider nucleon number in this case.)

30 An experiment is carried out in which the count rate is measured at a fixed distance from a sample of a certain radioactive material. The figure below shows the variation of count rate with time.



What is the approximate half-life of the material?

A 60 s **B** 80 s **C** 100 s **D** 120 s

Ans: A
Considering background count rate to be 8 counts s^{-1},
Half life is when count rate decreases from 58 (=50+8) to 33 (=25+8).
Best option is 60 s.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9749/02

Paper 2 Structured Questions **12 September 2018**

2 hours

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

Class	Reg No

Candidate Name: ______________________________

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 a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions.

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.

For Examiner's Use	
1	/ 6
2	/ 8
3	/ 11
4	/ 10
5	/ 10
6	/ 8
7	/ 7
8	/ 20
Deductions	
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_0	=	8.85×10^{-12} F m^{-1}
		=	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ 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	=	$-Gm/r$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translation kinetic energy 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	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** For an oscillating body, state what is meant by

(i) natural frequency of vibration,

....

....

.... [1]

(ii) resonance.

....

....

.... [1]

(b) State and explain one situation where resonance is useful.

....

....

....

.... [2]

(c) In some situations, resonance should be avoided.

State one such situation and how the effects of resonance are reduced.

....

....

....

.... [2]

2 A particle in a medium is oscillating because of the passage of a transverse wave W_1.

The wave has intensity I at this point. The amplitude of the oscillation is A.

Fig. 2.1 shows the variation with time t of the displacement x of the particle.

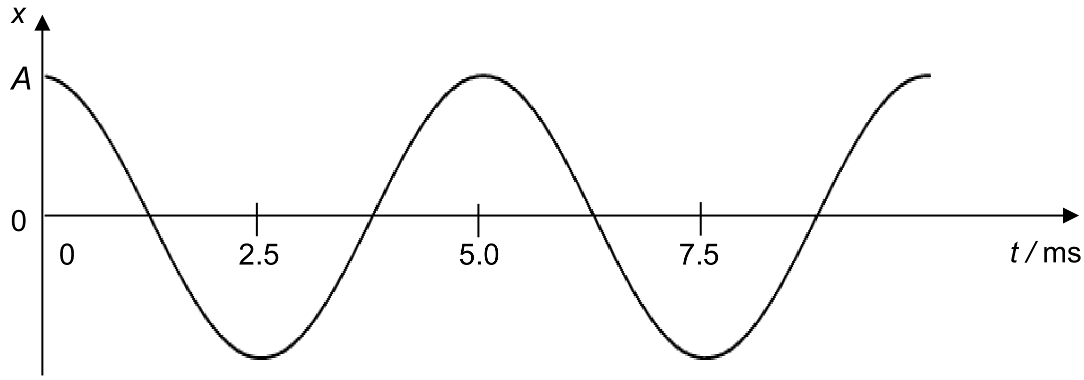


Fig. 2.1

A second, similar transverse wave W_2 has the same frequency and is incident on the same particle. The amplitude of the oscillation due to W_2 alone is $\frac{5}{2}A$ at this point.

(a) Calculate

(i) the frequency of the waves,

frequency = ... Hz [1]

(ii) the intensity, in terms of I, of the wave W_2.

intensity = ...I [2]

[Turn over

(b) **(i)** State two conditions which are necessary for the waves W_1 and W_2 to produce an observable interference pattern.

....

.... [2]

(ii) State the condition that must be satisfied if the waves are to interfere to produce a minimum resultant intensity at a point.

....

.... [1]

(iii) Calculate, in terms of I, this minimum intensity.

minimum intensity = ... I [2]

3 **(a)** State two differences between stationary waves and progressive waves.

1. ....

....

2. ....

.... [2]

(b) **(i)** A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating as shown in Fig. 3.1.

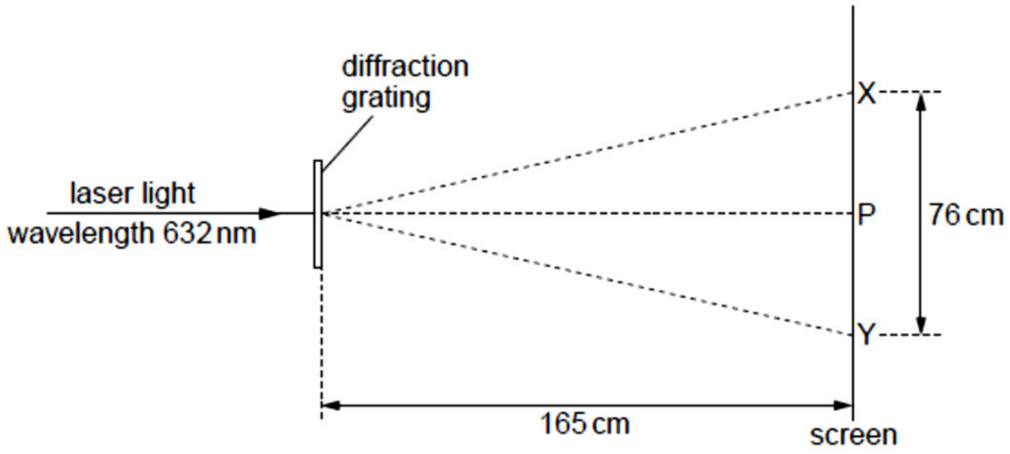


Fig. 3.1 (Top view)

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.

The brightest spot is P. The spots formed closest to P and on each side of P are X and Y.

X and Y are separated by a distance of 76 cm.

Calculate the number of lines per metre on the grating.

number per metre = ... m^{-1} [2]

(ii) The grating in **(b)(i)** is now rotated about an axis parallel to the incident laser beam, as shown in Fig. 3.2.

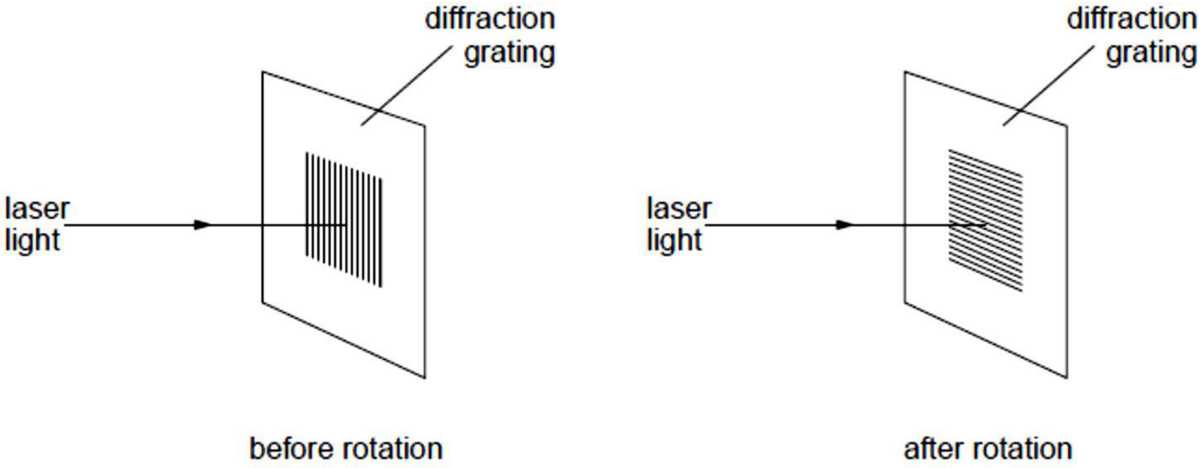


Fig. 3.2

State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

....

.... [2]

(iii) In another experiment using the apparatus in **(b)(i)**, a student notices that the distances XP and PY, as shown in Fig. 3.1 are not equal.

Suggest a reason for this difference.

....

....

.... [1]

(c) A cord is held under tension between two fixed points A and B, as shown in Fig. 3.3. The distance AB is 0.40 m.

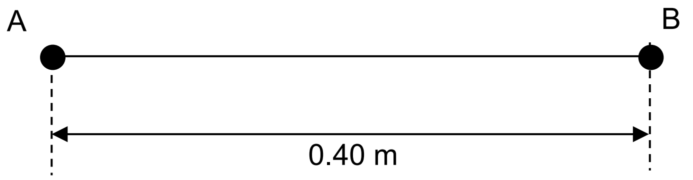


Fig. 3.3

(i) Explain why only stationary waves of certain frequencies are able to form between A and B.

....

....

.... [1]

(ii) The string is made to resonate in a mode with the third lowest possible frequency. Calculate the wavelength of this wave.

wavelength = ... m [1]

(iii) By reference to the formation of the stationary wave, explain the significance of the product of frequency and wavelength for a stationary wave.

....

....

....

.... [2]

4 **(a)** Fig. 4.1 shows a piece of metal, of mass 50 g, held in the flame of a Bunsen burner for several minutes. The metal is then quickly transferred and immersed in 130 g of water contained in a calorimeter.

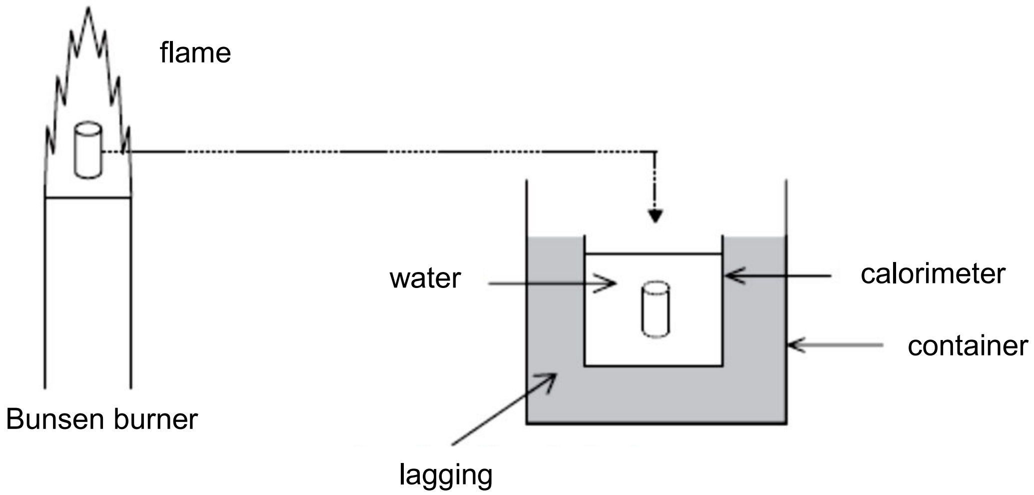


Fig. 4.1

The water into which the metal has been placed is stirred until it reaches a steady temperature. The following data are available:

heat capacity of metal	82.7 J K^{-1}
specific heat capacity of the water	4.2×10^3 J kg^{-1} K^{-1}
heat capacity of the calorimeter	54.6 J K^{-1}
initial temperature of the water	25 °C
final temperature of the water	90 °C

Use the data to calculate the temperature of the Bunsen flame and state an assumption made for your calculation.

temperature = ... °C

Assumption: ....

.... [3]

(b) The gas in the cylinder of a diesel engine can be considered to undergo a cycle of changes of pressure, volume and temperature. One such cycle, for an ideal gas, is shown in Fig. 4.2. Processes A to B and C to D take place without heat exchange with the surroundings.

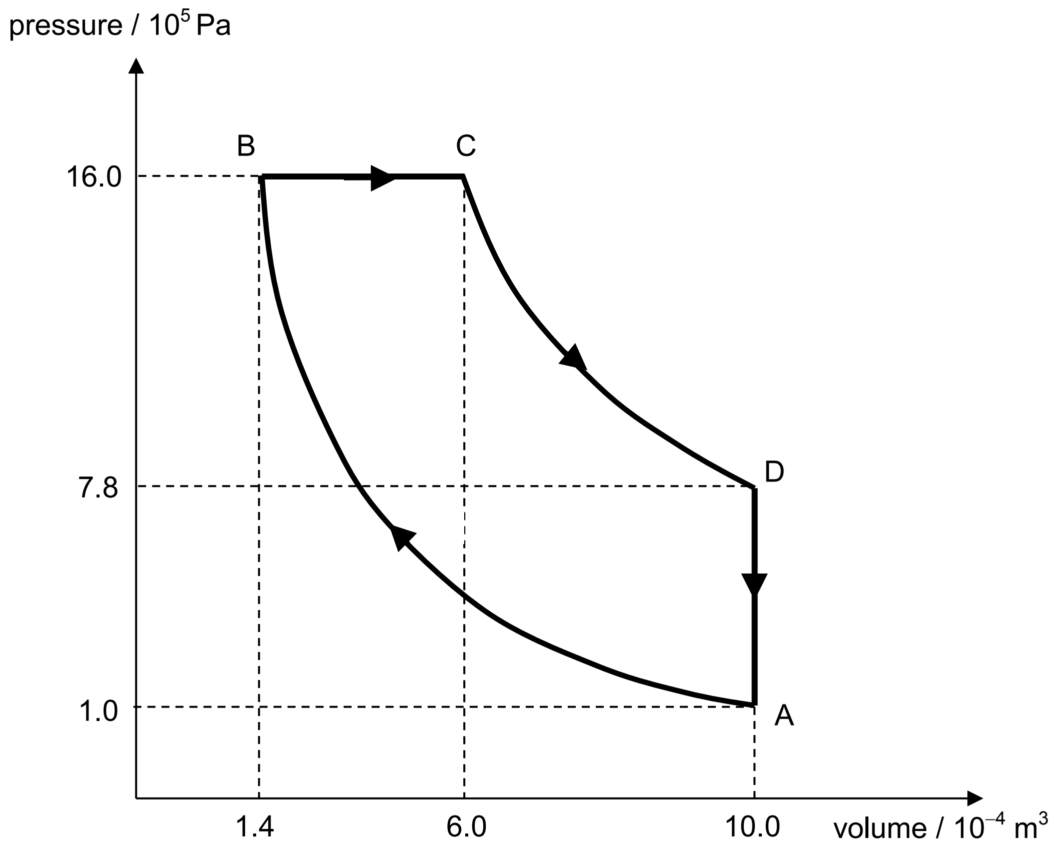


Fig. 4.2

Complete the table below.

Process	Heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A to B		300	
B to C	2580		
C to D		–440	
D to A	–1700		

[4]

(c) A fixed mass of ideal gas is heated from temperature T_1 to T_2 at constant volume. Explain why a greater amount of heat is required to heat the same mass of ideal gas from T_1 to T_2 at constant pressure.

....

....

....

.... [3]

5 **(a)** Define *magnetic flux*.

....

.... [1]

(b) Fig. 5.1 shows a 1.6 m long solenoid with 400 turns and a cross-sectional diameter of 4.0 cm. A coil Y, with 80 turns, is wounded tightly around the centre region of the solenoid.

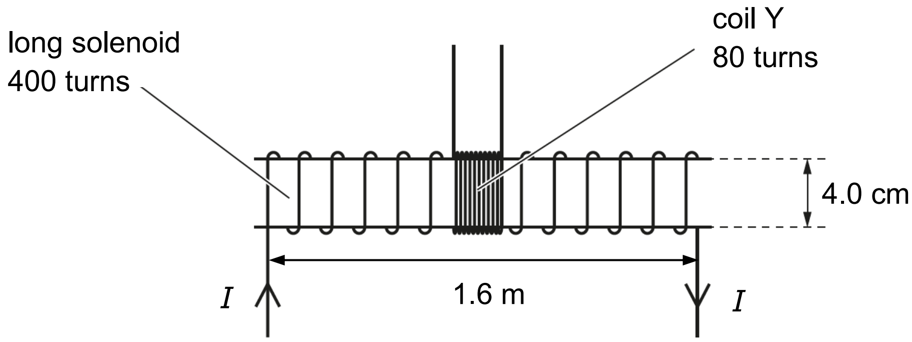


Fig. 5.1

(i) Show that, for a current I of 3.8 A in the solenoid, the magnetic flux linkage of coil Y is 1.2×10^{-4} Wb.

[2]

(ii) The current I in the solenoid in **(b)(i)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil Y.

mean e.m.f. = ... V [2]

(iii) The current I in the solenoid in **(b)(ii)** varies with time t as shown in Fig. 5.2.

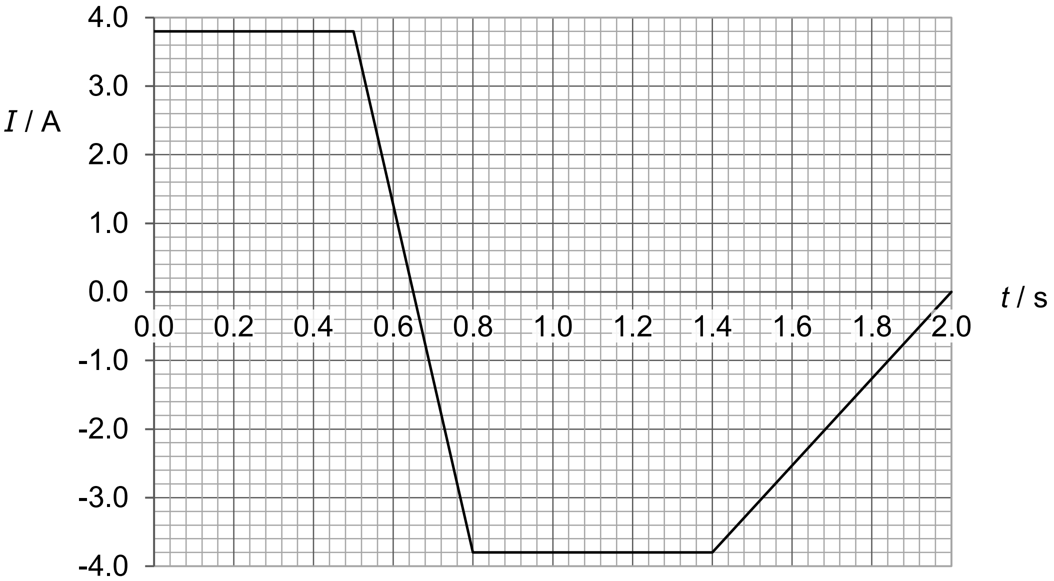
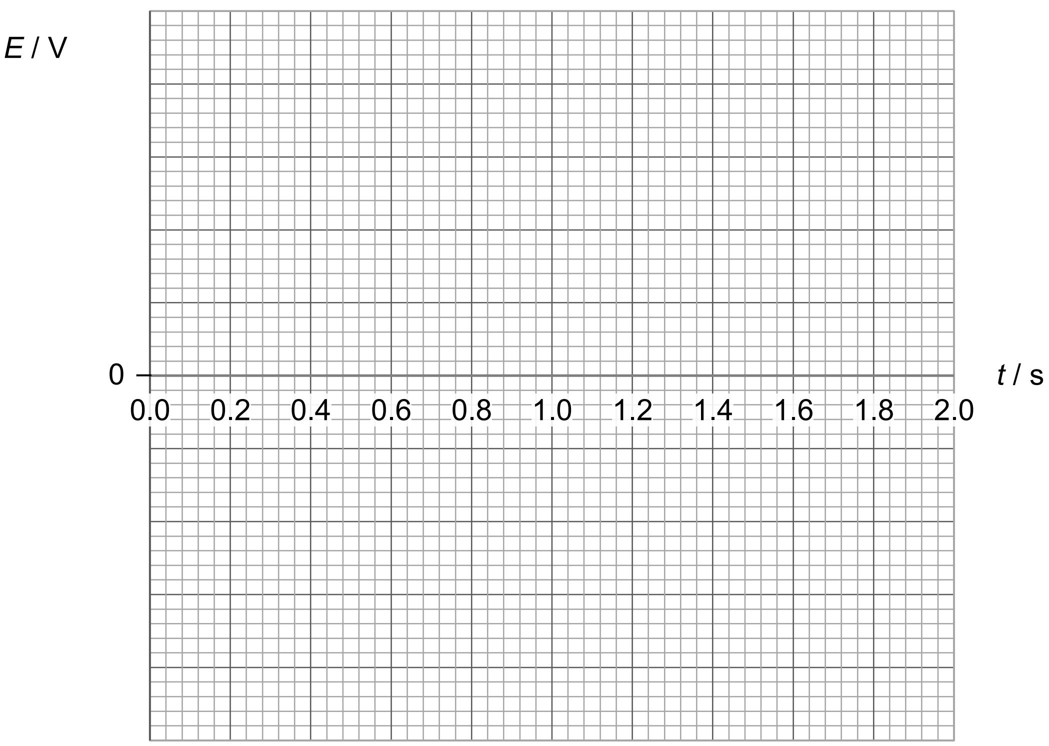


Fig. 5.2

Use your answer to **(b)(ii)** to sketch, on Fig. 5.3, the variation with time t of the e.m.f. E induced in coil Y.



[3]

(iv) An iron core is inserted into the solenoid and then held stationary within the solenoid. Explain the effect on the e.m.f. induced in coil Y.

....

....

.... [2]

6 **(a)** The photoelectric effect provides evidence for the particulate nature of electromagnetic radiation. State two experimental observations that could not be fully explained using the classical wave theory.

1. ....

....

....

2. ....

....

.... [2]

(b) In an experiment to investigate the photo-electric effect, the wavelength of the radiation incident on the metal surface was varied. For two values of wavelength λ, the stopping potential V_s was measured. The results are shown in Fig. 6.1.

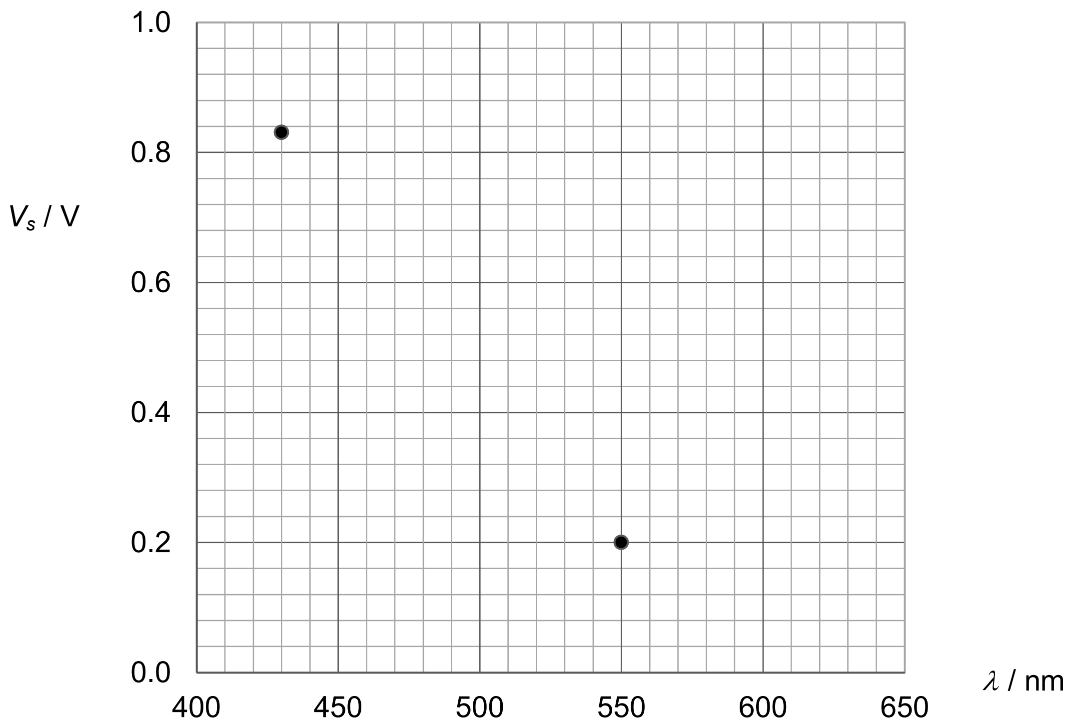


Fig. 6.1

(i) Determine the maximum kinetic energy of a photo-electron emitted from the metal surface by radiation of wavelength 550 nm.

maximum kinetic energy = ...J [1]

(ii) Hence, calculate the threshold wavelength of the metal.

threshold wavelength = ... m [2]

(iii) Suggest why it is not possible to deduce the threshold wavelength of the metal surface directly from Fig. 6.1.

....

.... [1]

(iv) The intensity of the radiation incident on the metal surface was kept constant as the wavelength was decreased from 550 nm to 430 nm.

State and explain the effect, if any, on the photocurrent.

....

....

.... [2]

7 X-ray photons are produced when electrons are accelerated through a potential difference towards a metal target. An X-ray spectrum is shown in Fig. 7.1.

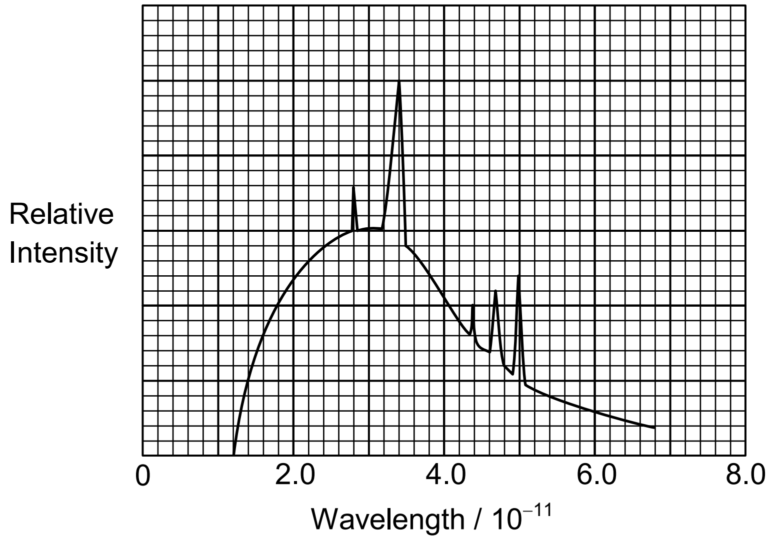


Fig. 7.1

(a) Explain how the most energetic X-ray photons are produced.

....

....

.... [2]

(b) **(i)** Explain how the characteristic X-ray K_α photons are produced.

....

....

.... [2]

(ii) Determine the momentum of the K_α X-ray photon.

momentum = ... N s [2]

(c) The potential difference used to accelerate the electrons is increased. On Fig. 7.1, sketch the new spectrum obtained. [1]

8 This question is about the movement of water from the roots of a tree to its leaves.

Water moves up a tree through its vast network of conduits. These conduits are similar to capillary tubes. It is suspected that water moves up the conduits due to low pressure in the conduits which "sucks" the water upwards, or by capillary action, or a combination of both. Capillary action is a phenomenon whereby water rises up a small tube due to upward forces caused by the adhesion of water to the walls of the tube.

To investigate capillary action, a capillary tube, open at both ends, is supported vertically with one end immersed in water, as shown in Fig. 8.1. The water in the narrow bore of the tube forms a column of height h.

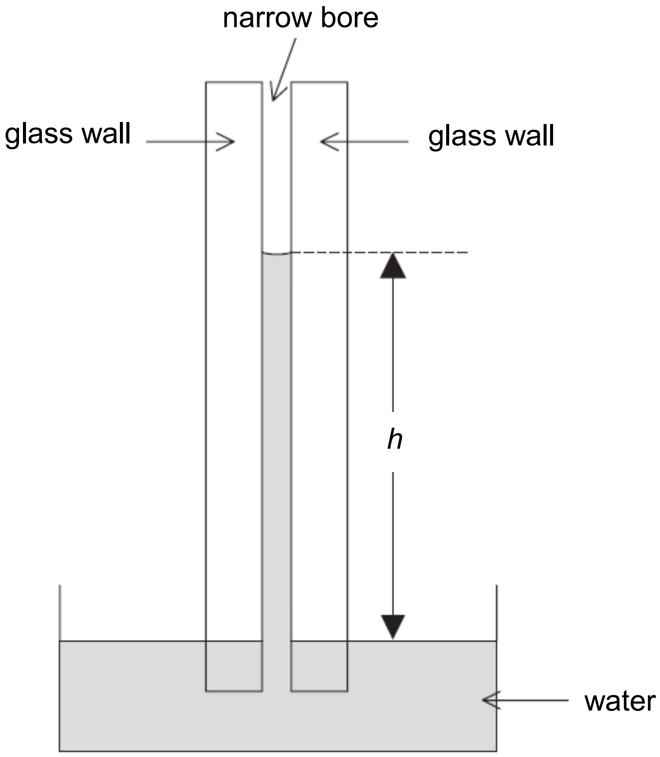


Fig. 8.1
(not to scale)

(a) The height h of the water column for a particular capillary tube was measured as the temperature of water θ was varied. Fig. 8.2 shows the data collected.

θ / °C	h / cm
30	14.0
40	13.2
50	12.5
60	11.5
70	10.9
80	10.0

Fig. 8.2

Fig. 8.3 shows the variation with temperature θ of height h.

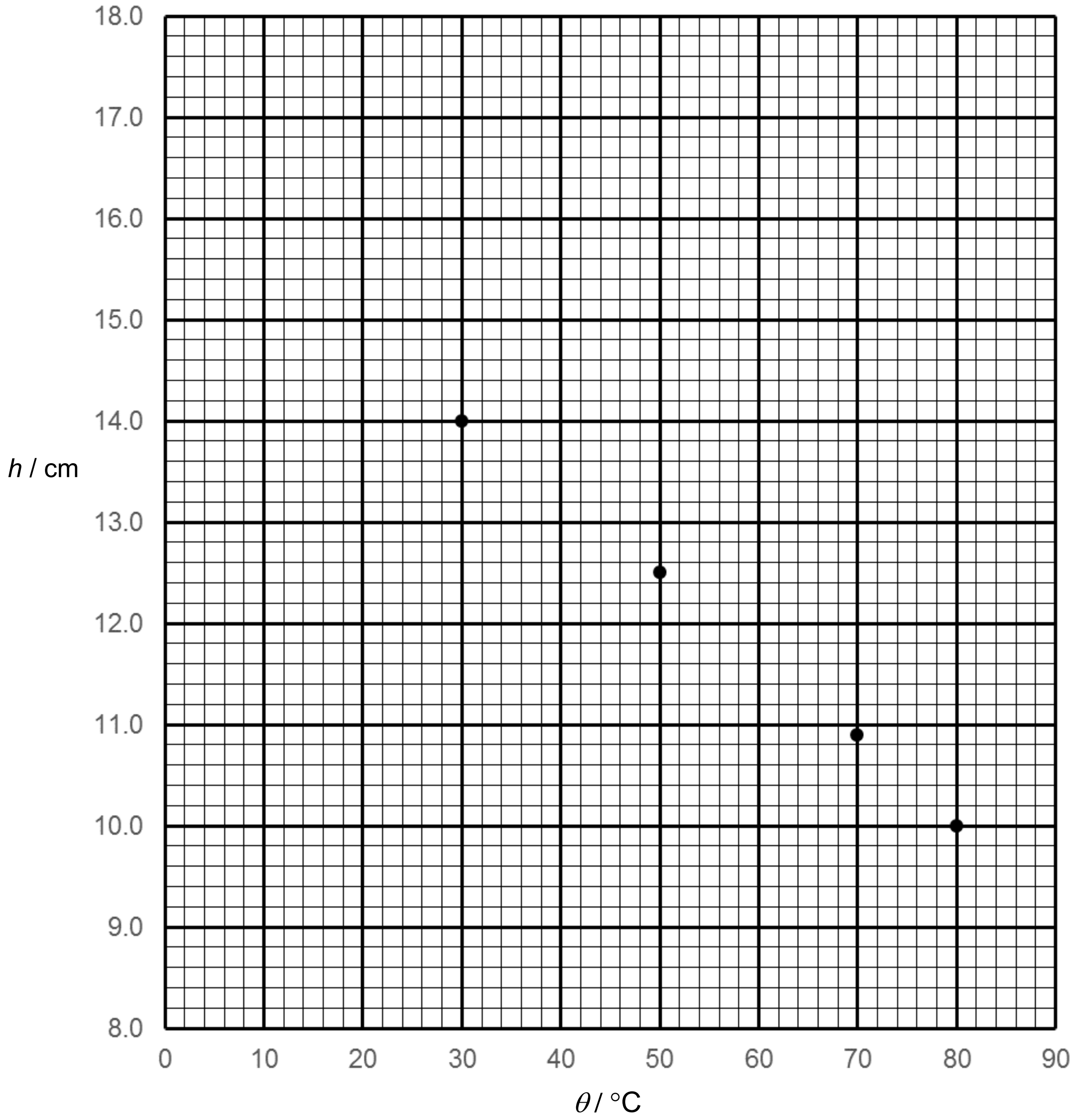


Fig. 8.3

(i) On Fig. 8.3, plot the points for θ = 40 °C and θ = 60 °C. Draw a line of best fit through the data points. [2]

(ii) Using Fig 8.3, determine the height h_0 of the water column when the temperature is 0 °C.

h_0 = ...cm [1]

(iii) It is suggested that the relationship between θ and h is

$$\frac{h}{h_0} = 1 - k\theta$$

where k is a constant.

Explain why the results of this experiment supports the relationship suggested.

....

....

....

.... [3]

(iv) Using the line drawn in **(a)(i)**, determine the value of k, including its units.

k = ... [3]

(b) The experiment is repeated using capillary tubes with bores of different radii r but keeping the water temperature constant. Fig. 8.4 shows the variation with $\frac{1}{r}$ of height h for a water temperature of 20 °C.

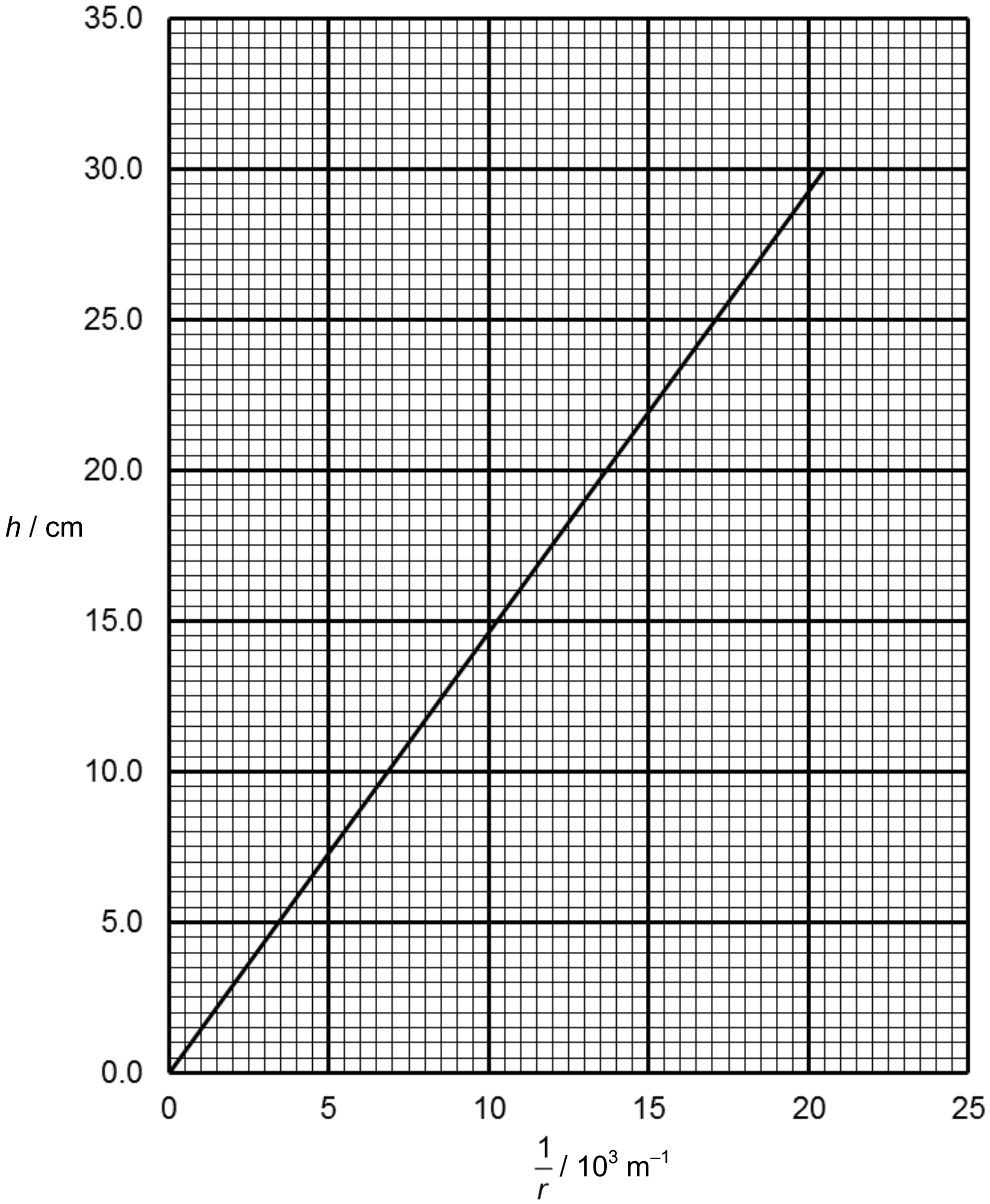


Fig. 8.4

(i) Use Fig. 8.4 to estimate the radius of the bore of the tubes in a 25-metre tall tree, which will enable water to be raised by capillary action from ground level to the top of the tree.

radius = ... m [3]

(ii) State one assumption made in your estimation in **(b)(i)**.

....

.... [1]

(iii) Comment on your answer obtained in **(b)(i)**.

....

....

.... [2]

(c) The other means of moving water up a tree is to create a low pressure in the bore of the tubes in the tree.

(i) Suggest how low pressure can be created in the bore of the tubes in a tree.

....

.... [1]

(ii) Using the following data, calculate the height which water can be moved up a tree via low pressure in the bore of the tubes.

Atmospheric pressure = 101 kPa

Pressure in the bore of the tubes in the tree = 7.8 kPa

Density of water = 1000 kg m^{-3}

height = ... [2]

(iii) Suggest and explain how the height in **(c)(ii)** will change during a hot day.

....

....

.... [2]

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9749/02

Paper 2 Structured Questions **12 September 2018**

2 hours

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

Class	Reg No

Candidate Name: ______________________

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 a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions.

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.

For Examiner's Use	
1	/ 6
2	/ 8
3	/ 11
4	/ 10
5	/ 10
6	/ 8
7	/ 7
8	/ 20
Deductions	
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_0	=	8.85×10^{-12} F m^{-1}
		=	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ 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	=	$-Gm/r$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translation kinetic energy 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	=	$v_0 \cos \omega t$
		=	$\pm\, \omega\sqrt{x_o^{\,2} - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** For an oscillating body, state what is meant by

(i) natural frequency of vibration,

When the system oscillates without any external periodic force applied, its frequency is called its natural frequency.

.... [1]

(ii) resonance.

Resonance occurs when the frequency of the driving force (driving frequency) is equal to the natural frequency of the system, giving a maximum amplitude of vibration.

.... [1]

(b) State and explain one situation where resonance is useful.

1) Microwave Cooking

In a microwave oven, microwaves with a frequency similar to the natural frequency of vibration of water molecules are used. When food containing water molecules is placed in the oven and radiated by microwave, the water molecules resonate, absorb energy from the microwaves and get heated up. This absorbed energy then spreads through the food and cooks it. The plastic or glass containers do not heat up as much since they do not contain water molecules.

2) Radio Receiver

Our air is filled with radio waves of many different frequencies which the aerial (antenna) picks up. The tuner can be adjusted so that the natural frequency of the electrical oscillations in the circuits is the same as that of the radio wave transmitted from a particular station (the desired station). The radio waves of that particular frequency cause much larger oscillations (due to resonance) resonance compared to the radio waves of other frequencies.

3) Magnetic resonance imaging

Strong, electromagnetic fields of varying radio frequencies are used to cause oscillations in atomic nuclei. When resonance occurs, energy is absorbed by the molecules. By analysing the pattern of energy absorption, a computer-generated image can be produced. The advantage of MRI scanner is that no ionising radiation (as in the process of producing X-ray images) is involved.

4) Swing

The swinging of the legs has to be synchronised and at the same frequency as the natural frequency of the swing so that a large amplitude of oscillation can be obtained.

5) Voice

6) Guitar / Musical instrument

.... [2]

(c) In some situations, resonance should be avoided.

State one such situation and how the effects of resonance are reduced.

1) Earthquakes and tidal waves
During an earthquake, when the frequencies of the vibration match with the natural frequencies of buildings, resonance may occur and result in serious damages. In regions of the world where earthquakes happen regularly, buildings may be built on foundations that absorb the energy of the shock waves. In this way, the vibrations are damped and the amplitude of the oscillations cannot reach dangerous levels.

2) Vibrations in machines / metal panels
If a loose part in a car rattles when the car is travelling at a certain speed, it is likely that a resonant vibration is occurring. A washing machine with an unbalanced load which has natural frequency matching the spinning frequency will get violent vibrations as resonance occurs. Place dampers in the machine / place strengthening struts across the panel or change its shape/area of panel

.... [2]

2 A particle in a medium is oscillating because of the passage of a transverse wave W_1.

The wave has intensity I at this point. The amplitude of the oscillation is A.

Fig. 2.1 shows the variation with time t of the displacement x of the particle.

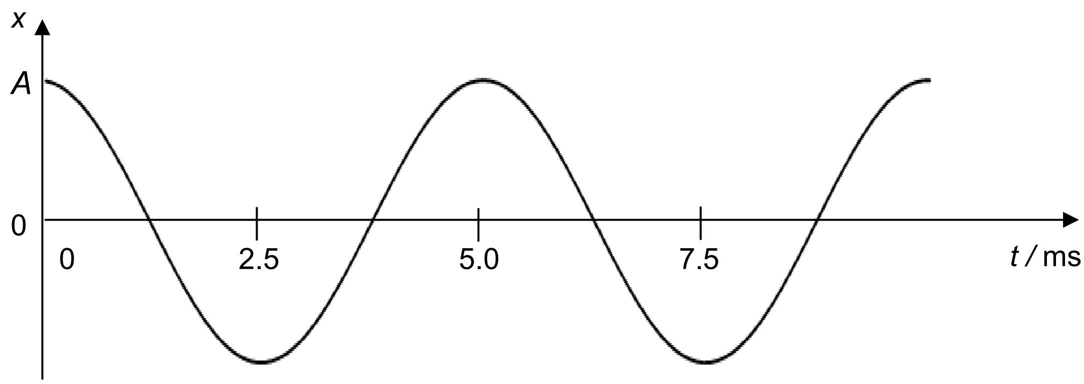


Fig. 2.1

A second, similar transverse wave W_2 has the same frequency and is incident on the same particle. The amplitude of the oscillation due to W_2 alone is $2.5\,A$ at this point.

(a) Calculate

(i) the frequency of the waves,

$$f = \frac{1}{T} = \frac{1}{5.0\times10^{-3}} = 200 \text{ Hz}$$ [B1]

frequency = ... Hz [1]

(ii) the intensity, in terms of I, of the wave W_2.

Intensity $\propto$ Amplitude^2

$$\frac{I_2}{I_1} = \frac{A_2^2}{A_1^2}$$

$$\frac{I_2}{I} = \frac{\left(\frac{5A}{2}\right)^2}{A^2}$$ [M1]

$$I_2 = \frac{25}{4} I = 6.25\, I$$ [A1]

intensity = ... I [2]

(b) **(i)** State two conditions which are necessary for the waves W_1 and W_2 to produce an observable interference pattern.

The two waves must be coherent, (with constant phase difference between the two waves). [B1]
They must either be unpolarised, or polarised in the same plane. [B1]

.... [2]

(ii) State the condition that must be satisfied if the waves are to interfere to produce a minimum resultant intensity at a point.

If the source is in phase, their path difference must be equal to (n+½) wavelengths where n is an integer. [B1]
Or
The two waves must be in antiphase with each other. [B1]

.... [1]

(iii) Calculate, in terms of I, this minimum intensity.

For minimum intensity, the resultant amplitude is $\frac{5A}{2} - A$ [M1]

$$\frac{I_{min}}{I} = \frac{\left(\frac{5A}{2} - A\right)^2}{A^2}$$

$$I_2 = \frac{9}{4} I = 2.25\, I$$ [A1]

minimum intensity = ... I [2]

3 **(a)** State two differences between stationary waves and progressive waves.

	Stationary Wave	**Progressive Wave**
Wave profile	• Varies from one extreme position to another, but does not advance.	• Advances with the speed of the wave.
Energy of wave	• Energy is retained within the vibratory motion of the wave.	• Energy is transferred in the direction of wave propagation.
Amplitude of oscillation of individual particles	• Depends on position along the wave • Particles at the antinodes oscillate with maximum amplitude • Particles at the nodes do not oscillate	• Same for all particles in the wave regardless of position (assuming no energy loss).
Wavelength	• Twice the distance between 2 adjacent nodes/ antinodes. • Equal to the wavelength of the component waves.	• Distance between any 2 consecutive points on the wave with the same phase.
Phase of wave particles in a wavelength	• All particles between 2 adjacent nodes are in phase. • Particles in alternate segments are in anti-phase (have a phase difference of π).	• Wave particles have different phases (0 to 2π) within a wavelength.
Any 2 rows [B1, B1]		

.... [2]

(b) **(i)** A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating as shown in Fig. 3.1.

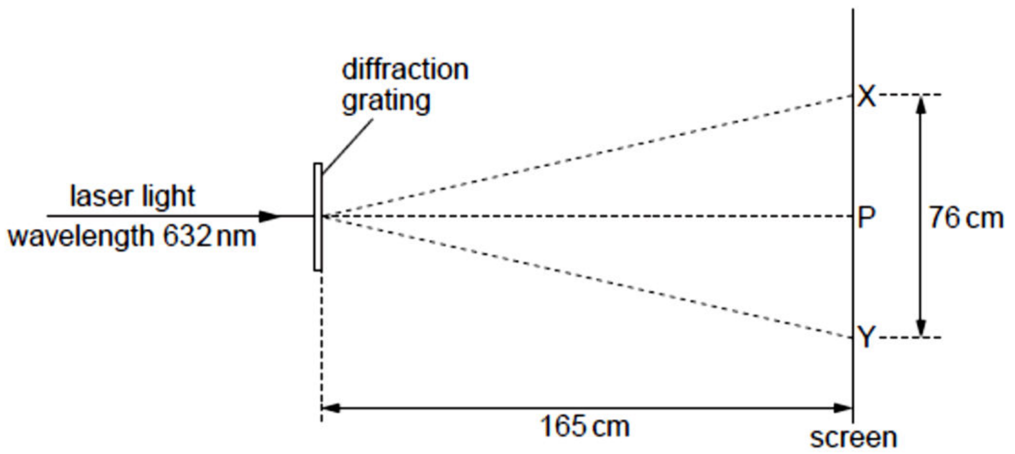


Fig. 3.1 (Top view)

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.

The brightest spot is P. The spots formed closest to P and on each side of P are X and Y.

X and Y are separated by a distance of 76 cm.

Calculate the number of lines per metre on the grating.

$$\tan\theta = \frac{38}{165}$$

$$\theta = 12.97° \ (13°)$$

$$d\sin\theta = n\lambda$$

$$d = \frac{632\times10^{-9}}{\sin 12.97°} = 2.82\times10^{-6} \quad \text{[M1]}$$

$$\text{number of lines per metre} = \frac{1}{d} = \frac{1}{2.82\times10^{-6}} = 3.6\times10^{5} \quad \text{[A1]}$$

number per metre = ... m^{-1} [2]

(ii) The grating in **(b)(i)** is now rotated about an axis parallel to the incident laser beam, as shown in Fig. 3.2.

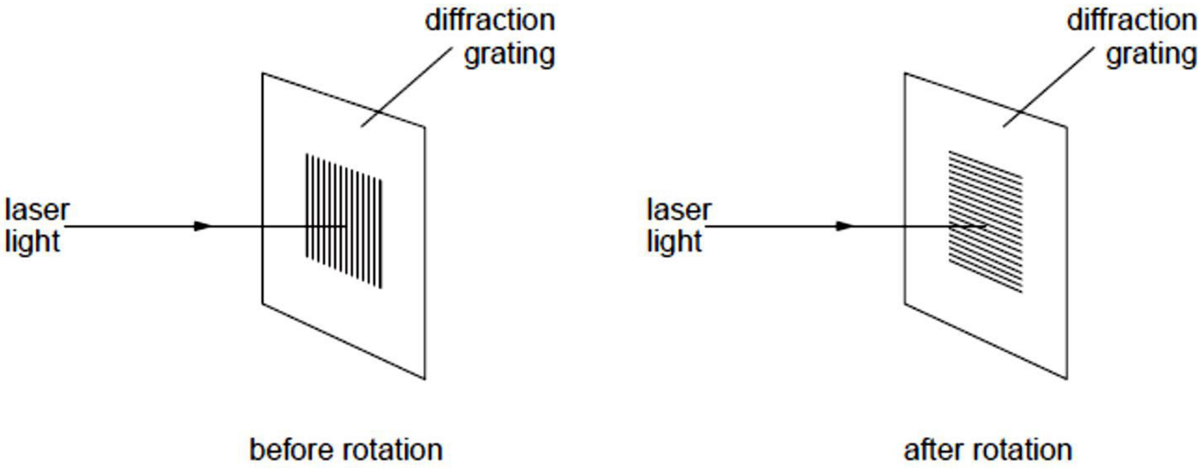


Fig. 3.2

State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

P remains in the same position [B1]
X and Y rotate through 90° [B1]

.... [2]

(iii) In another experiment using the apparatus in **(b)(i)**, a student notices that the distances XP and PY, as shown in Fig. 3.1 are not equal.

Suggest a reason for this difference.

Screen is not parallel to the diffraction grating. [B1]

or
The diffraction grating is not normal to the incident light. [B1]

.... [1]

(c) A cord is held under tension between two fixed points A and B, as shown in Fig. 3.3. The distance AB is 0.40 m.

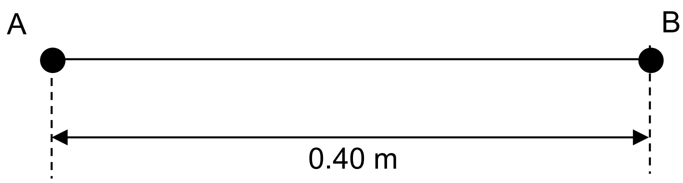


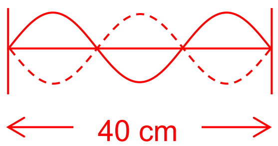
Fig. 3.3

(i) Explain why only stationary waves of certain frequencies are able to form between A and B.

Only standing waves that have a wavelength that fits the boundary conditions are possible. [B1]
OR
Standing waves are formed only when the length AB is an integer multiple of half wavelengths. [B1]

.... [1]

(ii) The string is made to resonate in a mode with the third lowest possible frequency. Calculate the wavelength of this wave.



3 loops / 3 segments

$\frac{3}{2}\lambda = 40$ cm

$\lambda = 26.7$ cm [A1]

wavelength = ... m [1]

(iii) By reference to the formation of the stationary wave, explain the significance of the product of frequency and wavelength for a stationary wave.

Stationary wave is formed by two oppositely moving waves of the same type and frequency. [B1]
This product is the speed of propagation of the individual wave that results in the stationary wave. [B1]

.... [2]

4 **(a)** Fig. 4.1 shows a piece of metal, of mass 50 g, held in the flame of a Bunsen burner for several minutes. The metal is then quickly transferred and immersed in 130 g of water contained in a calorimeter.

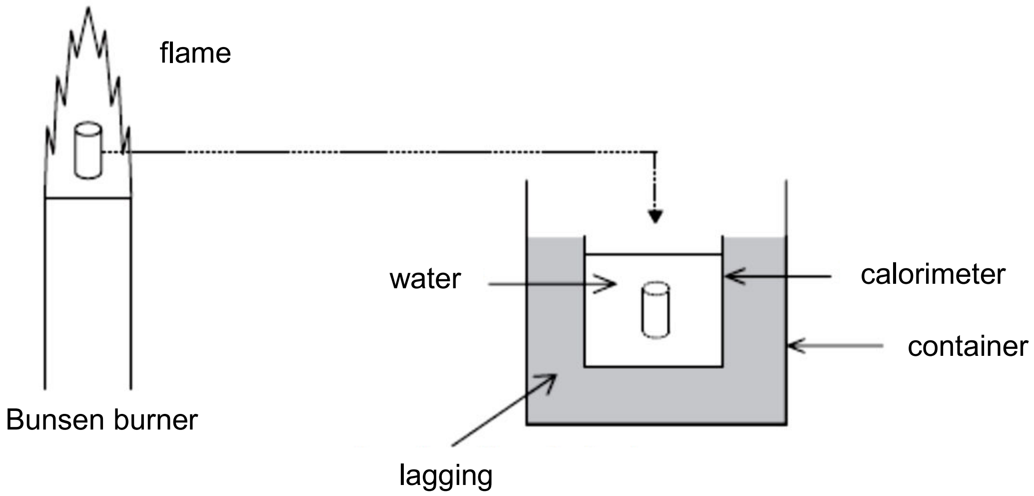


Fig. 4.1

The water into which the metal has been placed is stirred until it reaches a steady temperature. The following data are available:

heat capacity of metal	82.7 J K^{-1}
specific heat capacity of the water	4.2×10^3 J kg^{-1} K^{-1}
heat capacity of the calorimeter	54.6 J K^{-1}
initial temperature of the water	25 °C
final temperature of the water	90 °C

Use the data to calculate the temperature of the Bunsen flame and state an assumption made for your calculation.

energy lost by metal = energy gained by water + energy gained by calorimeter

$$82.7(T-90) = \left(0.130 \times 4.2 \times 10^3\right)(90-25) + 54.6(90-25)$$ [M1]

$$T = 562 \text{ °C}$$ [A1]

temperature = ... °C

There is no heat loss when the metal was transferred from the flame to the water. [B1]

Assumption: .... [3]

(b) The gas in the cylinder of a diesel engine can be considered to undergo a cycle of changes of pressure, volume and temperature. One such cycle, for an ideal gas, is shown in Fig. 4.2. Processes A to B and C to D take place without heat exchange with the surroundings.

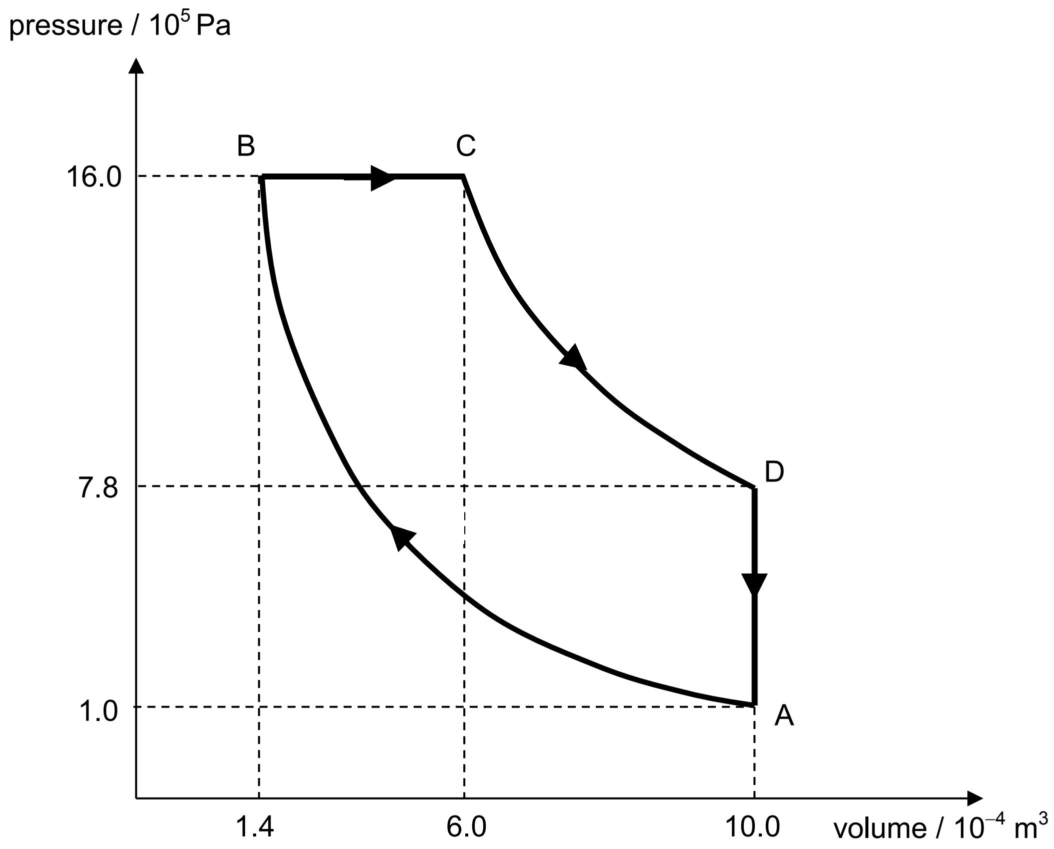


Fig. 4.2

Complete the table below.

Process	**Heat supplied to gas / J**	**Work done on gas / J**	**Increase in internal energy of gas / J** $\Delta U = Q + W$
A to B	0	300	300
B to C	2580	-740 $-p(\Delta V) = -1.6 \times 10^5 (4.6 \times 10^{-4})$	1840
C to D	0	-440	-440
D to A	-1700	0 $\Delta V = 0$	-1700

Each process (row) correct, award one mark.

[4]

(c) A fixed mass of ideal gas is heated from temperature T_1 to T_2 at constant volume. Explain why a greater amount of heat is required to heat the same mass of ideal gas from T_1 to T_2 at constant pressure.

Amount of energy required is greater at constant pressure. [A0]
For an ideal gas, internal energy is proportional to temperature. The change in internal energy ΔU is the same for both cases. [B1]
By 1st law of thermodynamics, $\Delta U = Q + W$.
At constant volume, internal energy increases, but no work is done. ($Q = \Delta U$) [B1]
At constant pressure and with volume increase, internal energy increases and work is done by the gas ($Q = \Delta U - W_{on} = \Delta U - (-W_{by})$) [B1]

.... [3]

5 **(a)** Define *magnetic flux*.

The magnetic flux through a plane surface is the product of the flux density normal to the surface and the area of the surface

.... [1]

(b) Fig. 5.1 shows a 1.6 m long solenoid with 400 turns and a cross-sectional diameter of 4.0 cm. A coil Y, with 80 turns, is wounded tightly around the centre region of the solenoid.

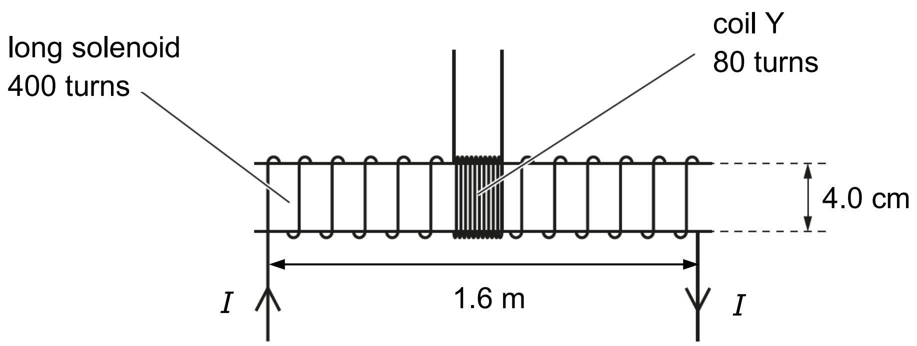


Fig. 5.1

(i) Show that, for a current I of 3.8 A in the solenoid, the magnetic flux linkage of coil Y is 1.2×10^{-4} Wb.

$B = \mu_0 n I = 4\pi \times 10^{-7}\left(\frac{400}{1.6}\right)3.8$ [C1]

$= 3.8 \times 10^{-4}\pi$

$\Phi = NBA$

$= 80 \times \left(3.8 \times 10^{-4}\pi\right) \times \pi\left(\frac{0.040}{2}\right)^2$ [M1]

$= 1.2 \times 10^{-4}$ Wb [A0]

[2]

(ii) The current I in the solenoid in **(b)(i)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil Y.

$E_{mean} = \frac{\Delta\Phi}{\Delta t}$

$= \frac{2 \times 1.2 \times 10^{-4}}{0.30}$ [M1]

$= 8.0 \times 10^{-4}$ V [A1]

mean e.m.f. = ... V [2]

(iii) The current I in the solenoid in **(b)(ii)** varies with time t as shown in Fig. 5.2.

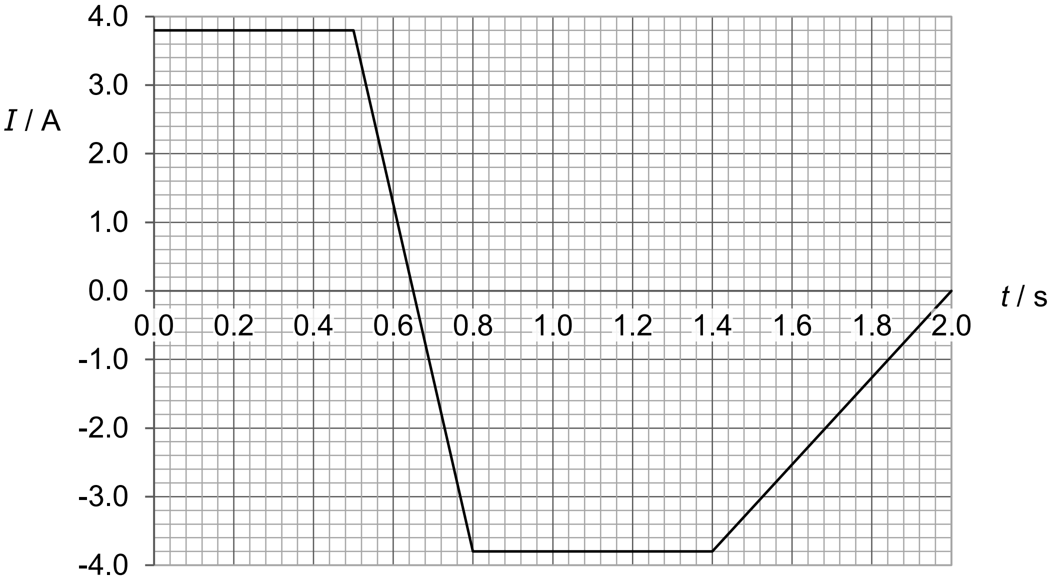
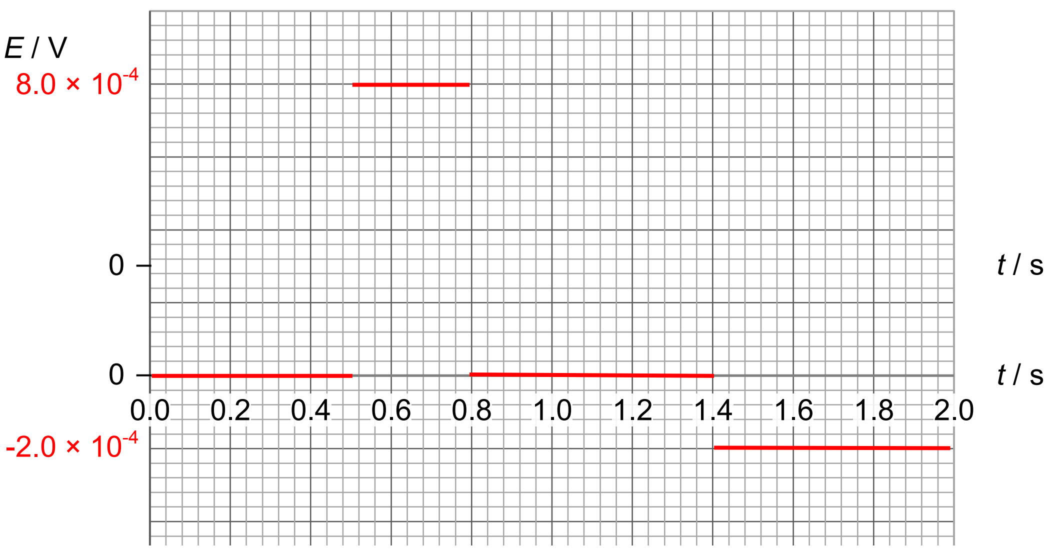


Fig. 5.2

Use your answer to **(b)(ii)** to sketch, on Fig. 5.3, the variation with time t of the e.m.f. E induced in coil Y.



E_1 = 0 V from t = 0 s to 0.3 s and 0.8 s to 1.4 s [B1]
E_2 = 8.0 × 10^{-4} V from t = 0.3 s to 0.8 s [B1]
E_3 = 2.0 × 10^{-4} V from t = 1.4 s to 2.0 s, in reverse polarity [B1]
No label but ratio between E_2 and E_3 is draw to scale = -1 mark
No label and wrong ratio between E_2 and E_3 = -2 marks

[3]

(iv) An iron core is inserted into the solenoid and then held stationary within the solenoid. Explain the effect on the e.m.f. induced in coil Y.

The iron core increases the magnetic flux density, resulting in a larger rate of change of flux linkage. [M1]
Hence, the e.m.f. induced in coil Y is larger (when it is not zero). [A1]

.... [2]

6 **(a)** The photoelectric effect provides evidence for the particulate nature of electromagnetic radiation. State two experimental observations that could not be fully explained using the classical wave theory.

-the existence of threshold frequency
-max ke independent of intensity / max ke dependent on frequency (note: NOT proportional)
-instantaneous emission of photoelectrons
[NOT: photocurrent depends on intensity (this observation corresponded to the prediction)]
[any 2 correct - 2 marks]

1. ....

2. .... [2]

(b) In an experiment to investigate the photo-electric effect, the wavelength of the radiation incident on the metal surface was varied. For two values of wavelength λ, the stopping potential V_s was measured. The results are shown in Fig. 6.1.

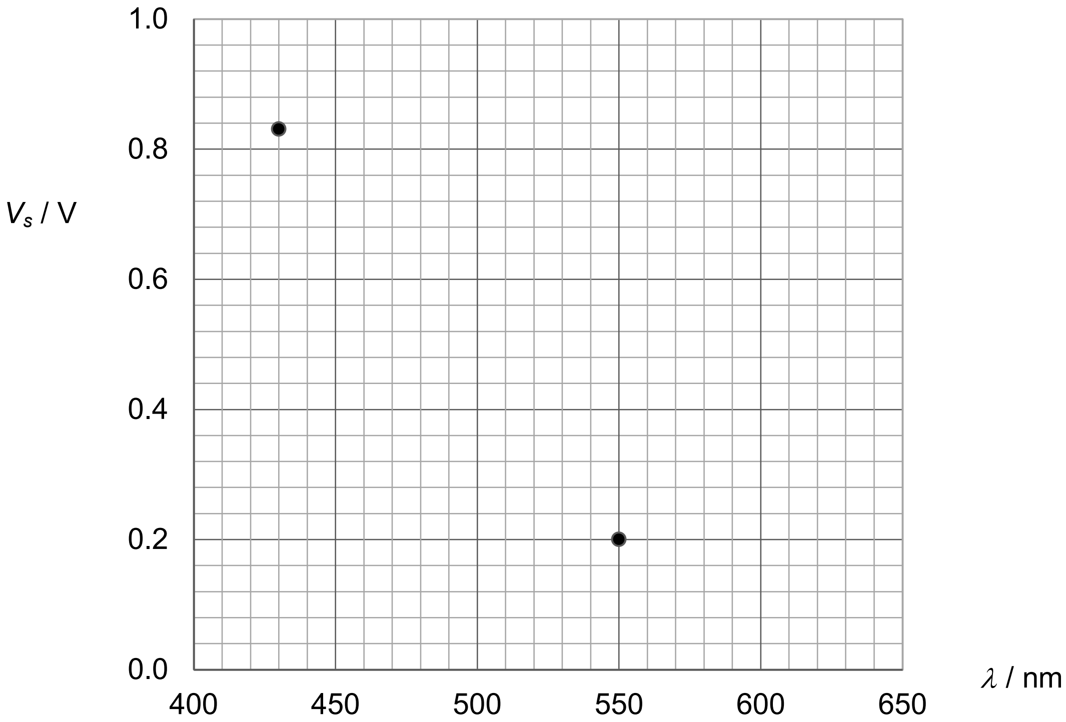


Fig. 6.1

(i) Determine the maximum kinetic energy of a photo-electron emitted from the metal surface by radiation of wavelength 550 nm.

$$KE_{max} = eV_s$$
$$= (1.6 \times 10^{-19})0.2$$
$$= 3.2 \times 10^{-20} \text{ J} \qquad \text{[B1]}$$

maximum kinetic energy = ...J [1]

(ii) Hence, calculate the threshold wavelength of the metal.

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + eV_s$$

$$\frac{6.63 \times 10^{-34}(3.0 \times 10^8)}{550 \times 10^{-9}} = \frac{6.63 \times 10^{-34}(3.0 \times 10^8)}{\lambda_0} + 3.2 \times 10^{-20} \qquad \text{[M1]}$$

$$\lambda_0 = 6.03 \times 10^{-7} \text{ m} \qquad \text{[A1]}$$

threshold wavelength = ... m [2]

(iii) Suggest why it is not possible to deduce the threshold wavelength of the metal surface directly from Fig. 6.1.

The relationship between *Vs* and radiation wavelength is not linear, hence the curve cannot be extrapolated with 2 data points [B1]

.... [1]

(iv) The intensity of the radiation incident on the metal surface was kept constant as the wavelength was decreased from 550 nm to 430 nm.

State and explain the effect, if any, on the photocurrent.

Each photon has more energy, but rate of incident photon is lower [M1]
lower rate of emission of electrons, hence photocurrent decreases. [A1]

.... [2]

7 X-ray photons are produced when electrons are accelerated through a potential difference towards a metal target. An X-ray spectrum is shown in Fig. 7.1.

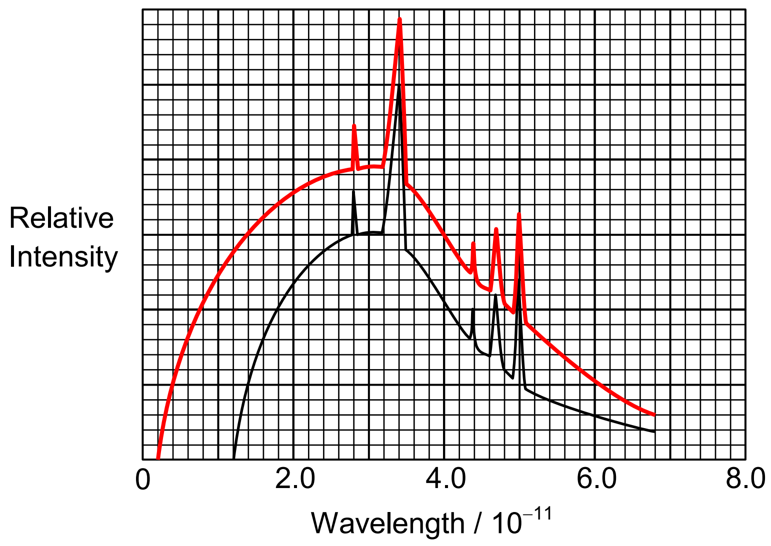


Fig. 7.1

(a) Explain how the most energetic X-ray photons are produced.

When the highly energetic electrons strikes the target metal and are suddenly decelerated by collision with the metal atoms, [B1]
the electrons lose all its energy and the energy lost is emitted as X-ray photons of equivalent energy. [B1]

.... [2]

(b) **(i)** Explain how the characteristic X-ray K_α photons are produced.

When the highly energetic electrons knock out the electrons in the K-shell of the atoms and leave a vacancy.
Electrons in the next higher energy level, L-shell, transit down to the vacancy and K_α photons are produced with energy equal to the energy difference between the 2 energy levels.

.... [2]

(ii) Determine the momentum of the K_α X-ray photon.

$\lambda \approx 3.4 \times 10^{-11}$ m

$$p = \frac{h}{\lambda} = \frac{(6.63 \times 10^{-34})}{3.4 \times 10^{-11}} = 1.9488 \text{ J} = 1.95 \text{ J}$$

momentum = ... N s [2]

(c) The potential difference used to accelerate the electrons is increased. On Fig. 7.1, sketch the new spectrum obtained. [1]

Same characteristic wavelengths, lower threshold wavelength, higher intensity

8 This question is about the movement of water from the roots of a tree to its leaves.

Water moves up a tree through its vast network of conduits. These conduits are similar to capillary tubes. It is suspected that water moves up the conduits due to low pressure in the conduits which “sucks” the water upwards, or by capillary action, or a combination of both. Capillary action is a phenomenon whereby water rises up a small tube due to upward forces caused by the adhesion of water to the walls of the tube.

To investigate capillary action, a capillary tube, open at both ends, is supported vertically with one end immersed in water, as shown in Fig. 8.1. The water in the narrow bore of the tube forms a column of height *h*.

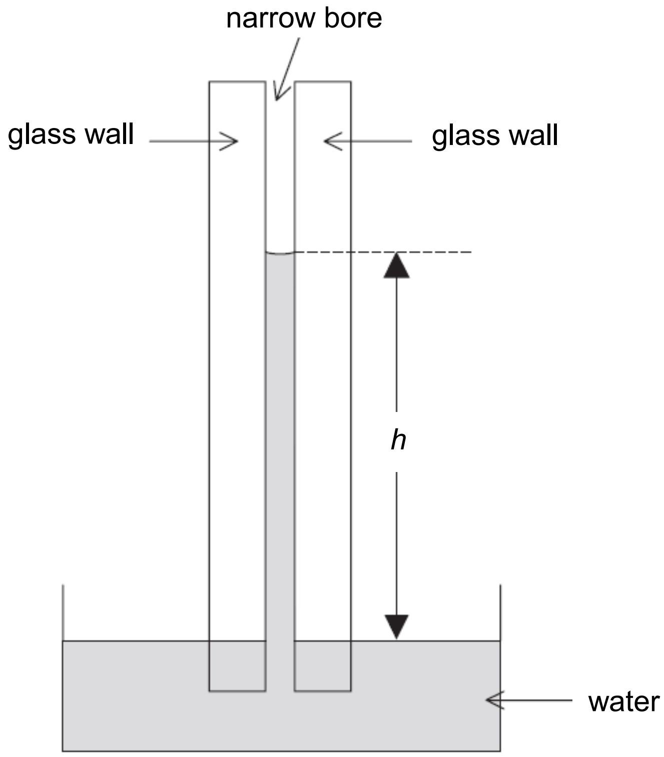


Fig. 8.1
(not to scale)

(a) The height h of the water column for a particular capillary tube was measured as the temperature of water θ was varied. Fig. 8.2 shows the data collected.

θ / °C	h / cm
30	14.0
40	13.2
50	12.5
60	11.5
70	10.9
80	10.0

Fig. 8.2

Fig. 8.3 shows the variation with temperature θ of height h.

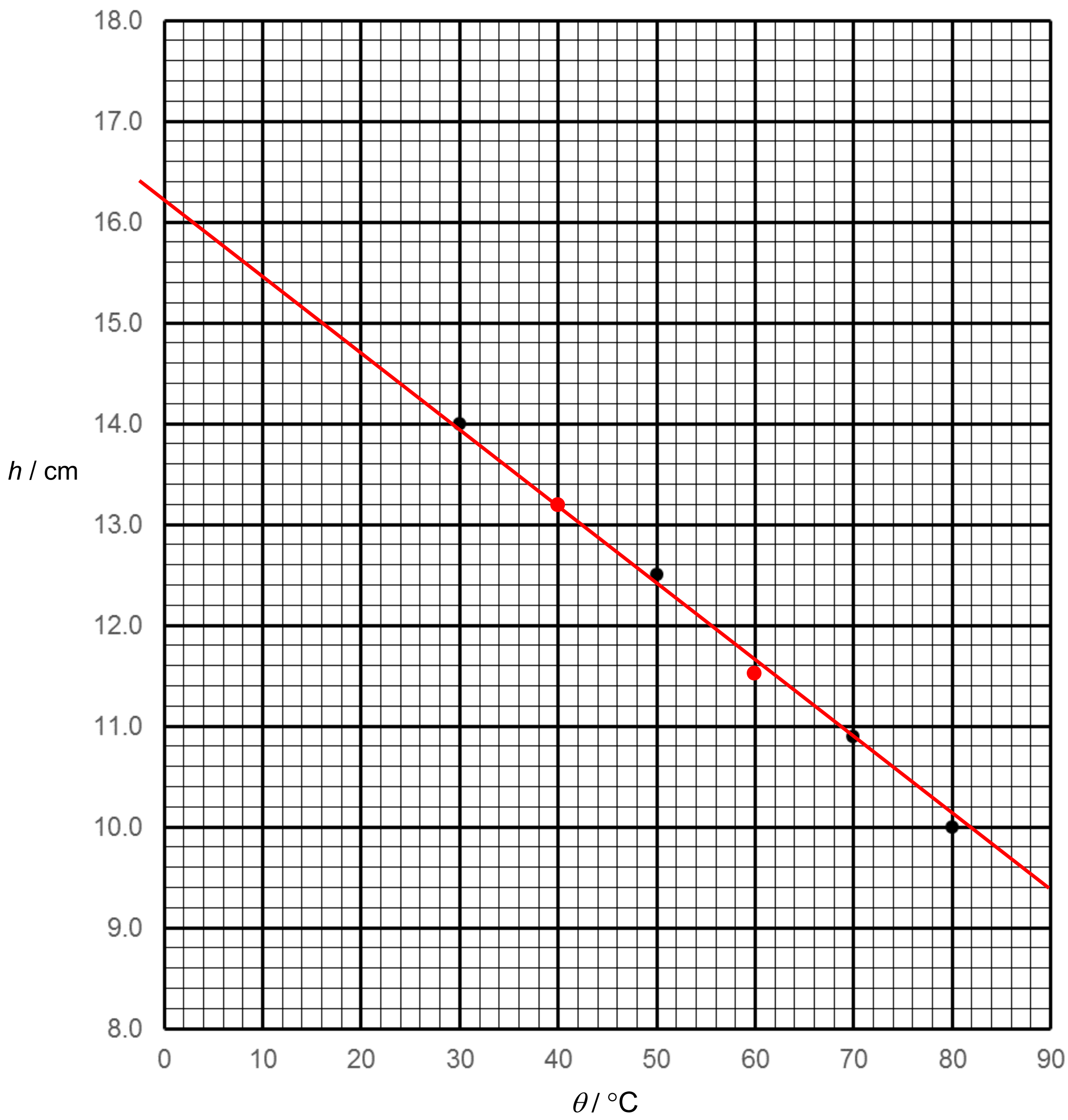


Fig. 8.3

(i) On Fig. 8.3, plot the points for θ = 40 °C and θ = 60 °C. Draw a line of best fit through the data points. [2]

Both points plotted correctly [B1]
Appropriate line of best fit [B1]

(ii) Using Fig 8.3, determine the height h_0 of the water column when the temperature is 0 °C.

Correct read off from vertical intercept [B1]
h_0 = 16.2 cm

h_0 = ...cm [1]

(iii) It is suggested that the relationship between θ and h is

$$\frac{h}{h_0} = 1 - k\theta$$

where k is a constant.

Explain why the results of this experiment supports the relationship suggested.

Rearrange to linear form: $h = h_0 - h_0 k\theta$ [B1]

State that a linear line is obtained / linear trend of data [B1]

State that gradient = $-h_0 k$, and vertical intercept = h_0 [B1]

Last B1 not awarded if student state gradient = $h_0 k$

.... [3]

(iv) Using the line drawn in **(a)(i)**, determine the value of k, including its units.

Gradient $= \dfrac{13.8 - 10.6}{32 - 74}$ [M1]

$= -0.0762$

$k = -\dfrac{\text{gradient}}{h_0} = -\dfrac{-0.0762}{16.2} = 4.70 \times 10^{-3}$ [A1]

Units = $°C^{-1}$ [B1]

Substitution of coordinates into equation to find k (no credit given)

If gradient coordinates used does not lie on line (e.g. use data point), minus 1 mark.

Minus 1 mark if gradient coordinates cannot be traced back to the graph (ie. Show 2 pairs of coordinates in the gradient calculations).

k = ... [3]

(b) The experiment is repeated using capillary tubes with bores of different radii r but keeping the water temperature constant. Fig. 8.4 shows the variation with $\frac{1}{r}$ of height h for a water temperature of 20 °C.

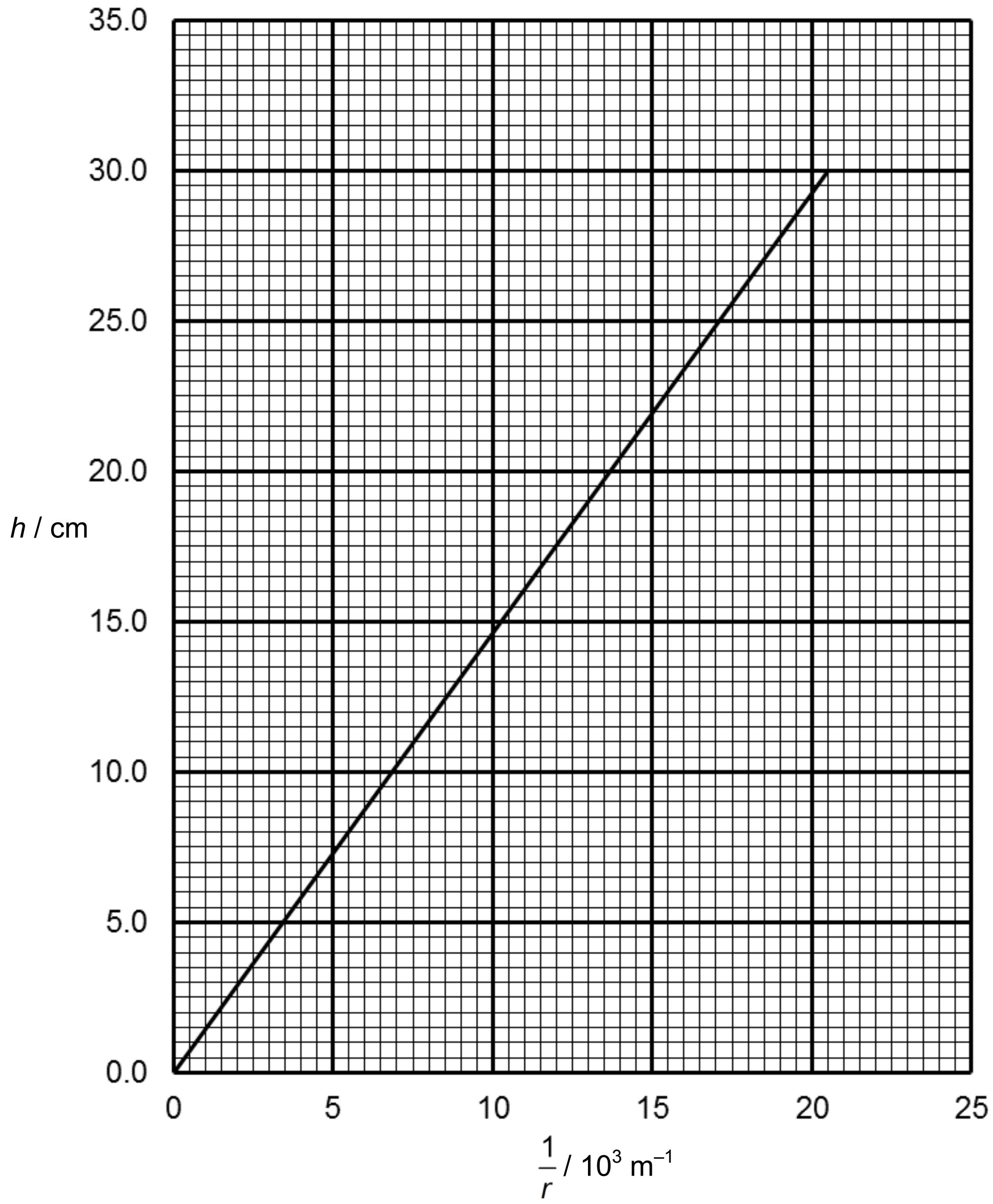


Fig. 8.4

(i) Use Fig. 8.4 to estimate the radius of the bore of the tubes in a 25-metre tall tree, which will enable water to be raised by capillary action from ground level to the top of the tree.

Graph is of form $h = \frac{C}{r}$ where C is a constant (= gradient) [M1]

$$C = \frac{(30.0 - 0) \times 10^{-2}}{(20.5 - 0) \times 10^{3}} = 1.46 \times 10^{-5} \quad \text{[M1]}$$

$$r = \frac{C}{h} = \frac{1.46 \times 10^{-5}}{25} = 5.85 \times 10^{-7} \text{ m} \quad \text{[A1]}$$

radius = ... m [3]

(ii) State one assumption made in your estimation in **(b)(i)**.

The trend of graph remains linear throughout all values of h (or up to 25 m) / h is inversely proportional to r throughout all values of h (or up to 25 m) [B1]

.... [1]

(iii) Comment on your answer obtained in **(b)(i)**.

Radius of bore obtained is too small [B1]
Unlikely that capillary action is the only means [B1]

.... [2]

(c) The other means of moving water up a tree is to create a low pressure in the bore of the tubes in the tree.

(i) Suggest how low pressure can be created in the bore of the tubes in a tree.

Evaluation of water through leaves (transpiration) [B1]
creates a low water vapour pressure in the bore

.... [1]

(ii) Using the following data, calculate the height which water can be moved up a tree via low pressure in the bore of the tubes.

Atmospheric pressure = 101 kPa

Pressure in the bore of the tubes in the tree = 7.8 kPa

Density of water = 1000 kg m^{-3}

$\Delta p = h\rho g$

$(101 - 7.8) \times 10^3 = h(1000)(9.81)$ [M1]

$h = 9.5$ m [A1]

height = ... [2]

(iii) Suggest and explain how the height in **(c)(ii)** will change during a hot day.

Evaporation rate will be higher; pressure difference will be greater [M1]
Hence height increases [A1]
OR
Water density will be lower [M1]
Hence height increases [A1]
OR
Bores of the capillary tubes becomes wider; lesser capillary action [M1]
Hence height decreases [A1]

.... [2]

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9749/03

Paper 3 Longer Structured Questions **17 September 2018**

2 hours

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

Candidate Name: ____________________

Class	Reg No

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 a 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend about one and a half hours on Section A and half an hour on Section B.

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.

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 7**
3	**/ 9**
4	**/ 4**
5	**/ 5**
6	**/ 10**
7	**/ 15**
Section B	
8	**/ 20**
9	**/ 20**
Deductions	
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_0	=	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	=	$-Gm/r$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translation kinetic energy 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	=	$v_0 \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^{\,2} - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

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

1 **(a)** **(i)** State Newton's first law of motion.

....

.... [1]

(ii) State the conditions for equilibrium.

....

....

....

.... [2]

(b) Fig. 1.1 shows a uniform ladder of weight 80 N resting on a smooth wall and a rough floor. The ladder makes an angle of 60° with the floor.

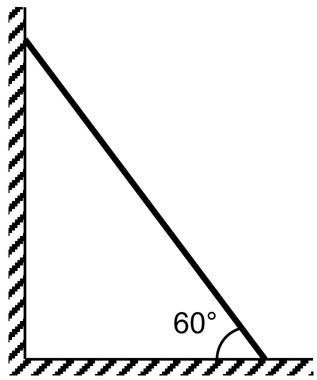


Fig. 1.1

(i) Show that the force exerted by the wall on the ladder is 23 N.

[2]

(ii) Calculate the force exerted by the floor on the ladder.

magnitude of force = ... N

direction of force : .... [3]

(iii) A person now stands on the ladder. The ladder remains stationary.

State and explain the effects, if any, on

1. the vertical force exerted by the floor on the ladder.

....

....

.... [1]

2. the horizontal force exerted by the wall on the ladder.

....

....

.... [1]

2 In an experiment to determine the specific heat capacity of a liquid, a student heated a fixed mass of the liquid for a fixed duration of time, using an electric heater. The student repeated the experiment three times to find the rise in temperature of the liquid. The following measurements were obtained:

Mass of liquid, m	309 ± 3 g
Voltage applied across heater, V	11.8 ± 0.3 V
Current flow in the heater, I	4.125 ± 0.002 A
Time taken, t	200.0 ± 0.5 s

The rise in temperature θ was recorded for each attempt:

Attempt:	1st	2nd	3rd
θ / K	10.2	9.7	10.5

(a) Estimate the uncertainty in θ.

uncertainty in θ = ... K [1]

(b) Calculate the specific heat capacity c of the liquid.

c = ... J kg^{-1} K^{-1} [2]

(c) Calculate the uncertainty in specific heat capacity c of the liquid and express the specific heat capacity c together with its uncertainty.

c = ... ± .... J kg^{-1} K^{-1} [3]

(d) State an assumption made in your calculation of the specific heat capacity c of the liquid.

....

.... [1]

3 **(a)** State Newton's second law of motion.

....

....

.... [1]

(b) A car of mass 800 kg was travelling on a horizontal road at a constant speed of 20 m s^{-1} before a net horizontal constant forward force of 4800 N acts on the car for 12 s.

Calculate

(i) the distance travelled by the car over the 12 s,

distance = ... m [2]

(ii) the speed of the car at the end of the 12 s,

speed = ... m s^{-1} [2]

(iii) the work done on the car during the 12 s

1. using the answer to **(b)(i)**;

work done = ...J [1]

2. using the answer to **(b)(ii)**.

work done = ...J [1]

(iv) the impulse exerted on the car over the 12 s.

impulse = ... N s [2]

4 A person threw a ball vertically upwards.

(a) Fig. 4.1 shows the variation with time of the velocity when air resistance is absent.

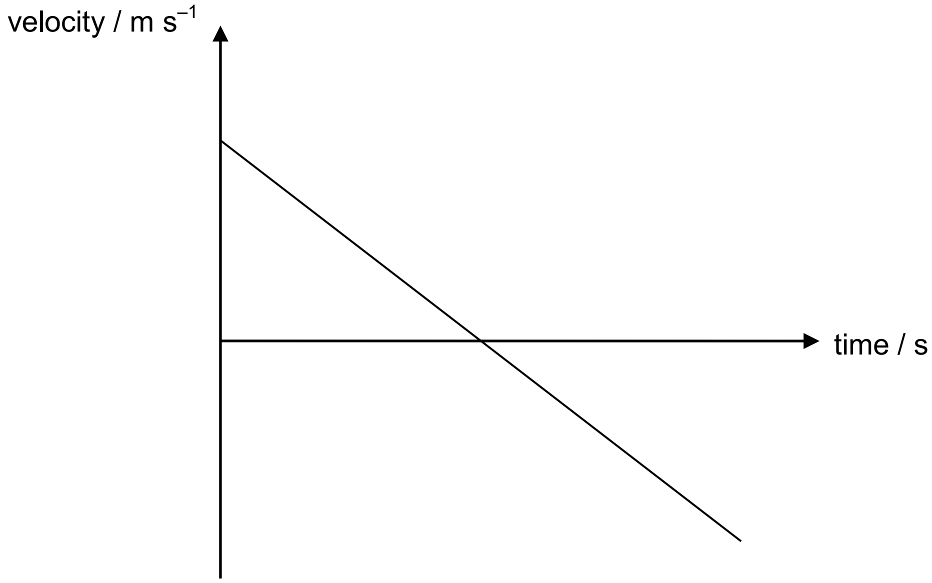


Fig. 4.1

Draw on Fig. 4.1 a second graph for the case where air resistance is present. [3]

(b) Explain how the presence of air resistance would affect the maximum height reached by the ball.

....

....

.... [1]

5 Ball A, of mass 800 g and travelling with a speed of 9.2 m s^{-1}, collided head-on with a stationary ball B of mass 2400 g. The collision is completely inelastic.

(a) Explain whether the total momentum is conserved during the collision.

....

....

.... [1]

(b) Calculate the percentage loss in total kinetic energy.

percentage loss = ... % [2]

(c) Shortly after the collision, Ball B comes into contact with a spring of spring constant 2500 N m^{-1}. Calculate the maximum compression of the spring.

maximum compression = ... m [2]

6 Fig. 6.1 shows an isolated conducting sphere which has been charged. Dashed lines (−−−−) join points of equal potential V. The potential difference between successive lines of equal potential is equal.

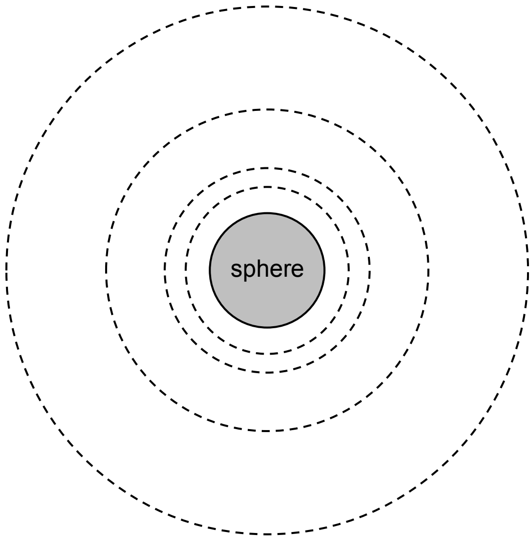


Fig. 6.1

For points on the surface or outside the sphere, the charge on the sphere behaves as if it were concentrated at the centre.

Measurements of the distance x from the centre of the sphere and the corresponding values of the potential V are given in Fig. 6.2. The values in Fig. 6.2 do not correspond to the dashed lines in Fig. 6.1.

x / m	V / V
0.19	-1.50×10^5
0.25	-1.14×10^5
0.32	-0.89×10^5
0.39	-0.73×10^5

Fig. 6.2

(a) On Fig. 6.1, draw the electric field lines. Label these lines E. [2]

(b) Explain how your drawing in **(a)** shows the relationship between electric potential *V* and the electric field *E*.

....

....

.... [2]

(c) **(i)** Use the data in Fig. 6.2 to show that the potential *V* is inversely proportional to the distance *x*. Explain your reasoning.

[2]

(ii) The potential at the surface of the sphere is -1.9×10^5 V. Calculate the radius of the sphere.

radius of sphere = ... m [2]

(iii) Determine the charge on the sphere.

charge = ...C [2]

7 (a) A power bank (which is basically a battery) can be used to power many devices at the same time. A power bank of e.m.f. 12.0 V and internal resistance 3.0 Ω is connected to multiple devices in the circuit shown in Fig. 7.1.

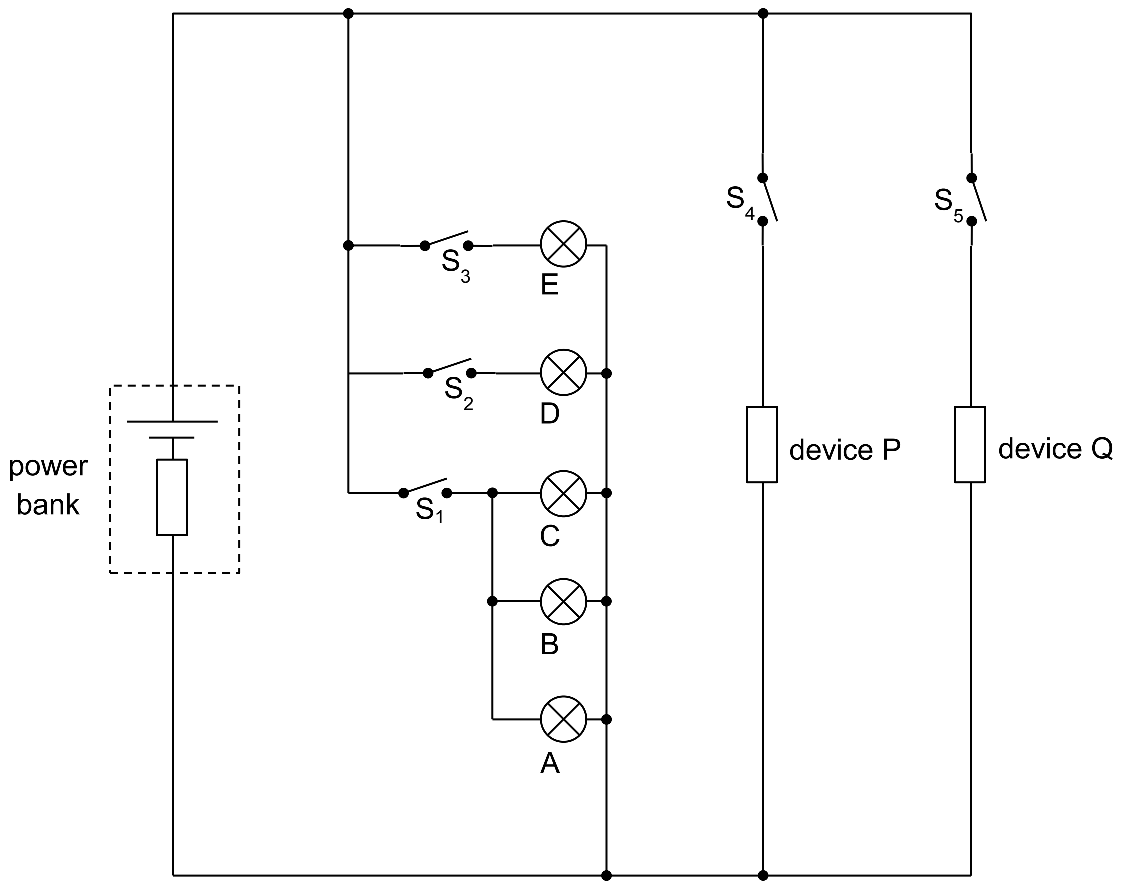


Fig. 7.1

The power bank is connected to 5 identical lamps (A, B, C, D and E) and 2 devices (P and Q). The lamps and devices can be turned on and off using the various switches (S_1, S_2, S_3, S_4 and S_5).

(i) Explain what is meant by "*e.m.f. of 12.0 V*" with reference to the power bank.

....

.... [2]

(ii) State the effect of closing switch S_1.

....

.... [1]

(iii) All the switches are now closed. Given the data below, calculate the current supplied by the power bank.

Resistance of each lamp = 25.0 Ω

Resistance of device P = 38.0 Ω

Resistance of device Q = 42.0 Ω

current = ... A [2]

(iv) Calculate the terminal potential difference of the power bank when all the switches are closed.

terminal potential difference = ... V [2]

(v) State and explain the effect, if any, on the brightness of the lamps if switches S_4 and S_5 are now opened while the rest remain closed.

....

....

....

.... [2]

(b) The same power bank from **(a)** is now connected in a potentiometer circuit as shown in Fig. 7.2.

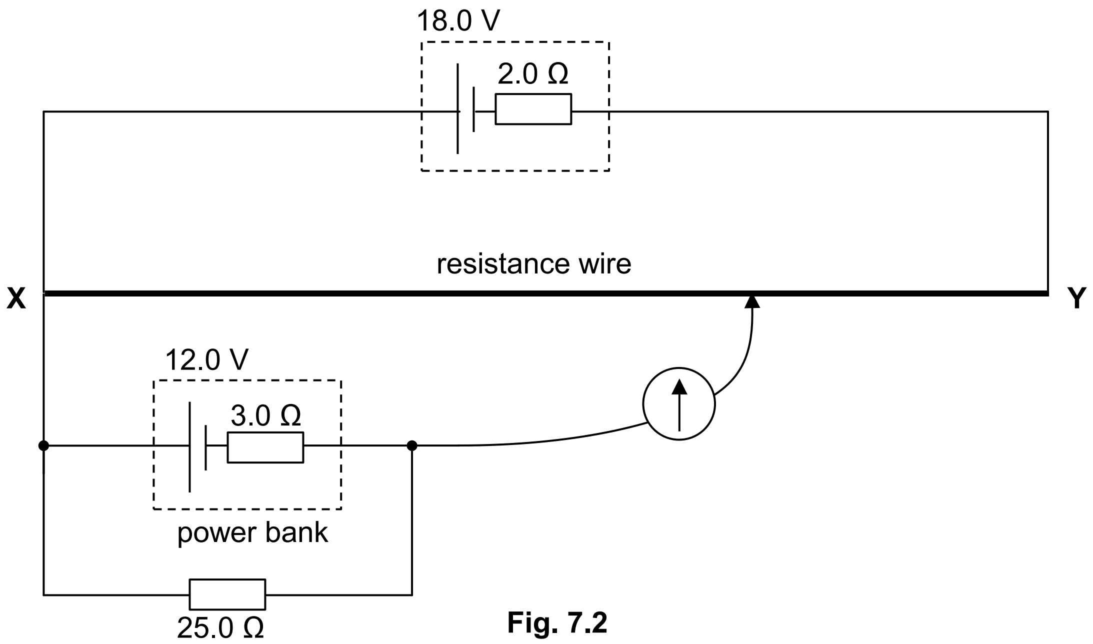


Fig. 7.2

A 18.0 V battery with internal resistance of 2.0 Ω is connected to a resistance wire XY. XY is 1.00 m long and has resistance of 7.2 Ω. A resistor of 25.0 Ω is connected in parallel to the power bank.

(i) Calculate the balance length when the galvanometer shows a reading of zero.

balance length = ... m [3]

(ii) Explain why it is desirable to obtain a balance point which is closer to end Y.

....

.... [1]

(iii) State and explain the effect, if any, on the balance length if resistance wire XY is now made of a material with higher resistivity.

....

.... [2]

Section B

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

8 **(a)** A binary star consists of two stars that orbit about a fixed point C, as shown in Fig. 8.1.

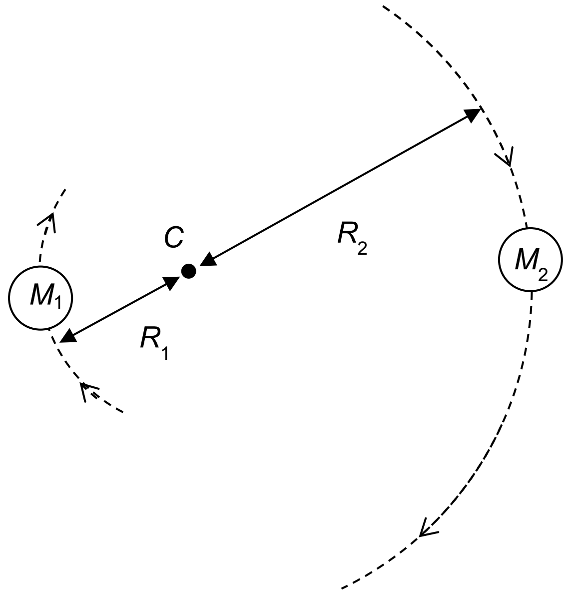


Fig. 8.1

The star of mass M_1 has a circular orbit of radius R_1 and the star of mass M_2 has a circular orbit of radius R_2. Both stars have the same angular speed ω about C.

(i) State the formula, in terms of G, M_1, M_2, R_1, R_2 and ω for

1. The gravitational force between the two stars

.... [1]

2. The centripetal force on the star of mass M_1.

.... [1]

(ii) The stars orbit each other in a time of 1.26 × 10^8 s. Calculate the angular speed ω for each star.

ω = ... rad s^{-1} [1]

(iii) Show that the ratio of the masses of the stars is given by the expression $\frac{M_1}{M_2} = \frac{R_2}{R_1}$.

[1]

(iv) The ratio $\frac{M_1}{M_2} = \frac{R_2}{R_1}$ is equal to 3.0 and the separation of the stars is 3.2×10^{11} m.

Determine the radii R_1 and R_2.

R_1 = ... m

R_2 = ... m [1]

(v) By considering the expressions in **(i)** and using the data calculated in **(ii)** and **(iv)**, determine M_2.

M_2 = ...kg [3]

(b) Fig. 8.2 shows an electron entering a region between two oppositely-charged parallel metal plates. The plates have length 5.1 cm.

The electric field in the region between the plates is uniform and is zero outside this region.

The original direction of motion of the electron is normal to the electric field.

The original speed of the electron is $v = 1.7 \times 10^7$ m s^{-1}.

The electric field strength between the plates E is 4000 V m^{-1}.

The electron exits the plates at an angle θ to the horizontal.

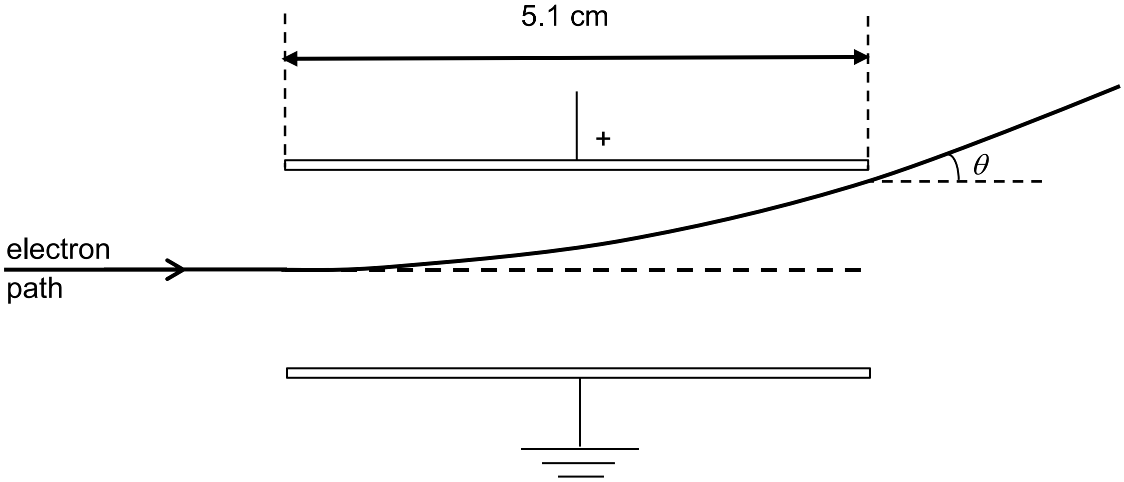


Fig. 8.2

(i) Show that the acceleration of the electron inside the electric field is 7.0×10^{14} m s^{-2}.

[1]

(ii) Calculate the magnitude of the final velocity of the electron, and the angle θ.

final velocity = ... m s^{-1}

θ = ... ° [4]

(iii) A proton is projected with the same initial velocity along the same line. Without detailed calculation, draw the path that the proton takes on Fig. 8.2. Explain your answer.

....

....

.... [2]

(c) Fig. 8.3 shows a uniform magnetic field *B* denoted by the shaded area. An electron moves into the field at the same speed *v* as in **(b)**, and is also deflected from its original path. The original direction of motion of the electron is normal to the magnetic field.

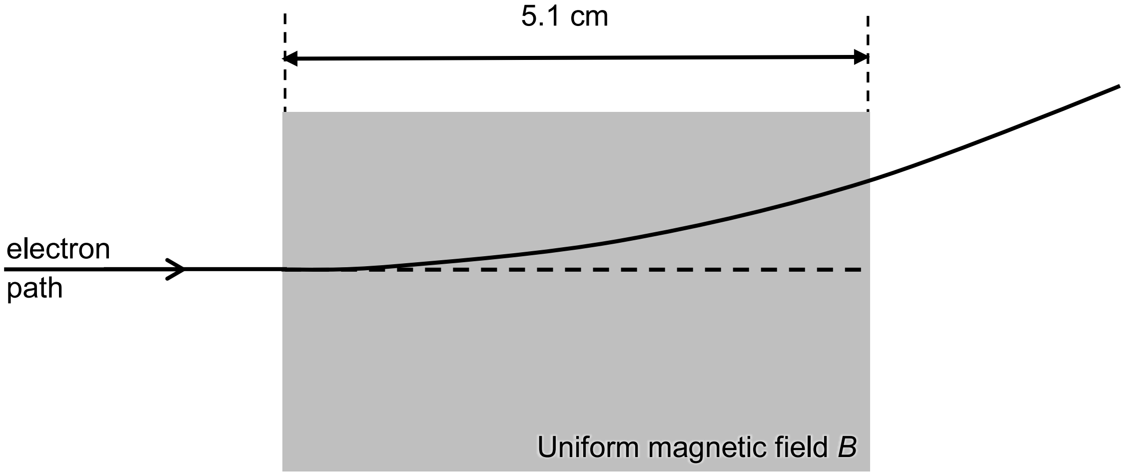


Fig. 8.3

(i) State the difference between the shape of the path taken by the electron in the magnetic field, and the shape of the path taken by the electron in the electric field described in **(b)**. Explain this difference.

....

....

....

....

....

....

.... [3]

(ii) State and explain how the final speed of the electron after passing through the magnetic field compares with the final speed of the electron after passing through the electric field in **(b)**.

....

....

.... [2]

9 A radon-222 ($^{222}_{86}\text{Rn}$) nucleus, originally at rest, spontaneously decays to form a polonium-218 ($^{218}_{84}\text{Po}$) nucleus and an alpha particle. It may be assumed that no gamma ray is emitted.

(a) Explain what is meant by *spontaneous*.

....

.... [1]

The rest masses of the nuclei are shown in Fig. 9.1.

$^{222}_{86}\text{Rn}$	222.0176 u
$^{218}_{84}\text{Po}$	218.0090 u
alpha particle	4.0026 u
proton	1.00727 u
neutron	1.00866 u

Fig. 9.1

(b) **(i)** Calculate the total kinetic energy of the decay products.

total kinetic energy = ...J [3]

(ii) Describe the subsequent motion of the decay products. Explain your answer with reference to the principle of conservation of momentum.

....

....

....

....

.... [2]

(iii) Show that the ratio $\frac{\text{kinetic energy of alpha particle}}{\text{kinetic energy of Po-218 nucleus}} \approx 54.5$.

[1]

(c) **(i)** Calculate the value of mass defect per nucleon $\left(\text{i.e. } \frac{\text{mass defect}}{\text{number of nucleons}}\right)$ for Radon-222. Leave your answer in terms of atomic mass units (u).

mass defect per nucleon for Radon-222 = ... u [3]

(ii) The mass defect per nucleon for Polonium-218 has a value of 8.08312×10^{-3} u. With reference to your answer in **(c)(i)**, explain whether Polonium-218 or Radon-222 is more stable.

....

....

....

....

....

.... [3]

(d) Radon-222 has a half-life of 3.8 days.

(i) State what is meant by *half-life*.

....

.... [1]

(ii) Calculate the probability of a given radon-222 nucleus decaying per second.

probability = ... s^{-1} [2]

(iii) A student stated that "radioactive materials with a short half-life always have a high activity". Discuss whether the student's statement is valid.

....

....

.... [1]

(e) A sample of Radon-222 was carefully measured out and sealed in a container. The rate of radioactive decay was measured using an accurate instrument, taking into account background radiation. The number of alpha particles detected was significantly higher than expected. State what this suggests about the stability of Polonium-218. Explain your answer.

....

....

....

....

.... [3]

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9749/03

Paper 3 Longer Structured Questions **17 September 2018**

2 hours

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

	Class	Reg No
Candidate Name: ______________________		

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 a 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend about one and a half hours on Section A and half an hour on Section B.

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.

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 7**
3	**/ 9**
4	**/ 4**
5	**/ 5**
6	**/ 10**
7	**/ 15**
Section B	
8	**/ 20**
9	**/ 20**
Deductions	
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_0	=	8.85×10^{-12} F m^{-1}
		=	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ 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	=	$-Gm/r$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translation kinetic energy 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	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

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

1 **(a)** **(i)** State Newton's first law of motion.

Newton's first law of motion states that a body continues at rest or at constant / uniform velocity unless acted on by a resultant (external) force. [A1]

.... [1]

(ii) State the conditions for equilibrium.

resultant force (in any direction) is zero [B1]
resultant moment / torque (about any axis) is zero [B1]

.... [2]

(b) Fig. 1.1 shows a uniform ladder of weight 80 N resting on a smooth wall and a rough floor. The ladder makes an angle of 60° with the floor.

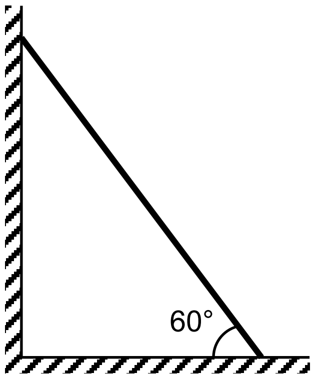


Fig. 1.1

(i) Show that the force exerted by the wall on the ladder is 23 N.

Using principle of moment and taking moment about the bottom of ladder: [B1]
clockwise moment = anticlockwise moment

$N \times L \sin 60° = W \times \frac{L}{2} \cos 60°$

$N \times L \sin 60° = 80 \times \frac{L}{2} \cos 60°$ [B1]

N = 23 N [A0]

[2]

(ii) Calculate the force exerted by the floor on the ladder.

Resolve vertically: ↑ Y = W = 80 N

Resolve horizontally ← X = N = 23 N [C1 for both equations]

force R = $\sqrt{X^2 + Y^2}$ = $\sqrt{23^2 + 80^2}$ = 83 N [A1]

angle R makes with floor = $\tan^{-1}\left(\frac{Y}{X}\right)$ = $\tan^{-1}\left(\frac{80}{23}\right)$ = 74°

Direction: 74° clockwise above horizontal [A1]
OR by vector triangle [C1]
get R [A1]
get angle above [A1]

magnitude of force = ... N

direction of force : .... [3]

(iii) A person now stands on the ladder. The ladder remains stationary.

State and explain the effects, if any, on

1. the vertical force exerted by the floor on the ladder.

(Due to the person's weight) there is now greater downward force on the ladder, and so (to maintain equilibrium) the floor exerts a larger upward vertical force on the ladder. [A1]

.... [1]

2. the horizontal force exerted by the wall on the ladder.

(Due to the person's weight) there is now a greater anticlockwise moment about the ladder bottom, and so (to maintain equilibrium) the wall exerts a greater clockwise moment and hence greater horizontal force. [A1]

.... [1]

2 In an experiment to determine the specific heat capacity of a liquid, a student heated a fixed mass of the liquid for a fixed duration of time, using an electric heater. The student repeated the experiment three times to find the rise in temperature of the liquid. The following measurements were obtained:

Mass of liquid, m	309 ± 3 g
Voltage applied across heater, V	11.8 ± 0.3 V
Current flow in the heater, I	4.125 ± 0.002 A
Time taken, t	200.0 ± 0.5 s

The rise in temperature θ was recorded for each attempt:

Attempt:	1st	2nd	3rd
θ / K	10.2	9.7	10.5

(a) Estimate the uncertainty in θ.

$$\text{uncertainty in } \Delta\theta = \frac{10.5-9.7}{2} = 0.4 \text{ K}$$

Accept:

$$\text{average } \Delta\theta = \frac{10.2+9.7+10.5}{3} = 10.13 \text{ K}$$

$$\text{uncertainty in } \Delta\theta = 10.13 - 9.7 = 0.433 = 0.4 \text{ K}$$

uncertainty in θ = ... K [1]

(b) Calculate the specific heat capacity c of the liquid.

$$c = \frac{Q}{m\theta} = \frac{IVt}{m\theta}$$

$$= \frac{4.125 \times 11.8 \times 200.0}{0.309 \times 10.13} \quad \text{[C1]}$$

$$= 3018.2 \quad \text{[A1]}$$

c = ... J kg^{-1} K^{-1} [2]

(c) Calculate the uncertainty in specific heat capacity c of the liquid and express the specific heat capacity c together with its uncertainty.

$$\frac{\Delta c}{c} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta t}{t} + \frac{\Delta m}{m} + \frac{\Delta(\theta)}{\theta}$$

$$= \frac{0.3}{11.8} + \frac{0.002}{4.125} + \frac{0.5}{200.0} + \frac{3}{309} + \frac{0.4}{10.1} \quad \text{[M1]}$$

$$= 0.077721$$

$$\Delta c = 3018.2 \times 0.077721 = 200 \quad \text{[M1]}$$

$$c = 3000 \pm 200 \text{ J kg}^{-1} \text{ K}^{-1} \quad \text{[A1]}$$

c = ... ± .... J kg^{-1} K^{-1} [3]

(d) State an assumption made in your calculation of the specific heat capacity *c* of the liquid.

No heat loss to surrounding. [B1]

.... [1]

3 **(a)** State Newton's second law of motion.

Newton's second law of motion states that the rate of change of momentum is proportional to the net / resultant (external) force (acting on it)
and the change (of momentum) takes place in the direction of the (net) force [A1]

.... [1]

(b) A car of mass 800 kg was travelling on a horizontal road at a constant speed of 20 m s^{-1} before a net horizontal constant forward force of 4800 N acts on the car for 12 s.

Calculate

(i) the distance travelled by the car over the 12 s,

$s = ut + \frac{1}{2}at^2 = (20)(12) + \frac{1}{2}\frac{4800}{800}(12)^2$ [C1]

$= 672$ m [A1]

distance = ... m [2]

(ii) the speed of the car at the end of the 12 s,

$v = u + at = 20 + \frac{4800}{800}(12)$ [C1]

$= 92$ m s^{-1} [A1]

speed = ... m s^{-1} [2]

(iii) the work done on the car during the 12 s

1. using the answer to **(b)(i)**;

work $= Fs = (4800)(672)$ [M0]

$= 3.23 \times 10^6$ J [A1]

work done = ...J [1]

2. using the answer to **(b)(ii)**.

work = gain in KE

$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2}(800)(92)^2 - \frac{1}{2}(800)(20)^2$ [M0]

$= 3.23 \times 10^6$ J [A1]

work done = ...J [1]

(iv) the impulse exerted on the car over the 12 s.

impulse = change in momentum
= $mv - mu$ = (800)(92) – (800)(20) [C1]
= 5.76×10^4 N s [A1]
OR use impulse = Ft = (4800)(12) = 5.76×10^4 N s

impulse = ... N s [2]

4 A person threw a ball vertically upwards.

(a) Fig. 4.1 shows the variation with time of the velocity when air resistance is absent.

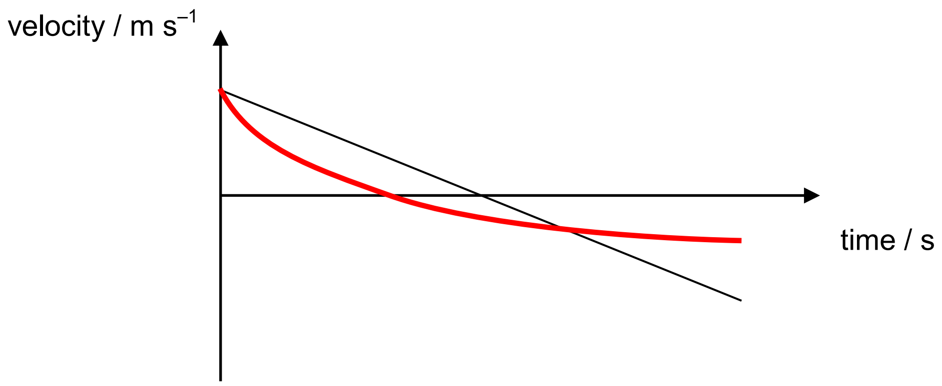


Fig. 4.1

Draw on Fig. 4.1 a second graph for the case where air resistance is present. [3]

curve from +15 m s^{-1} steepest at first then gentler and gentler [B1]
gradient at v = 0 should be same as that of original line. [B1]
areas under graph above and below x-axis are similar. [B1]

(b) Explain how the presence of air resistance would affect the maximum height reached by the ball.

greater resultant (downward opposing) force, so lesser height [A1]

.... [1]

5 Ball A, of mass 800 g and travelling with a speed of 9.2 m s^{-1}, collided head-on with a stationary ball B of mass 2400 g. The collision is completely inelastic.

(a) Explain whether the total momentum is conserved during the collision.

No resultant (external) force (acts on the car-truck system) so (by principle of conservation of momentum) the total momentum is conserved. [A1]

.... [1]

(b) Calculate the percentage loss in total kinetic energy.

conservation of momentum: → (0.800)(9.2) + 0 = (3.200) V ⇒ V = 2.3 m s^{-1} [C1]

initial kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(0.800)(9.2)^2 = 33.856$ J [A1]

final kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(3.200)(2.3)^2 = 8.464$ J

percentage loss in kinetic energy = $\frac{33.856 - 8.464}{33.856} \times 100\% = 75\%$

percentage loss = ... % [2]

(c) Shortly after the collision, Ball B comes into contact with a spring of spring constant 2500 N m^{-1}. Calculate the maximum compression of the spring.

conservation of energy: $\frac{1}{2}m_{A\&B}v^2 = \frac{1}{2}kx^2$

$\frac{1}{2}(3.2)(2.3)^2 = \frac{1}{2}(2500)x^2$ [M1]

$x = 0.082$ m [A1]

maximum compression = ... m [2]

6 Fig. 6.1 shows an isolated conducting sphere which has been charged. Dashed lines (––––) join points of equal potential *V*. The potential difference between successive lines of equal potential is equal.

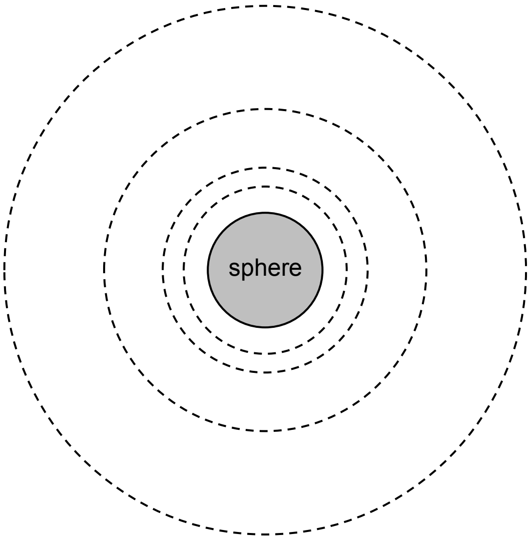


Fig. 6.1

For points on the surface or outside the sphere, the charge on the sphere behaves as if it were concentrated at the centre.

Measurements of the distance *x* from the centre of the sphere and the corresponding values of the potential *V* are given in Fig. 6.2. The values in Fig. 6.2 do not correspond to the dashed lines in Fig. 6.1.

x / m	*V* / V
0.19	-1.50×10^5
0.25	-1.14×10^5
0.32	-0.89×10^5
0.39	-0.73×10^5

Fig. 6.2

(a) On Fig. 6.1, draw the electric field lines. Label these lines *E*. [2]

Straight lines in uniform radial pattern centred on charge [B1]
Arrows pointing inwards [B1]

(b) Explain how your drawing in **(a)** shows the relationship between electric potential *V* and the electric field *E*.

Electric field points inwards, because *E* points from points of higher potential to lower potential.
OR potential is negative suggests that the sphere is negatively charged and hence electric field points inwards. [B1]

Electric field is numerically equal to the potential gradient and is stronger where the potential gradient is stronger (closer to the charged sphere). The stronger E field is shown by the closer spacing between the E field lines. [B1]

.... [2]

(c) **(i)** Use the data in Fig. 6.2 to show that the potential *V* is inversely proportional to the distance *x*. Explain your reasoning.

If V is inversely proportional to x, then Vx = constant [B1]
Multiplying **any 2** values [B1] to conclude that Vx is constant:

x / m	*V* / V	*Vx* / V m
0.19	-1.50×10^5	-28.5×10^3
0.25	-1.14×10^5	-28.5×10^3
0.32	-0.89×10^5	-28.48×10^3 $= -28.5 \times 10^3$
0.39	-0.73×10^5	-28.47×10^3 $= -28.5 \times 10^3$

[2]

(ii) The potential at the surface of the sphere is -1.9×10^5 V. Calculate the radius of the sphere.

Using value of $V_x = -28.5 \times 10^3$ V m [M1]
$R = -28.5 \times 10^3 / -1.9 \times 10^5 = 0.15$ m [A1]

radius of sphere = ... m [2]

(iii) Determine the charge on the sphere.

$$V = \frac{Q}{4\pi\varepsilon_0 r} \text{ [C1]}$$

$$Q = 4\pi\varepsilon_0 rV$$
$$= 4\pi\left(8.85\times10^{-12}\right)(0.15)\left(-1.9\times10^5\right)$$
$$= -3.17\times10^{-6}\,\text{C}$$
$$= -3.2\times10^{-6}\,\text{C [A1]}$$

charge = ...C [2]

7 **(a)** A power bank (which is basically a battery) can be used to power many devices at the same time. A power bank of e.m.f. 12.0 V and internal resistance 3.0 Ω is connected to multiple devices in the circuit shown in Fig. 7.1.

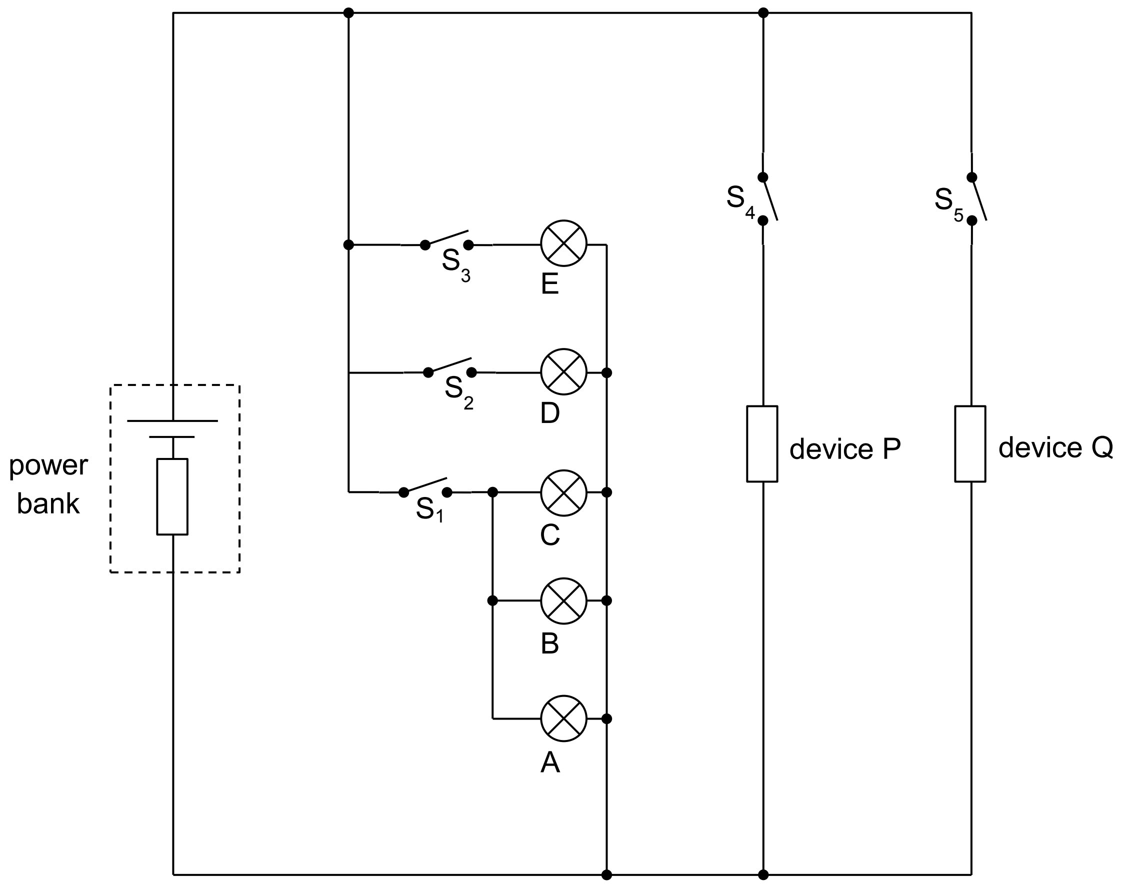


Fig. 7.1

The power bank is connected to 5 identical lamps (A, B, C, D and E) and 2 devices (P and Q). The lamps and devices can be turned on and off using the various switches (S_1, S_2, S_3, S_4 and S_5).

(i) Explain what is meant by "*e.m.f. of 12.0 V*" with reference to the power bank.

The power bank converts 12.0 J of electrical energy from chemical energy (or other forms) [B1]
when one coulomb of charge passes through [B1]

.... [2]

(ii) State the effect of closing switch S_1.

Lamps A, B and C will be turned on with equal brightness [B1]

.... [1]

(iii) All the switches are now closed. Given the data below, calculate the current supplied by the power bank.

Resistance of each lamp = 25.0 Ω

Resistance of device P = 38.0 Ω

Resistance of device Q = 42.0 Ω

Note that all the lamps and devices are parallel to each other.
Total effective resistance

$$= 3.0 + \left(\frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{25.0} + \frac{1}{38.0} + \frac{1}{42.0}\right)^{-1} \quad \text{[C1]}$$

$$= 6.998\ \Omega$$

$$I = \frac{V}{R} = \frac{12.0}{6.998} = 1.71\ \text{A} \quad \text{[A1]}$$

current = ... A [2]

(iv) Calculate the terminal potential difference of the power bank when all the switches are closed.

$$V_{\text{terminal}} = E - Ir$$

$$= 12.0 - (1.71)(3.0) \quad \text{[C1]}$$

$$= 6.86\ \text{V} \quad \text{[A1]}$$

terminal potential difference = ... V [2]

(v) State and explain the effect, if any, on the brightness of the lamps if switches S_4 and S_5 are now opened while the rest remain closed.

Effective resistance across the lamps increase, hence p.d. across lamps increase (by potential divider principle). [B1]

Since $P = \frac{V^2}{R}$, power dissipated by lamps increase, hence brightness increase. [B1]

.... [2]

(b) The same power bank from **(a)** is now connected in a potentiometer circuit as shown in Fig. 7.2.

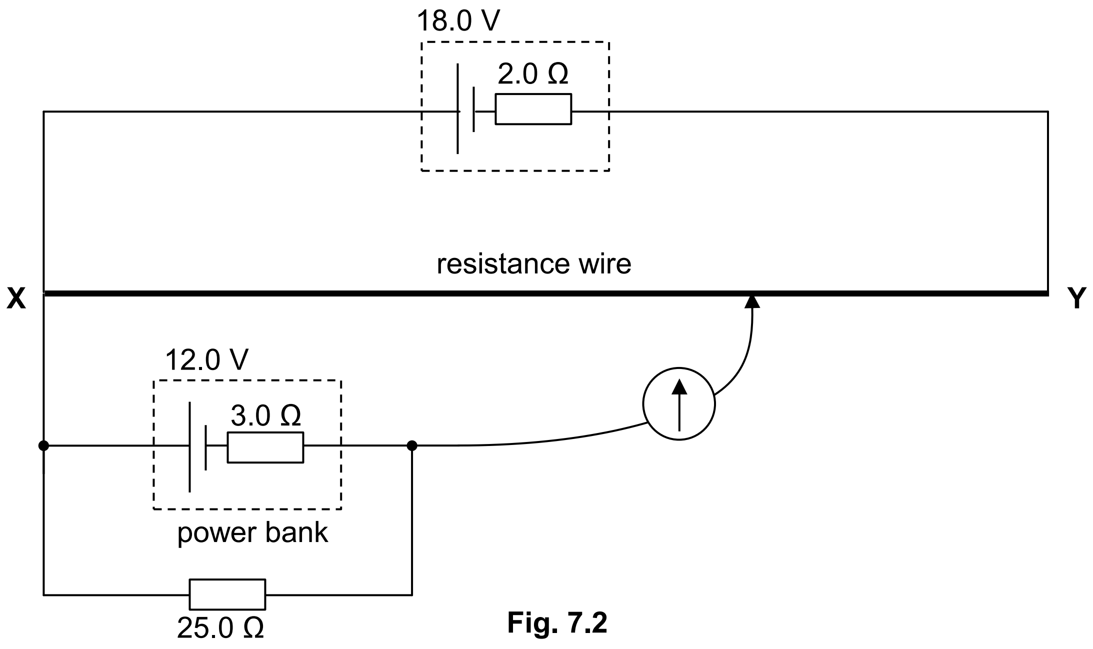


Fig. 7.2

A 18.0 V battery with internal resistance of 2.0 Ω is connected to a resistance wire XY. XY is 1.00 m long and has resistance of 7.2 Ω. A resistor of 25.0 Ω is connected in parallel to the power bank.

(i) Calculate the balance length when the galvanometer shows a reading of zero.

$$V_{XY} = \frac{7.2}{7.2+2.0}(18.0) = 14.087 \text{ V} \quad [C1]$$

$$V_{\text{power bank}} = \frac{25.0}{25.0+3.0}(12.0) = 10.714 \text{ V} \quad [M1]$$

$$V_{\text{power bank}} = \frac{L}{L_{XY}} V_{XY}$$

$$10.714 = \frac{L}{1.00}(14.087)$$

$$L = 0.761 \text{ m} \quad [A1]$$

balance length = ... m [3]

(ii) Explain why it is desirable to obtain a balance point which is closer to end Y.

To reduce percentage or fractional uncertainty of balance length [B1]

.... [1]

(iii) State and explain the effect, if any, on the balance length if resistance wire XY is now made of a material with higher resistivity.

XY will have higher resistance, thus higher p.d. across XY by potential divider principle. [M1]
Thus a smaller balance length is needed to balance p.d. across the power bank. [A1]

.... [2]

Section B

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

8 **(a)** A binary star consists of two stars that orbit about a fixed point C, as shown in Fig. 8.1.

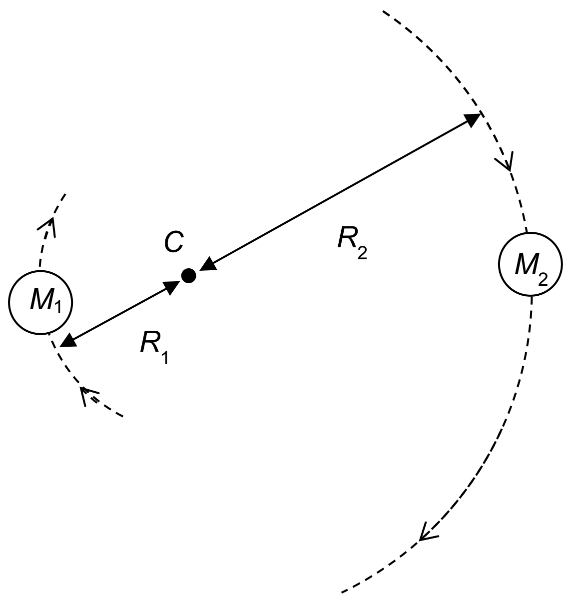


Fig. 8.1

The star of mass M_1 has a circular orbit of radius R_1 and the star of mass M_2 has a circular orbit of radius R_2. Both stars have the same angular speed ω about C.

(i) State the formula, in terms of G, M_1, M_2, R_1, R_2 and ω for

1. The gravitational force between the two stars

$$\frac{GM_1M_2}{(R_1+R_2)^2}$$

.... [1]

2. The centripetal force on the star of mass M_1.

$$M_1R_1\omega^2$$

.... [1]

(ii) The stars orbit each other in a time of 1.26 × 10^8 s. Calculate the angular speed ω for each star.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{1.26\times10^8} = 5.0\times10^{-8}$$

ω = ... rad s^{-1} [1]

(iii) Show that the ratio of the masses of the stars is given by the expression $\frac{M_1}{M_2} = \frac{R_2}{R_1}$.

Force on each of the stars is the same, $\frac{GM_1M_2}{(R_1+R_2)^2}$

$$\frac{GM_1M_2}{(R_1+R_2)^2} = M_1R_1\omega^2 = M_2R_2\omega^2$$

Since angular velocity is the same,

$$M_1R_1 = M_2R_2$$

Hence $\frac{M_1}{M_2} = \frac{R_2}{R_1}$

[1]

(iv) The ratio $\frac{M_1}{M_2} = \frac{R_2}{R_1}$ is equal to 3.0 and the separation of the stars is 3.2×10^{11} m.

Determine the radii R_1 and R_2.

$R_1 = 0.80 \times 10^{11}$ m
$R_2 = 2.4 \times 10^{11}$ m

R_1 = ... m

R_2 = ... m [1]

(v) By considering the expressions in **(i)** and using the data calculated in **(ii)** and **(iv)**, determine M_2.

$$\frac{GM_1M_2}{(R_1+R_2)^2} = M_1R_1\omega^2 \quad [C1]$$

$$M_2 = \frac{R_1\omega^2(R_1+R_2)^2}{G}$$

$$= \frac{(0.80\times10^{11})(5.0\times10^{-8})^2(3.2\times10^{11})^2}{6.67\times10^{-11}} \quad [M1]$$

$$= 3.1\times10^{29} \quad [A1]$$

M_2 = ...kg [3]

(b) Fig. 8.2 shows an electron entering a region between two oppositely-charged parallel metal plates. The plates have length 5.1 cm.

The electric field in the region between the plates is uniform and is zero outside this region.

The original direction of motion of the electron is normal to the electric field.

The original speed of the electron is $v = 1.7 \times 10^7$ m s^{-1}.

The electric field strength between the plates E is 4000 V m^{-1}.

The electron exits the plates at an angle θ to the horizontal.

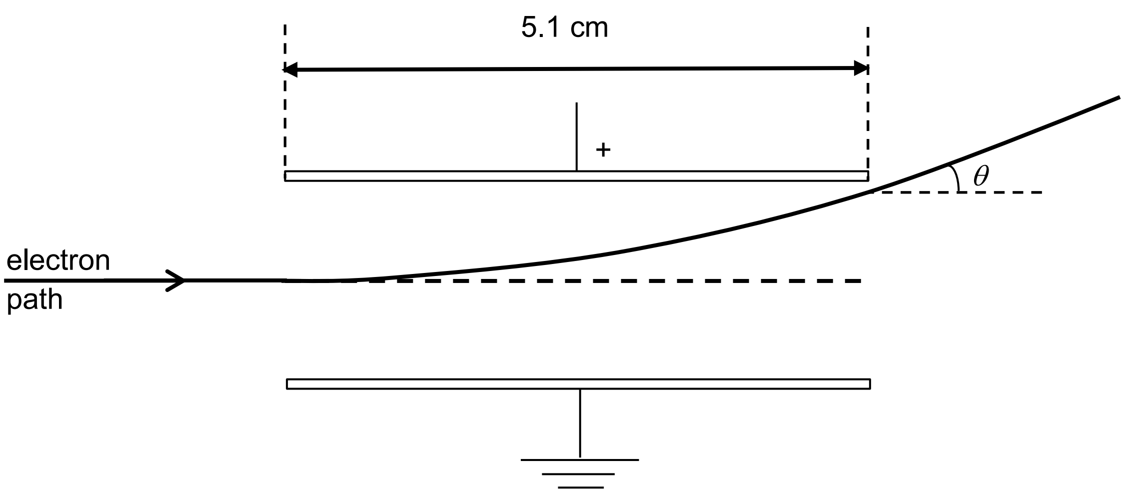


Fig. 8.2

(i) Show that the acceleration of the electron inside the electric field is 7.0×10^{14} m s^{-2}.

Force on electron = $qE = (1.6\times10^{-19})(4000) = 6.4\times10^{-16}$ N
Acceleration of electron $a_y = F / m = (6.4\times10^{-16}) / (9.11\times10^{-31})$ [M1]
$= 7.025 \times 10^{14}$ m s^{-2} [A0]

[1]

(ii) Calculate the magnitude of the final velocity of the electron, and the angle θ.

Time taken = length / horizontal speed = $(5.1\times10^{-2}) / 1.7\times10^7 = 3.0\times10^{-9}$ s[C1]
Final vertical component of velocity $v_y = u_y + a_y t = 0 + (7.025\times10^{14})(3.0\times10^{-9}) = 2.1\times10^6$ m s^{-1} [C1]
Final velocity =

$$\sqrt{v_x^2 + v_y^2} = \sqrt{(1.7\times10^7)^2 + (2.1\times10^6)^2} = 1.713\times10^7 \text{ m s}^{-1}$$

[A1]

$$\theta = \tan^{-1}\left(\frac{2.1\times10^6}{1.7\times10^7}\right) = 7.04°$$ [A1]

final velocity = ... m s^{-1}

θ = ... ° [4]

(iii) A proton is projected with the same initial velocity along the same line. Without detailed calculation, draw the path that the proton takes on Fig. 8.2. Explain your answer.

Deflection in opposite direction [A0] due to different sign of charge [M1]
Path is less curved [A0] because proton is less strongly deflected. Proton has same magnitude of charge as electron, experiences same magnitude of electric force, but proton has much larger mass -> acceleration is much smaller [M1]

.... [2]

(c) Fig. 8.3 shows a uniform magnetic field B denoted by the shaded area. An electron moves into the field at the same speed v as in **(b)** and is also deflected from its original path. The original direction of motion of the electron is normal to the magnetic field.

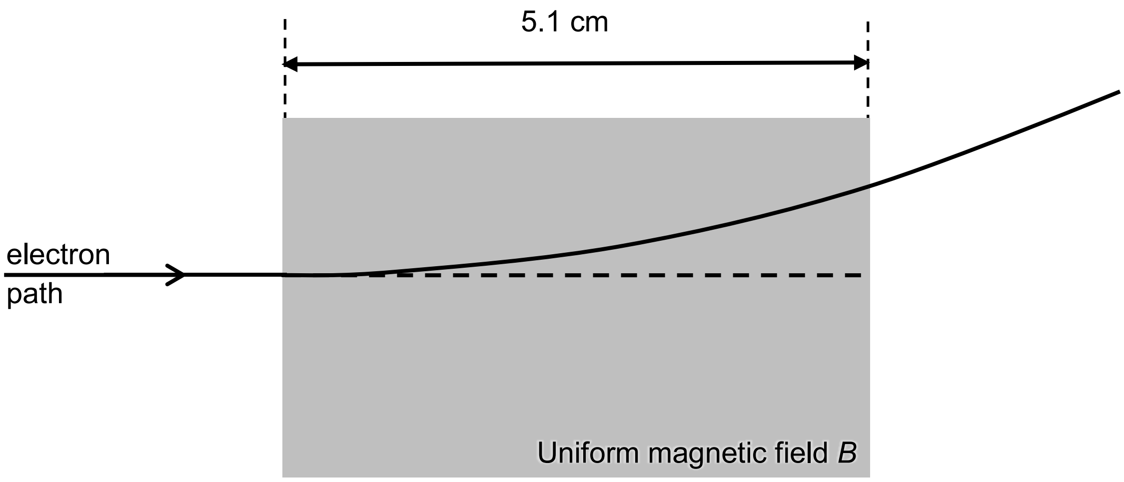


Fig. 8.3

(i) State the difference between the shape of the path taken by the electron in the magnetic field, and the shape of the path taken by the electron in the electric field described in **(b)**. Explain this difference.

Path in B-field is circular, Path in E-field is parabolic. [B1]
Circular – because magnetic force is (constant in magnitude and) always perpendicular to the velocity, so provides constant centripetal force toward a centre, causing uniform circular motion [B1]
Parabolic – because electric force is constant (in magnitude and direction) and in only one direction (perpendicular to the initial velocity), so acceleration in one direction and constant velocity in perpendicular direction. [B1]

.... [3]

(ii) State and explain how the final speed of the electron after passing through the magnetic field compares with the final speed of the electron after passing through the electric field in **(b)**.

Because centripetal force only changes direction and not magnitude of velocity [M1]
(Electron is in uniform circular motion),
Final speed of electron is the same as initial speed = 5.1×10^{7} m s^{-1}
Higher than the final speed of electron in (b) [A1]

.... [2]

9 A radon-222 ($^{222}_{86}Rn$) nucleus, originally at rest, spontaneously decays to form a polonium-218 ($^{218}_{84}Po$) nucleus and an alpha particle. It may be assumed that no gamma ray is emitted.

(a) Explain what is meant by *spontaneous*.

Not affected by external stimuli / conditions [B1]

.... [1]

The rest masses of the nuclei are shown in Fig. 9.1.

$^{222}_{86}Rn$	222.0176 u
$^{218}_{84}Po$	218.0090 u
alpha particle	4.0026 u
proton	1.00727 u
neutron	1.00866 u

Fig. 9.1

(b) **(i)** Calculate the total kinetic energy of the decay products.

Total mass of products = 218.0090 + 4.0026 = 222.0116 u
Total mass of reactant = 222.0176 u
Difference in total mass = 0.0060 u [M1]
Conversion from u to kg = 00060 × 1.66 × 10^{27} = 9.96 × 10^{30} kg
Energy liberated = mc^2 = (9.96 × 10^{30})× (3.0 × 10^{8})^2 = [C1]
= 8.96 × 10^{-13} J [A1]

total kinetic energy = ...J [3]

(ii) Describe the subsequent motion of the decay products. Explain your answer with reference to the principle of conservation of momentum.

Since total momentum is conserved, and initial momentum of Rn-222 was zero,
The total momentum of the decay products must add up to zero. [M1]
The Po-218 and alpha particle move in opposite directions with equal (magnitude of) momentum. [B1]

.... [2]

(iii) Show that the ratio $\dfrac{\text{kinetic energy of alpha particle}}{\text{kinetic energy of Po-218 nucleus}} \approx 54.5$.

Since the mass of alpha particle / mass of Po-218 = 4 / 218
The speed of alpha particle / speed of Po-218 = 218 / 4
[B1]
Hence the kinetic energy of alpha particle / kinetic energy of Po-218 = 218/4 = 54.5 [A0]
(Using exact values given, 54.47)

[1]

(c) **(i)** Calculate the value of mass defect per nucleon $\left(\text{i.e. } \dfrac{\text{mass defect}}{\text{number of nucleons}}\right)$ for Radon-222. Leave your answer in terms of atomic mass units (u).

	Number of neutrons	Number of protons	Mass of constituent nucleons in u	Mass defect in u	$\dfrac{\text{mass defect}}{\text{number of nucleons}}$
$^{222}_{86}Rn$	222-86 = 136	86	(86×1.00727) + (136×1.00866) = 223.80298	223.80298 – 222.0176 = 1.78538	1.78538 / 222 = 8.04225×10^{-3}

Number of
[C1 for correct number of neutrons and protons for both Rn-222 or Po-218]
[C1 for correct substitution / value for mass defect for Rn-222 and Po-218]
[A1 for correct final answers]

mass defect per nucleon for Radon-222 = ... u [3]

(ii) The mass defect per nucleon for Polonium-218 has a value of 8.08312×10^{-3} u. With reference to your answer in **(c)(i)**, explain whether Polonium-218 or Radon-222 is more stable.

Since mass defect is directly proportional to binding energy, a higher value of mass defect per nucleon means a higher binding energy per nucleon. [B1]

[Turn over

On average, it requires higher energy to break apart Po-218 into its constituent nucleons, compared to Rn-222. [B1]
Hence, Po-218 is more stable. [A1]

.... [3]

(d) Radon-222 has a half-life of 3.8 days.

(i) State what is meant by *half-life*.

It is the time taken for half the original number of radioactive nuclei to decay. [B1]

.... [1]

(ii) Calculate the probability of a given radon-222 nucleus decaying per second.

Decay constant = ln2 / $t_{1/2}$ = ln 2 / (3.82 x 24 x 60 x 60)

probability = ... s^{-1} [2]

(iii) A student stated that "radioactive materials with a short half-life always have a high activity". Discuss whether the student's statement is valid.

Not valid [A0] as activity also depends on amount of radioactive material present [M1], and not just the half-life. ($A = \lambda N$)

.... [1]

(e) A sample of Radon-222 was carefully measured out and sealed in a container. The rate of radioactive decay was measured using an accurate instrument, taking into account background radiation. The number of alpha particles detected was significantly higher than expected. State what this suggests about the stability of Polonium-218. Explain your answer.

The observation suggests that Po-218 is unstable [B1]

The additional alpha particles detected come from the decay of Po-218 (and its daughter nuclides). [B1]

The almost-immediate decay of Po-218 (and its daughter nuclides) after it is produced shows that Po-218 has a very short half-life (half-lives), i.e. further alpha decays [B1]

.... [3]

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics 9749/4

Paper 4 Practical

28 August 2018

2 hours 30 minutes

Class	Reg Number

Candidate Name: ____________________________

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page, page **9** and **13**.
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, glue or correction fluid.

Answer **ALL** the questions.

You are allowed 1 hour to answer Questions 1 and 2; and you are allowed another 1 hour to answer Question 3.

Question 4 is a question on the planning of an investigation and does not require apparatus.

Write your answers in the space provided in 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 or if you do not use appropriate units.

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

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

Shift
Laboratory

Examiner's Use	
1	
2	
3	
4	
Total	**/55**

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1 In this question you will investigate how the period of oscillation of a bent metal wire varies with the angle between the straight parts of the wire.

(a) **(i)** Secure the cork in the clamp so that the pin is mounted horizontally.

(ii) Make a sharp bend in the wire at its centre so that the angle θ between the straight parts of the wire is about 130° as shown in Fig. 1.1.

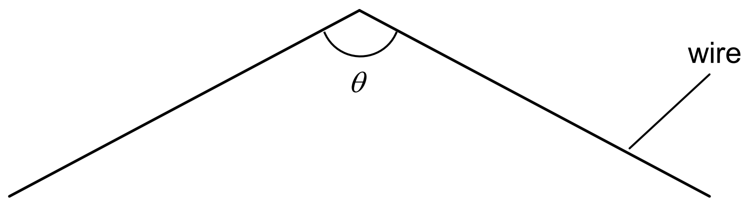


Fig. 1.1

(iii) Measure and record the angle θ.

θ = ... [1]

(iv) Estimate the percentage uncertainty in this measurement of θ. Show your working.

percentage uncertainty in θ = ... [1]

(b) **(i)** Suspend the wire from the pin so that the arrangement is as shown in Fig. 1.2.

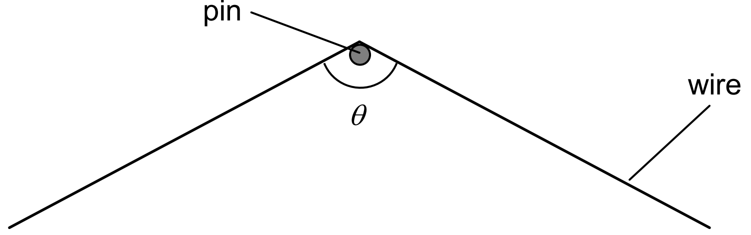


Fig. 1.2

(ii) Displace the wire from its equilibrium position and release it so that it performs small oscillations in a vertical plane, as shown in Fig. 1.3.

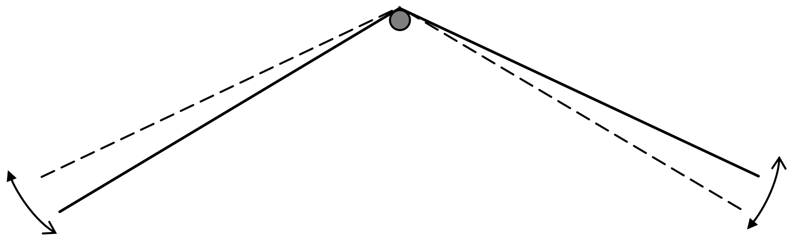


Fig. 1.3

(iii) Make and record measurements to determine the period *T* of these oscillations.

T = ... [2]

(c) Remove the wire from the pin. Change the value of θ by gently bending the wire. The new value of θ should be in the range $60° \leq \theta \leq 90°$. Record down the value of θ and repeat steps in **(b)** to obtain period *T*.

θ = ...

T = ... [2]

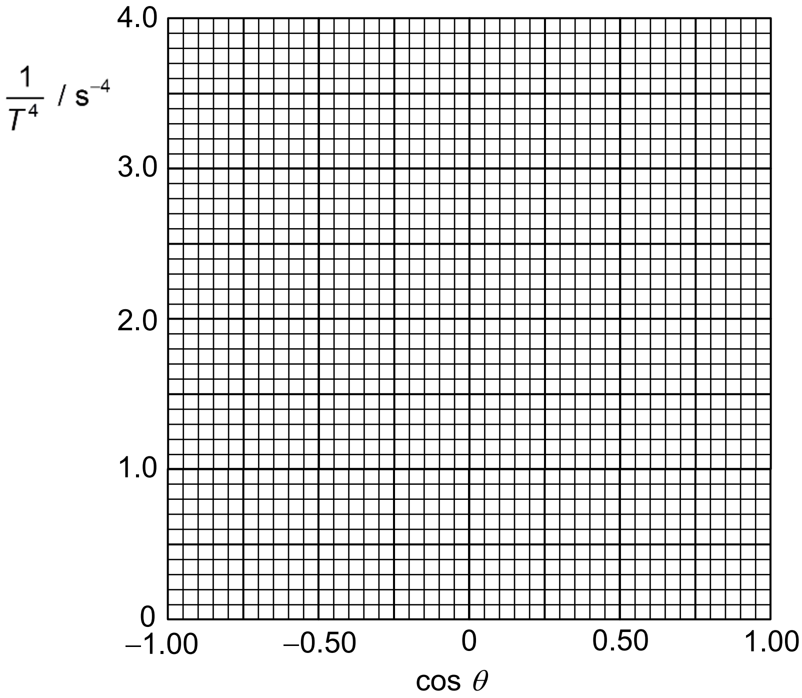
(d) The experiment is repeated using a wire with another length and the angle θ of the bent wire is varied. The results are shown in Fig. 1.4. Values of $\frac{1}{T^4}$ and $\cos\theta$ are included.

θ / °	cos θ	T / s	$\frac{1}{T^4}$ / s^{-4}
159		1.56	0.169
135		1.16	0.552
110		0.942	1.27
96		0.884	1.64
74		0.816	2.26
45		0.745	3.25

Fig. 1.4

(i) Complete Fig. 1.4. [1]

(ii) Plot the points on the grid and draw the straight line of best fit.



[2]

(iii) Using the graph in **(d)(ii)**, state and explain whether $\frac{1}{T^4}$ is proportional to cos θ.

....

....[2]

[Total: 11 marks]

2 In this experiment, you will investigate how the rate of heat loss from a beaker of hot water depends on the insulation of the container.

(a) Measure the room temperature T_{room}.

T_{room} = ...

(b) Pour hot water into a beaker until it reaches the 80 ml mark.

(c) **(i)** Place the thermometer in the water.

(ii) When the temperature of the water decreases to 80 °C, start the stopwatch.

Measure and record the water temperature T_0 when time t = 60 s and t = 120 s in Fig. 2.1. [1]

t / s	T_0 / °C	$T_{insulated}$ / °C	$(T_{insulated} - T_0)$ / °C
60			
120			

Fig. 2.1

(d) **(i)** Empty the beaker.

(ii) Pour hot water into beaker until it reaches the 80 ml mark.

(iii) Wrap insulating material around the sides of the beaker. Secure the insulating material to the beaker using a rubber band, as shown in Fig. 2.2.

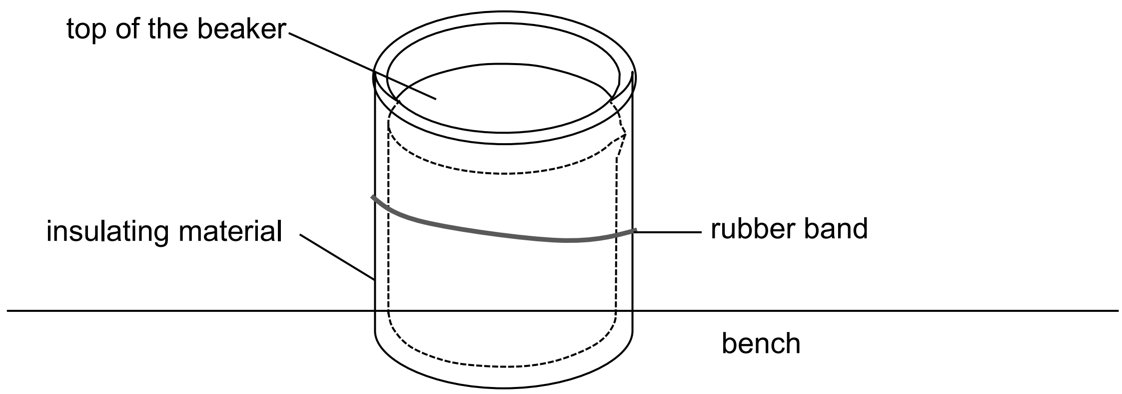


Fig. 2.2

(iv) Repeat **(c)** to measure the water temperature $T_{insulated}$ at the same time intervals.

Record the values of $T_{insulated}$ and $(T_{insulated} - T_0)$ in Fig. 2.1. [2]

(e) It is suggested that T_0 and $T_{insulated}$ for the corresponding t are related by the expression

$$\left(T_{insulated} - T_0\right) = AT_0 + B$$

where A and B are constants.

Using your results from Fig. 2.1, determine the values of A and B.

A = ...

B = ... [3]

(f) Use your values from **(a)** and **(e)** to determine the value of $T_{insulated}$ when T_0 reaches room temperature T_{room}.

$T_{insulated}$ = ... [1]

(g) **(i)** State and explain two significant sources of error or limitations of the procedures for this experiment.

1. ....

....

2. ....

.... [2]

(ii) Suggest one improvement that could be made to the experiment to address one of the errors identified in **(g)(i)**. You may suggest the use of other apparatus or different procedures.

....

.... [1]

(h) A vacuum flask is an insulating storage vessel that lengthens the time over which its contents remain hotter or cooler than the flask's surroundings.

A vacuum flask manufacturer wishes to investigate how evaporation affects the heat retention of the vacuum flask.

Suggest changes that could be made to your experiment to investigate how the rate of heat loss from an insulated container depends on evaporation.

....

....

....

....

.... [2]

[Total: 12 marks]

Candidate Name: ______________________________( ) Class: ________________

3 In this experiment you will investigate how the power P generated in a resistor varies with the resistance R of the resistor.

(a) You are supplied with a fixed resistor labelled Q and a variable resistor of resistance R. Construct the circuit shown in Fig. 3.1.

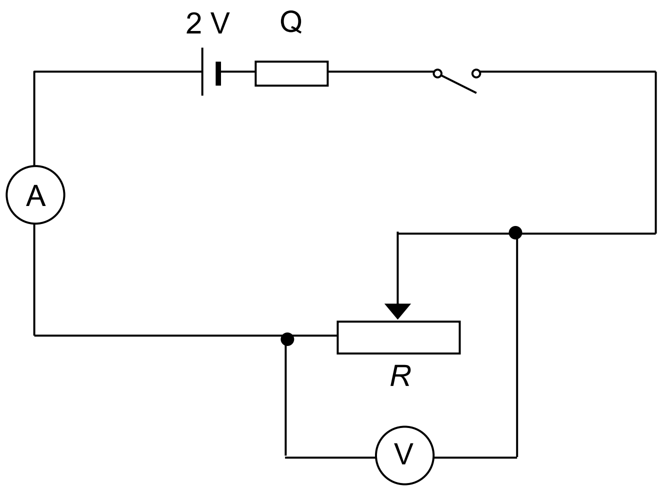


Fig. 3.1

(b) **(i)** Close the switch.

(ii) Adjust the slider of the variable resistor such that the voltmeter reading V is approximately 0.5 V.

(iii) Measure and record the potential difference V and the current I.

V = ...

I = ...[2]

(iv) Open the switch.

(v) Calculate the values of resistance R of the variable resistor and power P where $R = \frac{V}{I}$ and $P = IV$.

R = ...

P = ...

(vi) Justify the number of significant figures which you have quoted for R and P.

....

....[1]

(c) Change the resistance of the variable resistor to increase the value of *V*. Repeat steps **(b)(i)**, **(iii)**, **(iv)** and **(v)** to obtain at least 7 further sets of readings for $V < 1.3$ V.

[7]

(d) **(i)** Plot a graph of *P* against *R*. [3]

(ii) Hence, state the value of *R* when *P* is a maximum.

R = ... [2]

(e) By drawing a tangent to the curve, determine the rate of change of P with R when R = 6 Ω.

rate of change of P = ... [3]

(f) The power P and the current I are related by the expression

$$P = I^2R$$

By drawing a second line on your graph in page 11, determine the value(s) of P when I = 100 mA. Label this line **Z**.

P = ...W [2]

[Total: 20 marks]

Candidate Name: ______________________________ (   ) Class: ________________

4 A student wishes to investigate projectile motion.

A small ball is rolled with velocity v along a horizontal surface. When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface. The vertical displacement of the ball is h and the horizontal displacement of the ball is d, as shown in Fig. 4.1.

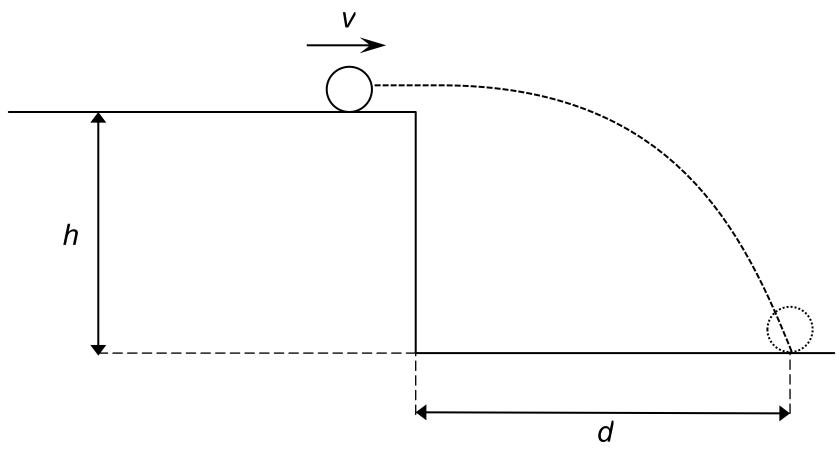


Fig. 4.1

The student suggests that d is dependent on h and v according to the equation

$$d = kh^p v^q$$

where k, p and q are constants to be determined.

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

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use and measurements to be taken,

(c) procedure to be followed,

(d) the analysis of the data,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

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[Total: 12 marks]

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Apparatus list

JC2 Preliminary Examination 28 Aug 2018

SS to check Q1 & 2 during change over

Question 1:

- 1 x retort stand + boss and clamp *(to dismantle fully during change over)*
- 1 x half-metre rule
- 1 x cork with optical pin *(to insert back if taken out by student)*
- 1 x stopwatch
- 1 x protractor
- 1 x 30 cm wire *(to replace with new wire during change over)*

Question 2:

- 1 x 100 ml beaker *(pour away water during change over)*
- 1 x rubber band
- 1 x thermometer
- Hot water of at least 90 °C *(to top up water when planning starts)*
- 1 x cloth
- 1 x styrofoam cup *(pour away water during change over)*
- 1 x stopwatch
- 1 x insulating material

Lab staff to check Q3 during change over

Question 3:

- 1 x 2 V accumulator
- 2 x DMM with connecting leads *(leads take out, turn dial to 12 o'clock, during change over)*
- 3 x connecting wire
- 1 x switch
- 1 x variable resistor
- 1 x 10Ω resistor, labelled "Q".

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics 9749/4

Paper 4 Practical

28 August 2018

2 hours 30 minutes

Class	Reg Number

Candidate Name: ______________________________

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page, page **9** and **13**.
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, glue or correction fluid.

Answer **ALL** the questions.

You are allowed 1 hour to answer Questions 1 and 2; and you are allowed another 1 hour to answer Question 3.

Question 4 is a question on the planning of an investigation and does not require apparatus.

Write your answers in the space provided in 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 or if you do not use appropriate units.

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

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

Shift
Laboratory

Examiner's Use	
1	
2	
3	
4	
Total	**/55**

1 In this question you will investigate how the period of oscillation of a bent metal wire varies with the angle between the straight parts of the wire.

(a) **(i)** Secure the cork in the clamp so that the pin is mounted horizontally.

(ii) Make a sharp bend in the wire at its centre so that the angle θ between the straight parts of the wire is about 130° as shown in Fig. 1.1.

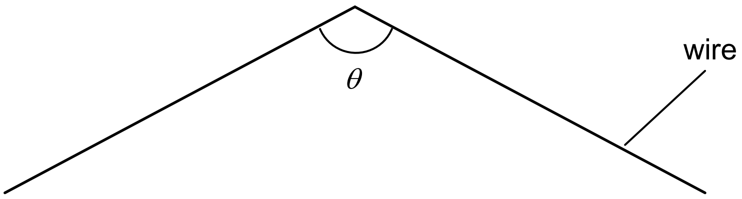


Fig. 1.1

(iii) Measure and record the angle θ.

$$\theta = \frac{129 + 131}{2} = 130°$$

θ = ...130°...... [1]

(iv) Estimate the percentage uncertainty in this measurement of θ. Show your working.

$$\text{percentage uncertainty} = \frac{2}{130} \times 100\% = 1.5\%$$

Accept $\Delta\theta$ from 2° - 5°

percentage uncertainty in θ = ...1.5%...... [1]

(b) **(i)** Suspend the wire from the pin so that the arrangement is as shown in Fig. 1.2.

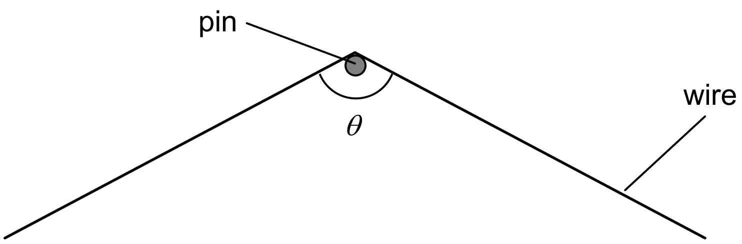


Fig. 1.2

(ii) Displace the wire from its equilibrium position and release it so that it performs small oscillations in a vertical plane, as shown in Fig. 1.3.

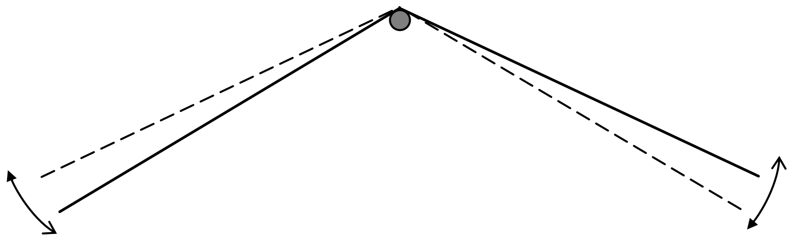


Fig. 1.3

(iii) Make and record measurements to determine the period T of these oscillations.

$n = 14$ oscillations

$$t = \frac{13.8 + 13.6}{2} = 13.7 \text{ s}$$

$$T = \frac{13.7}{14} = 0.977 \text{ s}$$

t should be more than 20 s.
Repeated readings of t and t > 20 s. t record to nearest 0.1 s. [M1]
Correct calculation of T with correct s.f. & units [A1]

T = 0.977 s .... [2]

(c) Remove the wire from the pin. Change the value of θ by gently bending the wire. The new value of θ should be in the range 60° ≤ θ ≤ 90°. Record down the value of θ and repeat steps in **(b)** to obtain period T.

$$\theta = \frac{69 + 68}{2} = 69°$$

Check for correct range of θ. Repeated reading. Nearest degree. [B1]
$n = 30$ oscillations

$$t = \frac{21.2 + 21.2}{2} = 121.2\text{s}$$

$$T = \frac{21.2}{30} = 0.707 \text{ s}$$

Repeated readings of t and t > 10 s. t record to nearest 0.1 s.
Correct calculation of T with correct s.f. & units [B1]

θ = 69° ....

T = 0.707 s .... [2]

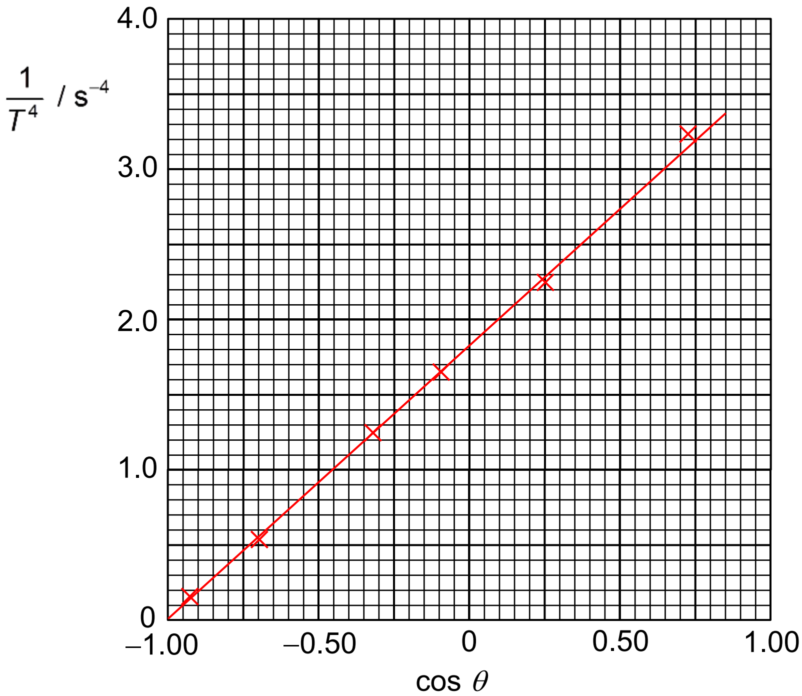
(d) The experiment is repeated using a wire with another length and the angle θ of the bent wire is varied. The results are shown in Fig. 1.4. Values of $\frac{1}{T^4}$ and $\cos\theta$ are included.

θ / °	$\cos\theta$	T / s	$\frac{1}{T^4}$ / s^{-4}
159	–0.934	1.56	0.169
135	–0.707	1.16	0.552
110	–0.342	0.942	1.27
96	–0.10	0.884	1.64
74	0.28	0.816	2.26
45	0.71	0.745	3.25

Fig. 1.4

(i) Complete Fig. 1.4. [1]

(ii) Plot the points on the grid and draw the straight line of best fit.



[2]

(iii) Using the graph in **(d)(ii)**, state and explain whether $\frac{1}{T^4}$ is proportional to $\cos\theta$.

Since the vertical intercept is not zero [M1]

$\frac{1}{T^4}$ is not proportional to $\cos\theta$. [A1]

.... [2]

[Total: 11 marks]

2 In this experiment, you will investigate how the rate of heat loss from a beaker of hot water depends on the insulation of the container.

(a) Measure the room temperature T_{room}.

T_{room} = 31.5 °C ....

(b) Pour hot water into a beaker until it reaches the 80 ml mark.

(c) **(i)** Place the thermometer in the water.

(ii) When the temperature of the water decreases to 80 °C, start the stopwatch.

Measure and record the water temperature T_0 when time t = 60 s and t = 120 s in Fig. 2.1. [1]

t / s	T_0 / °C	$T_{insulated}$ / °C	$(T_{insulated} - T_0)$ / °C
60	**76.5**	**77.0**	**0.5**
120	**73.5**	**74.5**	**1.0**

Fig. 2.1

(d) **(i)** Empty the beaker.

(ii) Pour hot water into beaker until it reaches the 80 ml mark.

(iii) Wrap insulating material around the sides of the beaker. Secure the insulating material to the beaker using a rubber band, as shown in Fig. 2.2.

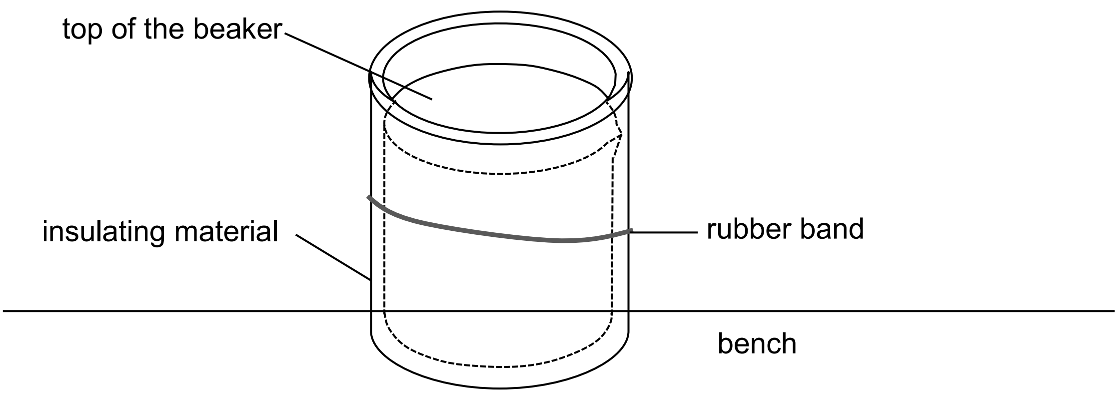


Fig. 2.2

(iv) Repeat **(c)** to measure the water temperature $T_{insulated}$ at the same time intervals.

Record the values of $T_{insulated}$ and $(T_{insulated} - T_0)$ in Fig. 2.1. [2]

[Turn over

(e) It is suggested that T_0 and $T_{insulated}$ for the corresponding *t* are related by the expression

$$(T_{insulated} - T_0) = AT_0 + B$$

where *A* and *B* are constants.

Using your results from Fig. 2.1, determine the values of *A* and *B*.

77.0 – 76.5 = A (76.5) + B

75.0 – 73.5 = A (73.5) + B

A = –0.333 (unitless)

B = 26.0 °C

A = –0.333 ....

B = 26.0 °C .... [3]

(f) Use your values from **(a)** and **(e)** to determine the value of $T_{insulated}$ when T_0 reaches room temperature T_{room}.

T_2 – 27.0 = -0.333(27.0) + 26.0
T_2 = 44.0 °C

$T_{insulated}$ = 44.0 °C .... [1]

(g) **(i)** State and explain two significant sources of error or limitations of the procedures for this experiment.

1. Temperature differences are small compared to precision of the instrument
Heat escaping from the bottom of the beaker

2. Reading stopwatch and thermometer simultaneously
2 sets of data not sufficient to draw a conclusion [2]

(ii) Suggest one improvement that could be made to the experiment to address one of the errors identified in **(g)(i)**. You may suggest the use of other apparatus or different procedures.

Use thermometer with greater precision
Insulate bottom of the beaker
Use a temperature probe with data logger
Collect 6 sets of data, plot a graph of $T_2 - T_1$ against T_1 and determine gradient *A* and vertical intercept *B* [1]

(h) A vacuum flask is an insulating storage vessel that lengthens the time over which its contents remain hotter or cooler than the flask's surroundings.

A vacuum flask manufacturer wishes to investigate how evaporation affects the heat retention of the vacuum flask.

Suggest changes that could be made to your experiment to investigate how the rate of heat loss from an insulated container depends on evaporation.

Method to reduce evaporation. e.g. adding a lid + show how the thermometer should be inserted through a hole of the lid / use a layer of oil.
Use insulated beaker for both runs and compare the temperature of the contents at equal intervals

.... [2]

[Total: 12 marks]

Candidate Name: ______________________________ (   ) Class: ________________

3 In this experiment you will investigate how the power P generated in a resistor varies with the resistance R of the resistor.

(a) You are supplied with a fixed resistor labelled Q and a variable resistor of resistance R. Construct the circuit shown in Fig. 3.1.

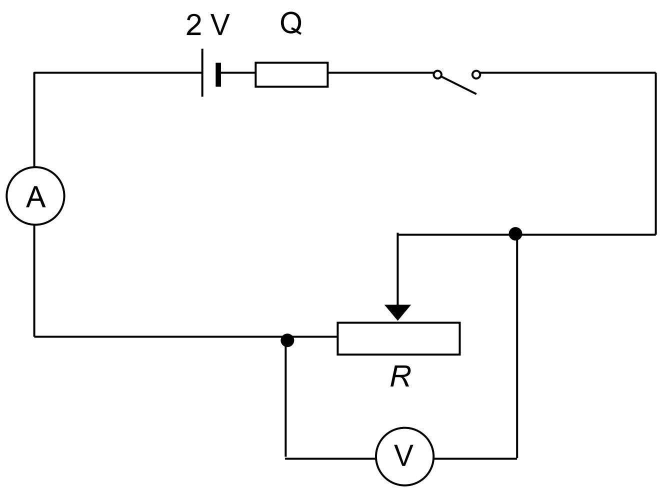


Fig. 3.1

(b) **(i)** Close the switch.

(ii) Adjust the slider of the variable resistor such that the voltmeter reading V is approximately 0.5 V.

(iii) Measure and record the potential difference V and the current I.

V = 0.506 V ....

I = 141.2 mA .... [2]

(iv) Open the switch.

(v) Calculate the values of resistance R of the variable resistor and power P where $R = \frac{V}{I}$ and $P = IV$.

$R = 3.58\ \Omega$

$P = (0.506)(0.1412) = 0.0714$ W

R = 3.58 Ω ....

P = 7.14×10^{-2} W ....

(vi) Justify the number of significant figures which you have quoted for *R* and *P*.

Since *P* and *R* are calculated with *I* and *V* values, they follow the least significant figure of *I* and *V* values used (or least s.f. plus 1).

.... [1]

(c) Change the resistance of the variable resistor to increase the value of *V*. Repeat steps **(b)(i)**, **(iii)**, **(iv)** and **(v)** to obtain at least 7 further sets of readings for $V < 1.3$ V.

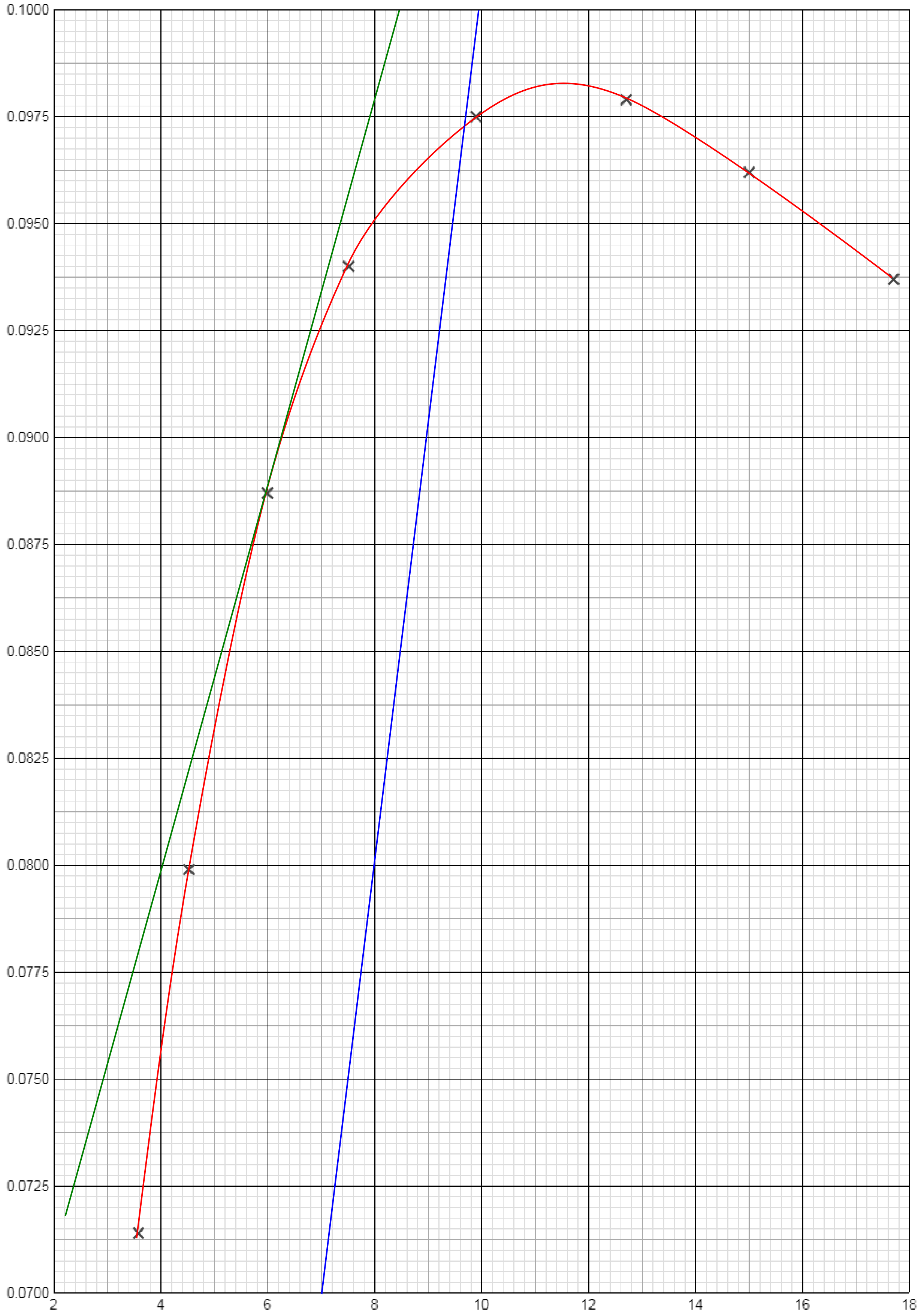
***V* / V**	***I* / mA**	***R* / Ω**	***P* / W**
0.506	141.2	3.58	7.14×10^{-2}
0.601	132.9	4.52	7.99×10^{-2}
0.729	121.7	5.99	8.87×10^{-2}
0.840	111.9	7.51	9.40×10^{-2}
0.982	99.3	9.87	9.75×10^{-2}
1.115	87.8	12.7	9.79×10^{-2}
1.201	80.1	15.0	9.62×10^{-2}
1.287	72.8	17.7	9.37×10^{-2}

[7]

(d) **(i)** Plot a graph of *P* against *R*. [3]

(ii) Hence, state the value of *R* when *P* is a maximum.

R = 11.7 Ω .... [2]


0.1000
0.0975
0.0950
0.0925
0.0900
0.0875
0.0850
0.0825
0.0800
0.0775
0.0750
0.0725
0.0700
2
4
6
8
10
12
14
16
18

(e) By drawing a tangent to the curve, determine the rate of change of P with R when R = 6 Ω.

Tangent drawn correctly. [M1]

$$\text{gradient} = \frac{0.09975 - 0.07625}{8.4 - 3.2} \quad \text{[M1]}$$

$$= 4.52 \times 10^{-3}\ \text{W}\ \Omega^{-1} \quad \text{[A1]}$$

rate of change of P = 4.52×10^{-3} W Ω^{-1} .... [3]

(f) The power P and the current I are related by the expression

$$P = I^2 R$$

By drawing a second line on your graph in page 11, determine the value(s) of P when I = 100 mA. Label this line **Z**.

Plot P against R, a straight line graph passing through the origin will be obtained with I^2 as the gradient.

When R = 7 Ω, $P = (10 \times 10^{-3})^2(7)$ = 70 mW
R = 10 Ω, $P = (10 \times 10^{-3})^2(10)$ = 100 mW

Reading off intersection point, P = 97.25 mW

P = 97.3×10^{-3} ....W [2]

[Total: 20 marks]

Candidate Name: ______________________________( ) Class: ________________

4 A student wishes to investigate projectile motion.

A small ball is rolled with velocity v along a horizontal surface. When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface. The vertical displacement of the ball is h and the horizontal displacement of the ball is d, as shown in Fig. 4.1.

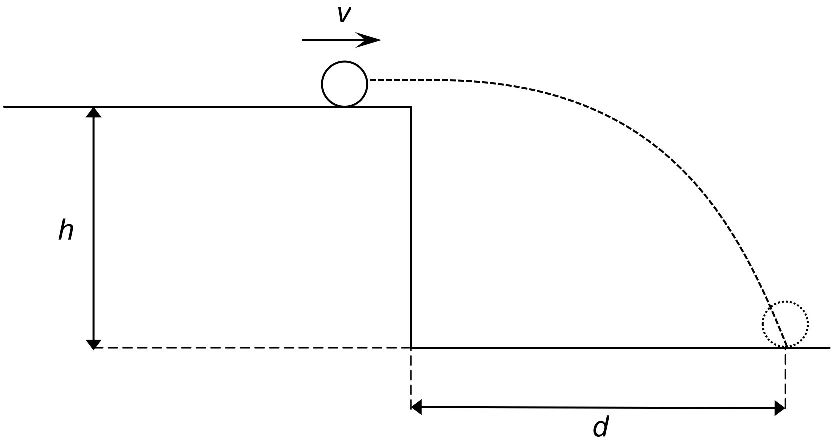


Fig. 4.1

The student suggests that d is dependent on h and v according to the equation

$$d = kh^p v^q$$

where k, p and q are constants to be determined.

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

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use and measurements to be taken,

(c) procedure to be followed,

(d) the analysis of the data,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Basic Procedure (1)	BP1: Vary *h* while keeping v constant + Vary *v* while keeping h constant
Diagram (1)	D1: Labelled diagram showing way of launching ball and determining speed that the ball leaves the edge
Control (1)	C1: Method to ensure that the surfaces remain horizontal, e.g. spirit level/check height at different places. C2: Any other valid points
Measurements (4)	M1: Workable method to vary *h*. (eg. stacking of multiple planks to raise the height of ground. / table with adjustable height) M2: Workable method to launch ball so that it can be varied or kept constant as required (eg. ball roll down a slope of varying steepness / ball launched from spring compressed to different extent) M3: Workable method to measure v (e.g. using video analysis, light gates with distance and method, motion sensor etc) or determine v by calculation M4: Use ruler/measuring tape to measure *d* and *h*.
Analysis of data (1)	A1: Plot a suitable graph of ln *d* vs ln *h* (keeping <u>*v* constant</u>). gradient = p ; vertical-intercept = ln (kv^q) and: Plot a suitable graph of ln *d* vs ln v (keeping <u>*h* constant</u>). gradient = q ; vertical-intercept = ln (kh^p) Use both graphs to determine *p* and *q* and *k*
Reliability (3)	R1: Detail on method of improving precision of measurement of *d* e.g. slow motion playback including scale / marking on A4 using a carbon paper / sand. R2: Method to ensure *d* is measured from just below edge of upper surface e.g. use set square, plumb line. R3: Show understanding of random error in experiment: Take many readings of *d* for each *h* and *v* and average R4: Take 6 sets of readings for each graph
	R5: Method to ensure that velocity of ball is horizontal only when it reaches table, e.g. curved track. R6: Ensure that the ball leaves the table at 90°, e.g. set square/protractor on upper surface. R7: Detail on measuring *d* – location of landing position e.g. centre of crater/start of track. R8: Use of high density ball to minimise the effects of air resistance R9: Any other valid points
Safety precaution (1)	S1: Experiment is relatively safe S2: Reasoned method to prevent ball rolling on floor e.g. box below / storage box for balls / sand box. Reasoned method to prevent ball causing injury e.g. goggles / safety screen.

[Total: 12 marks]

Catholic Junior College

JC2 Mid-Year Examinations

Higher 2

CANDIDATE NAME	**MARK SCHEME**
CLASS	**2T**

PHYSICS — 9749/02

Section B: Structured Questions — **9 May 2018**

Section C: Longer Structured Questions — **2 hours**

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Section B.
Answer **ONE** out of two questions in Section C.
Circle the question number attempted in Section C.

A maximum of 2 marks will be deducted for wrong significant figures and incorrect/lack of units.

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 7			
Q2	/ 8			
Q3	/ 7			
Q4	/ 5			
Q5	/ 8			
Q6	/ 4			
Q7	/ 11			
Q8	/ 10			
Q9	/ 10			
Q10	/ 10			
Q11	/ 10			
SECTION B & C	/ 80			
SECTION A	/ 15			
SF/UNITS				
TOTAL	/ 95			

Section B

Answer **all** questions from this section.

1 A machine shoots out a steady stream of balls each of mass 0.20 kg at a rate of 60 balls per minute at a speed of 20 m s^{-1} as shown in Fig.1.1. Each ball strikes the wall perpendicularly and rebounds at the same speed. The time of impact for each ball is 0.2 s.

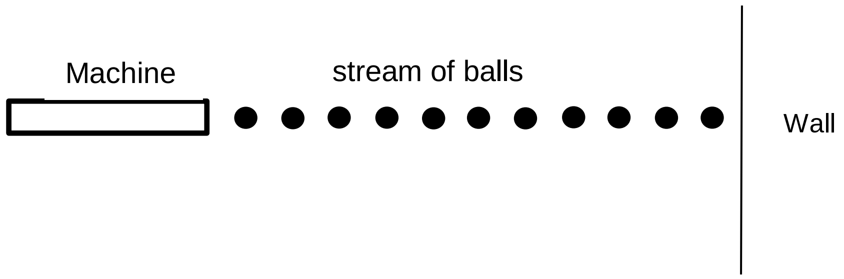


Fig.1.1

(a) Calculate the change in momentum of each ball during the impact.

change in momentum = …………………….. kg m s^{-1} [2]

L2 **Solution:**

For each ball, the change in momentum = $m(v - u)$ = 0.20[20 - (-20)] M1

= 8.0 kg m s^{-1} A1

Examiner's Comments:

- Candidates that did not earn full credit did not pick up that each ball rebounds off at the same speed before it hits the wall.
- Candidates also need to recall that momentum is a vector quantity and therefore the direction of the velocity and hence momentum is important to take note.

(b) Calculate the average force acting on the wall by each ball during the impact.

average force on the wall by each ball during impact: …………………..N [2]

L2 Solution:

Average force on wall
= average force on ball (by Newton's third law of motion) M1
= change in momentum / time taken (newton's second law of motion)
= 8.0 / 0.2 A1
=40 N

Examiner's Comments:

- This was generally well done by the candidates.
- Candidates that did not gain credit were not able to recall the formula linking the change in momentum to the average force with time taken.

(c) On Fig.1.2, sketch a graph to show how the force exerted on the wall due to the stream of balls varies with time over 3.0 s. Label the graph "A".

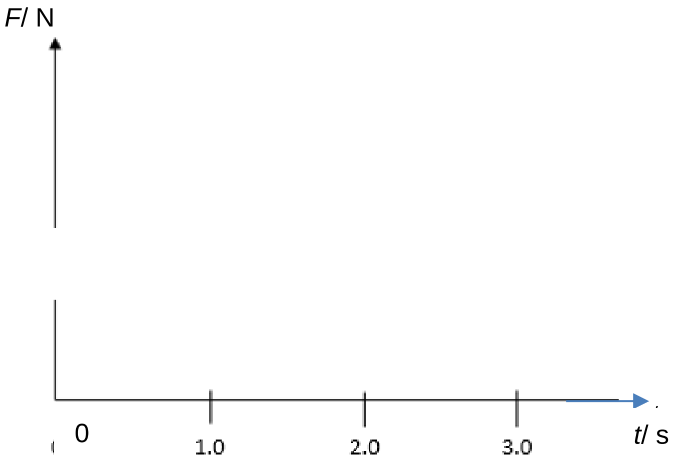


Fig.1.2

[2]

L3

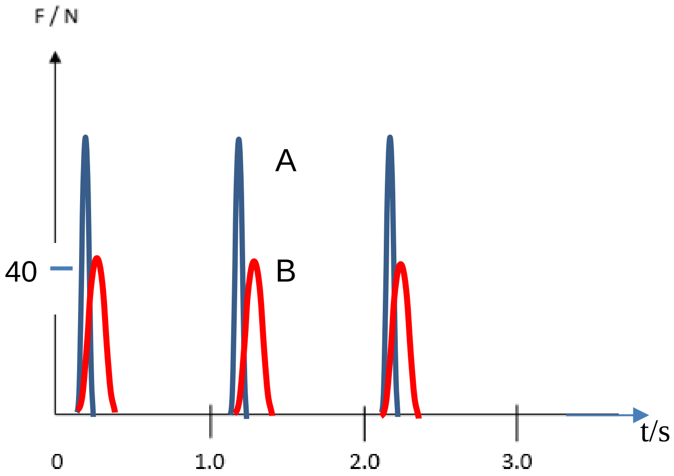


Fig.1.2

B1 – Shape of graph at interval of 1 s — B1
B1 – Correct labels including average force at approximately half of the maximum — B1

Examiner's Comments:

- This was poorly attempted by majority of the candidates.
- Candidates must be able to draw the link between the features of the graph given, in this case a force against time graph. Candidates should then deduce the link between the area underneath the graph drawn to the change in momentum, which is calculated in part (a). Therefore should have an idea of how the graph would look like.
- Candidates should take note of the keywords that the time of impact for graph B is twice of that for graph A and therefore the shape of graph B must be shorter but wider since the change in momentum is the same.
- Candidates should also pay attention to the rate at which the ball hits the wall and a simple calculation should show that for every second, there is an impact on the wall.

	(d)		On Fig.1.2, sketch a second graph to show how the force exerted on the wall due to the stream of balls if the time of impact is 0.4 s. Label this graph "B".	[1]
	L3		Solution Same shape but peak is approximately half Same time interval of 1 second.	B1

2	**(a)**	Define *electric field strength.*	
		…………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………	[2]
	L1	**Solution:** Electric field strength at a point in an electric field is the <u>force per unit positive charge</u> acting on a <u>stationary</u> test charge placed at that point. Examiner's Comments: • This was poorly attempted by candidates. • Candidates must also take note of the keywords for the definition as underlined.	B2
	(b)	Fig. 2.1a shows the position of a fixed point charge of $+q$ at position Z. Position Y is 0.30 m away along the x-axis. Fig. 2.1b shows the variation with distance x of the electric field strength E due to the point charge at Z.	

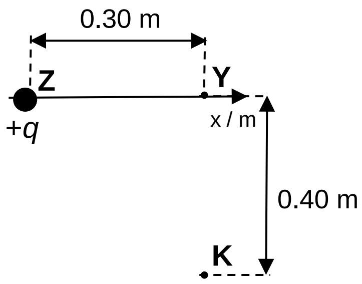


Fig. 2.1a

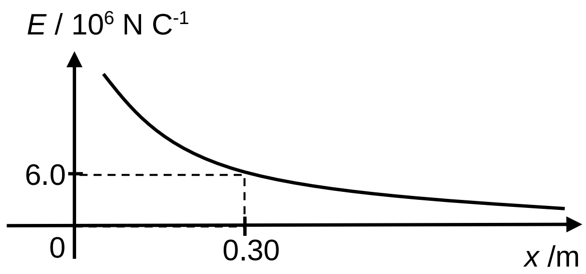
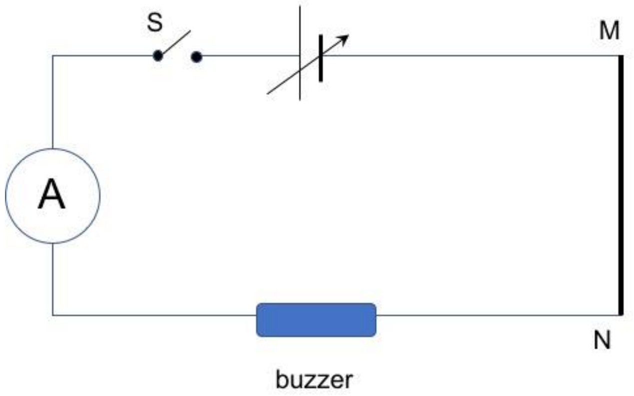


Fig. 2.1b

		(i) Calculate the charge at Z.	
		charge at Z = ………………. C	[2]
	L2	**Solution:** $Q = E(4\pi\varepsilon_o r^2)$ $= (6.0 \times 10^6) \times 4\pi\varepsilon_o \times 0.3^2$ $= 6.0 \times 10^{-5}$ C	M1 A1

		Examiner's Comments: • Candidates that failed to obtain full credit were mainly due to being unable to recall the formula for electric field strength, making careless mistakes, not paying enough attention to the units of the given physical quantities from the graphs.	
		(ii) Calculate the magnitude of the electric force acting on a –2.0 C point charge when it is placed at position Y.	
		magnitude of electric force = …………………… N	[1]
	L2	**Solution:** Electric force = qE = 2.0 x 6.0 x 10^6 = 1.20 x 10^7 N No marks is awarded if candidates indicate a minus sign. Examiner's Comments: • Candidates must again pay attention to what the question is asking. Those that failed to gain credit either made careless mistakes or that the minus sign was included in their final answer.	M0 A1
		(iii) The point charge of –2.0 C is displaced from position Y to K. Calculate the work done by the external force on this point charge during this movement.	
		work done by external force = ……………… N m	[3]
	L3	**Solution:** Let r_k and r_y be the distance from point Z at Y and K respectively. $r_k = \sqrt{(0.3^2 + 0.4^2)} = 0.5$ m Work done = Q (Δ V) = $\{Q_1Q_2/(4\pi\varepsilon_o)\}(1/r_k - 1/r_y)$ = {(-2) x (6.01 x 10^{-5}) / ($4\pi\varepsilon_o$)} x {(1/0.5) – (1/0.3)} = + 1.44 x 10^6 J Examiner's Comments: • This was poorly attempted by majority of the candidates. • Candidates must be able to identify that the electric potentials at position Y and K are different. Therefore, going back to the definition of electric potential, the difference in the work done by the external force at both positions would give the work done by the external force in bringing this charge from positions Y to K. • Candidates cannot simply find the distance between position X and K and then use the formula for electric potential energy to determine the work done. This is because the electric force changes/varies from position X to K! Also, the question asks for the work done **during this movement**! Question essentially is asking for the change in electric potential energy.	M1 M1 A1

Q3	A buzzer rated at 6 V operating voltage and with a resistance of 200 Ω is connected to a variable voltage d.c. source of negligible resistance, a uniform cross-section nichrome wire MN and an ideal ammeter as shown in Fig. 3.1. The wire MN is of length 1.00 m and of radius 0.34 mm. There are 9.0×10^{28} mobile electrons per cubic metre in the nichrome wire. The ammeter reads 30 mA when switch S is closed.  **Fig. 3.1**			
	(a)	**(i)**	Calculate the average time taken for an electron to travel along the nichrome wire from M to N.	
			time taken = ………………… s	**[2]**
	L2		**Solution:** Since $I = nAvq$ $v = \dfrac{I}{nAq}$ $v = \dfrac{MN}{nAq}$ $t = \dfrac{nAqMN}{I}$ $= \dfrac{(9.0\times10^{28})(\pi \times 0.34^2 \times 10^{-6})(1.6 \times 10^{-19})(1.0)}{30 \times 10^{-3}}$ $= 1.74 \times 10^5$ s OR Calulation fo drift speed Claculation of time. Examiner's Comments: • This question is poorly done. Many students were unaware how to use the desired equation. Instead, many tried to work from scratch: finding the total number of charges by trying to calculate the volume of the wire and multiplying with the number density. • There is a significant number of students who equated the measured current to the rate of flow of the charge of a single electron.	**M1** **A1** **M1** **A1**
		(ii)	Explain why the time duration between the closing of the circuit and the start of the buzzing of the buzzer is much shorter than the value calculated in **(a)(i)**.	

			....	**[1]**
	L3		**Solution:** Once the circuit is closed, all the electrons in the circuit (in the nichrome wire as well as in the buzzer) will move together at the drift speed. This will thus cause the buzzer to sound almost instantaneously. Examiner's Comments: • This question is poorly done. • It was surprising to have a significant number of scripts stating that the electron has traveled at the speed of light.	**B1**
	(b)	A particular negative temperature coefficient (NTC) thermistor with an I-V characteristic as shown in Fig. 3.2.		

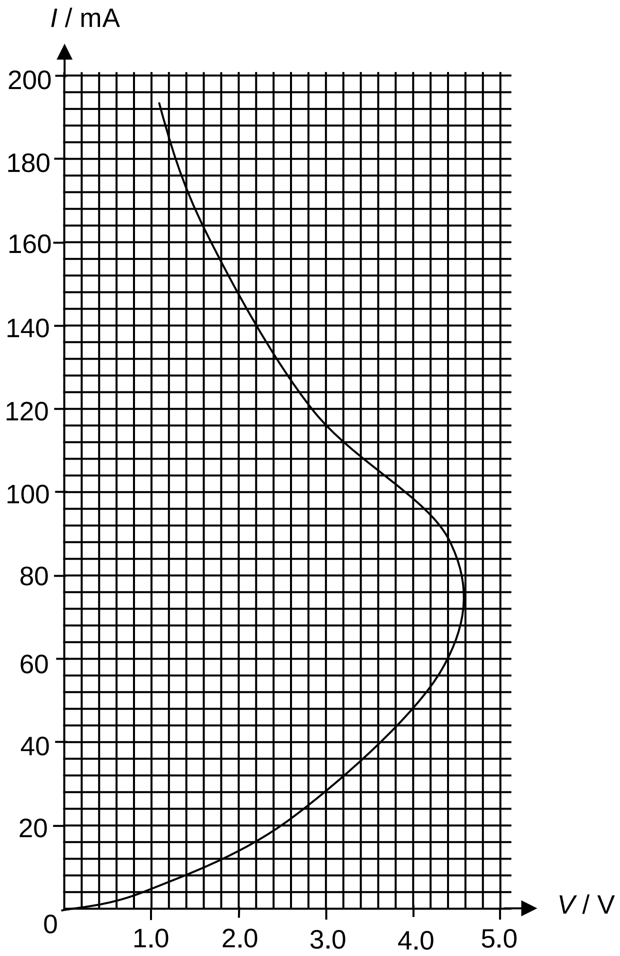
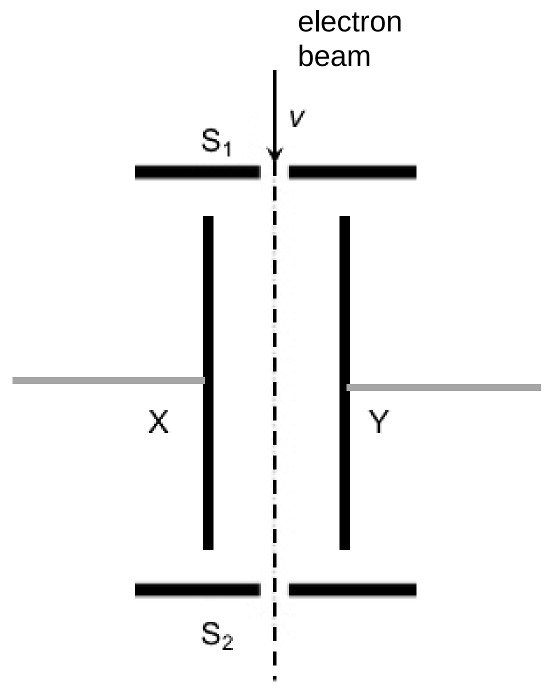


Fig. 3.2

		(i)	Define *resistance* of an electric component.	
			....	[1]

			…………………………………………………………………………………………………	
	L1		**Solution:** It is the ratio of the potential difference across the component to the current through it. Examiner's Comments: • There is a significant number of scripts who has candidates write "voltage" rather than potential difference.	B1
		(ii)	Determine the resistance of this thermistor when the applied potential difference across it is 4.6 V.	
	L1		resistance = …………….. Ω	[1]
			Solution: $R = \frac{4.6}{76 \times 10^{-3}}$ $= 61\ \Omega$ *Accept* $I = 72 \times 10^{-3}$*A*, 73×10^{-3}*A*, 74×10^{-3}*A*, 77×10^{-3}*A*, 78×10^{-3}*A* *Do not accept* 0.5×10^{-3}*A for current read-off.*	B1
		(iii)	With reference to Fig. 3.2, state and explain how the resistance of the thermistor vary as the current increases from 0 mA to 180 mA.	
			………………………………………………………………………………………………… ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………	[2]
	L3		**Solution:** From Fig. 5.2, the ratio of I to V increases and the ratio of V to I decreases as the current increases. The resistance of the thermistor decreases as current increases from 0 mA to 192 mA. (Since resistance of an electrical component is the ratio of the potential difference across the component to the current that passes through it). Examiner's Comments: • Many scripts did not refer to the diagram to take reference to the ratio of V to I. Instead, many sudents use the gradient concept to calculate resistance, hence not being able to be awarded the mark.	**M1** **A1**

4	**(a)**	A beam of electrons enter the slit S_1 as shown in Fig 4.1 below.  **Fig. 4.1** In the region between slits S_1 and S_2, a uniform magnetic field is applied in a direction out of the page and a uniform electric field is provided by a potential difference between two parallel plates X and Y. The electrons pass through slit S_2 undeflected and emerged from the slit S_2 with the same velocity as it enters slit S_1.		
		(i)	State which plate, X or Y, is at a higher potential.	
			plate at higher potential: ………	[1]
	L2		**Solution:** Electrons are negatively charged → Magnetic force acts to the right. → Electric force acts to the left since they are undeflected. Hence, X: + Y: - Examiner's Comments: • Most candidaes got this part correct.	B1
		(ii)	By using energy considerations, explain how this combination of the magnetic field and electric field allow the electrons to pass through slit S_2 at the same speed as it enters slit S_1.	
			…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………	**[2]**
	L3		**Solution:**	

			This combination of electric and magnetic fields will cause the net force on the electrons to be zero. Thus, there will not be any net work done on the electrons by the external field, resulting in a zero change in their KE. Therefore, there will not be a change in the speed of the electrons. Examiner's Comments: • There is a significant number of candidaes who did not get this part correct, as they did not specify the concept of a zero net force and thus no work done. • Many candidates treated the gain of energy/work done as a vector quantity rather than a scalar. Many had analysed the gain f energy according to a specified direction and thus "cancelling" out of the gain of energy in the opposite direction.	**M1** **A1**
	(b)	The electron beam is now replaced by a stream of α- particles with the same speed as that of the electrons in Fig. 4.1. Explain whether the α-particles will pass through S_2 undeflected.		
		…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………		[2]
	L2	**Solution:** The alpha particles are not deflected Magnetic force on the particles is equal and opposite to the electric force on them $F_m = F_E$ $Bqv = qE$ $v = E/B$ The velocity v is only dependent on E and B which are unchanged Therefore, the alpha particles can still pass through S_2 without being deflected even though they have dfferent mass and charge as compared to electrons. Examiner's Comments: • There is a significant number of candidates who did not know that the alpha particle is positively charged. Many are not cognizant of the fact that so long as the ratio of the electric to the magnetic fkux density is still the same as the speed of the particles, the particles will not deflect, regardless or mass and charge.		**B1** **B1**

5 A long straight wire carrying a current of 2.0 A is placed on the same plane as a small square coil of wire of 5 turns. The length of each side of the coil is 1.0 cm. The coil is moved perpendicularly away from the straight wire at a constant speed, as shown in Fig. 5.1.

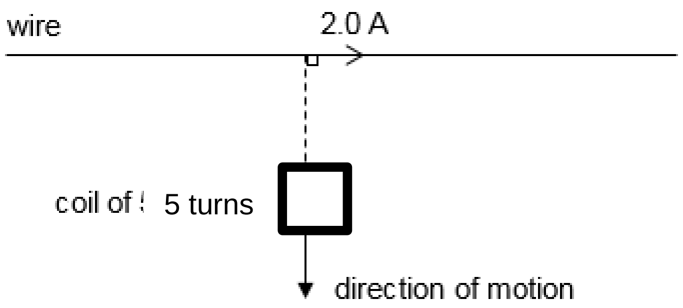


Fig. 5.1

(a) Show that the magnetic flux density at a perpendicular distance of 10.0 cm from the wire is 4.0×10^{-6} T.

[1]

L1 Solution:

$$B = \frac{\mu_0 I}{2\pi d}$$

$$= \frac{(4\pi \times 10^{-7})(2.0)}{2\pi(0.10)}$$ **M1**

$= 4.0 \times 10^{-6}$ T **A0**

Examiner's Comments:

- For a "show" question, students are expected to input the values of the quantities, including the value of μ_0 into the equation.

(b) The coil is moved such that the distance between the wire and the centre of the coil changes from 10.0 cm to 20.0 cm in a duration of 0.40 s.

Assuming that the magnetic flux density through the entire coil is the same as the value at the centre of the coil, determine the magnitude of the average e.m.f. induced in the coil.

magnitude of average e.m.f. = …………………. V **[3]**

L2 Solution:

At d = 20 cm from wire: $B = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi \times 10^{-7})(2.0)}{2\pi(0.20)} = 2.0 \times 10^{-6}$ T **M1**

$$|\langle E \rangle| = \left| -\frac{\Delta(NAB)}{\Delta t} \right|$$

$$= \left| NA\frac{\Delta B}{\Delta t} \right|$$

$$= \left| -(5)(0.010 \times 0.010)\frac{(2.0 \times 10^{-6} - 4.0 \times 10^{-6})}{(0.40)} \right|$$ **M1**

$= 2.5 \times 10^{-9}$ V **A1**

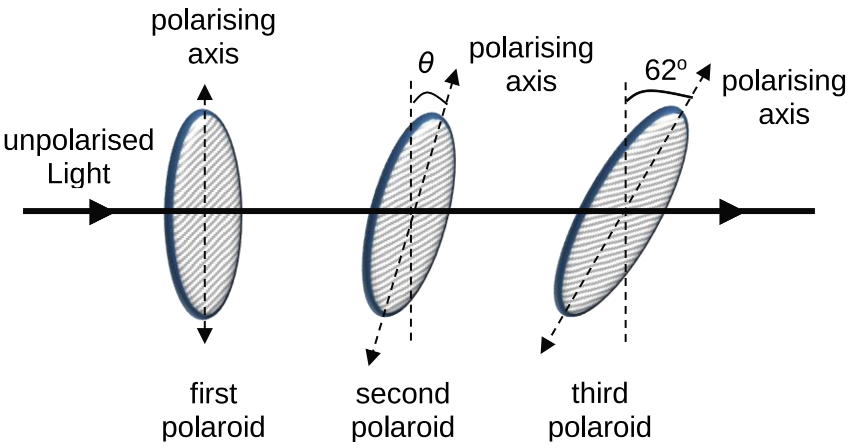
Examiner's Comments:

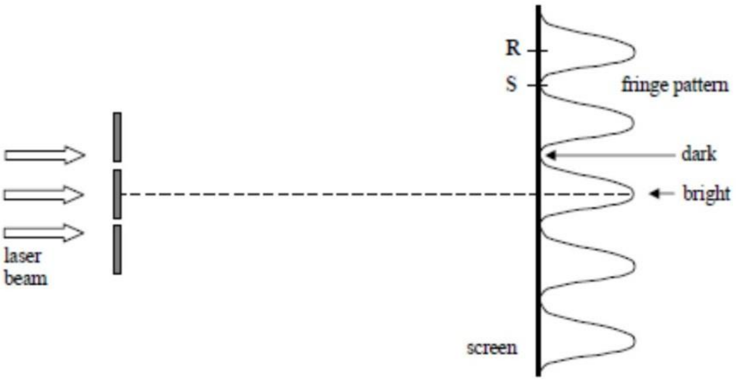
- Majority of students cannot perform successfully the calculation, either missing out the value of N, or A (area) in the calculations.

			• Some wrongly used E = BLv which is used to find the induced emf for a straight conductor sweeping a magnetic field. • Do note that area of a square is Length x length. Need to convert the length which is in cm to m.	
	(c)	**(i)**	With reference to Lenz's law, state and explain the direction of the induced current in the coil.	
			…………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………….. ……………………………………………………………………………………………	**[2]**
	L2		Solution: By Lenz's law, the induced current in the coil will flow in a way to **produce a magnetic field** (or an effect) **to oppose the decrease in magnetic flux density.** Hence, the induced current flows in the **clockwise direction** and produces a magnetic field to reinforce the magnetic flux density into the paper. OR As the coil is being pulled away from the wire, by Lenz's law, the induced current in the coil flows in a way to **oppose this motion**. Hence, the current carrying wire must **produce a net magnetic force which acts upwards** by **flowing clockwise** (to produce a larger attractive force on the upper side, due to larger B at the upper side, and a smaller repulsive force on the lower side). Examiner's Comments: • Candidates were required to describe what exactly was the change experienced by the coil (i.e. a decreasing magnetic flux density as the further it moves away from the wire, the field strength decreases) • Since this is a coil, students need to use the words "clockwise" or "anticlockwise" to describe the direction of current. • Do not just state Lenz law too (no marks awarded for that). Show how Lenz law is applied by mentioning the effect produced to oppose the change.	**B1** **B1** **B1** **B1**
		(ii)	Explain why work has to be done to move the coil away from the straight wire at a constant velocity.	
			…………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………	**[2]**

	L2		**Solution:** The induced current in the coil produces **<u>a magnetic force that opposes the coil's motion.</u>** Therefore, an **<u>external force must be applied in the direction of motion</u>** for forces to balance and to maintain a constant velocity (or applied to pull the coil away from the wire at a constant velocity). Hence, work has to be done by the external force. OR Since the coil moves at a constant speed, there is **<u>no change in kinetic energy</u>**. Therefore, the **<u>electrical energy</u>** (or induced current) produced in the coil has to be **<u>produced by the work done by an external force.</u>** Examiner's Comments: • Students need to be specific and clear about the which force does the work. The direction of forces must be clearly stated as well (for eg. The coil experiences an attractive force <u>towards the wire).</u> • Students should also note that work done is a scalar quantity and has no direction. Therefore, they should be cautious and NOT mentioned work done in a specific direction.	**B1** **B1** **B1** **B1**

6	**(a)**		State how a *polarised* transverse wave differs from an *unpolarised* transverse wave.	
			....	**[1]**
	L1		Solution: In a polarised wave, the **<u>oscillation of the transverse wave are confined to one direction</u>** only; whereas in an unpolarised wave there is **<u>infinite number of directions of oscillation.</u>** Examiner's Comments: • Many students lost marks here because they fail to mention that it is the "vibration" or "oscillations" which is confined to one direction for polarized wave or infinite direction for unpolarised waves. The use of the word "move" or "travel" are not acceptable as they are not indicative of a back and forth periodic motion.	**B1**

	(b)		Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at θ and 62° respectively, to that of the first, as shown in Fig. 6.1.  **Fig. 6.1** When an unpolarised light is incident on the stack of polaroids, the light has amplitude of A_1 after it passes through the first polaroid, A_2 after it passes through the second polaroid and A_3 after it passes through the third polaroid. If θ = 23°, determine	
		(i)	A_2 in terms of A_1, and	
			A_2 = …………………… A_1	**[1]**
	L1		Solution: $A_2 = \cos(23°) A_1 = 0.92 A_1$ Examiner's Comments: • Students must leave their answers in the complete form of 0.92 instead of cos 23 (incomplete!).	**B1**
		(ii)	A_3 in terms of A_1. A_3 = …………………… A_1	**[2]**
	L3		Solution $A_2 = A_1 \cos(23°)$ ------ (1) $A_3 = A_2 \cos(62° - 23°)$ ---(2) Substituting (1) into (2) $A_3 = A_1 \cos(23°) \cos(62°-23°)$ $= 0.715 A_1$ Examiner's Comments: • Many students did not subtract (62-23) and inserted 62 alone for equation 2. Note that the angle should be between polarizing axis 3 and polarizing axis 2 which is (62-23).	**M 1** **A1**

7	(a)		A double slit system is illuminated by a laser beam and produces an interference pattern as shown in Fig. 7.1. The laser beam emits an intense, coherent and monochromatic light of wavelength 633 nm and power output of 1.0 mW. The diagram is not drawn to scale.  **Fig. 7.1** Calculate the path difference between the laser beams emerging from the two slits at	
		(i)	point R, and	
			path difference = …………………… m	[1]
	L1		Solution: Since R is the 2nd order bright fringe, its path difference = 2 (wavelength) $= 2 \times 633 \times 10^{-9}$ $= 1.27 \times 10^{-6}$ m Examiner's Comments: • This part was generally well done by students. Please note the difference between path and phase difference. Some who could not score in this part gave the phase difference instead of path difference.	A1
		(ii)	point S.	

			path difference = ... m	[1]
L1			Solution: Since S is the 2nd order dark fringe, its path difference = 1.5 (wavelength) = 1.5 x 633 x 10^{-9} = 9.50 x 10^{-7} m Examiner's Comments: • Same comments as above.	A1

(b) Monochromatic light is passed through a rectangular slit of width *b* of 0.20 mm. The light is observed on a screen placed 0.75 m from the slit, as shown in Fig. 7.2.

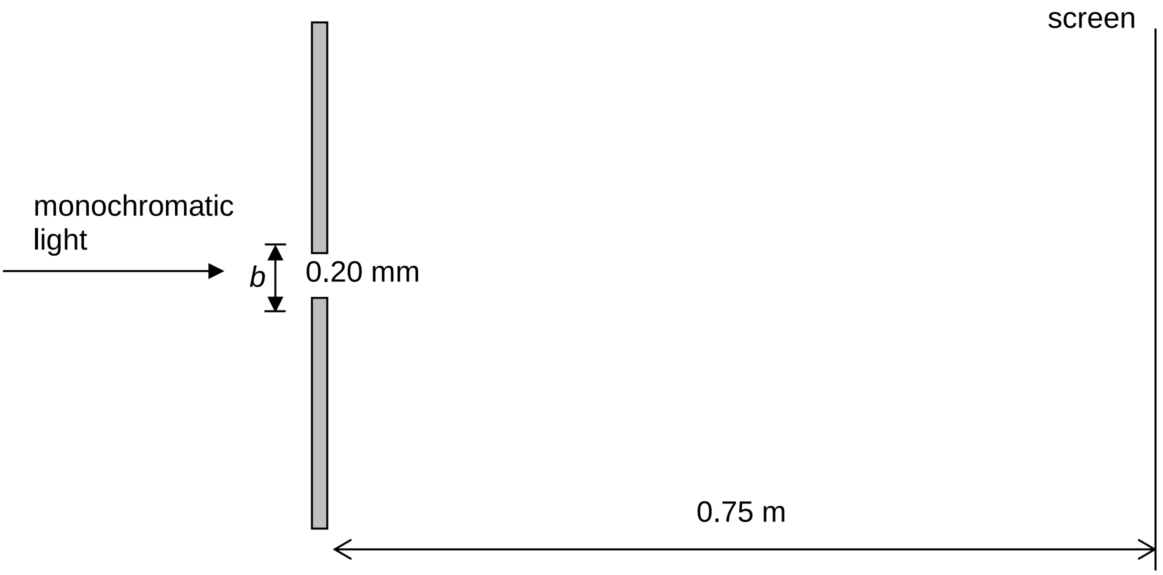


Fig. 7.2

The variation of the intensity I of the light with the angle of diffraction θ is shown in Fig. 7.3.

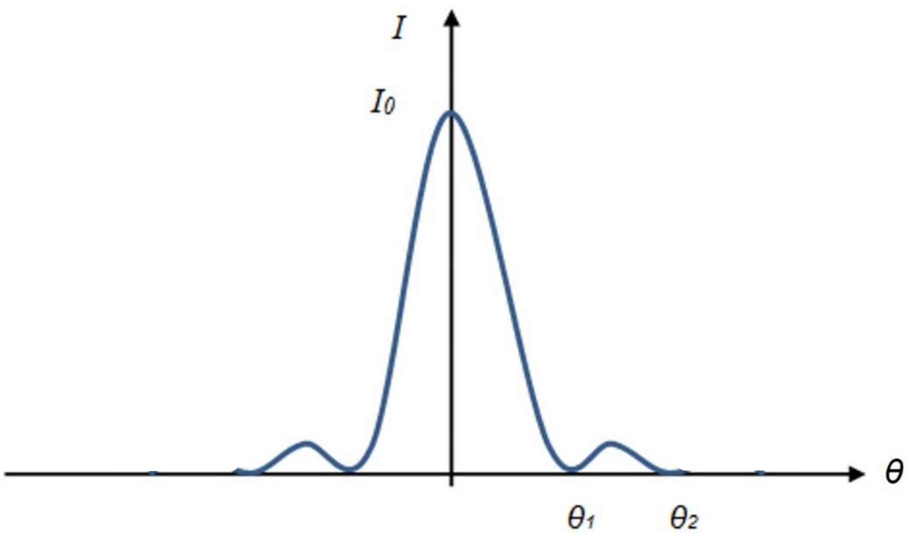
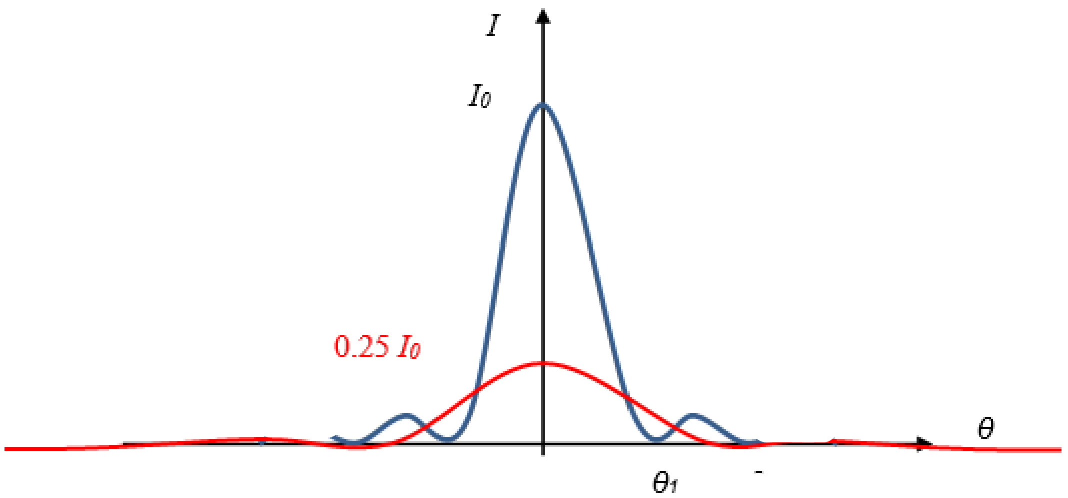


Fig. 7.3

		The maximum value of intensity is I_0 and the value of θ_1, the location of the first order minima is 0.169°.		
		(i)	Determine the wavelength of the monochromatic light. wavelength = ……………….. nm	[2]
	L2		Solution: $\sin\theta = \frac{\lambda}{b}$ For first order minima θ_1 = 0.169° λ = b sin θ_1 = (0.2 x 10^{-3}) sin (0.169°) = 590 nm Examiner's Comments: • Students need to be familiar with the equation for single slit. Some wrongly gave the double slit equation. Some students also did not note that the units were in nanometre and gave their answers to the wrong power of ten.	M1 A1
		(ii)	**1.** Sketch, on the axes of Fig. 7.3, how the intensity of the light varies with θ if the slit width is halved.	[2]
	L3		Solution:  **Fig. 7.3** Same shape Larger angle of diffraction	**B1** **B1**

Examiner's Comments:

- Do note that intensity is actually a quarter of the original. Likewise the angle of diffraction for first minima should be doubled to be more precise. Marks were given on a BOD this round as long as students showed a larger angle of diffraction but at the A levels, students ought to show a doubling of angle of diffraction for first minima.

(iii) Two beams of light, of the same wavelength, is now incident on the slit as shown in Fig. 7.4.

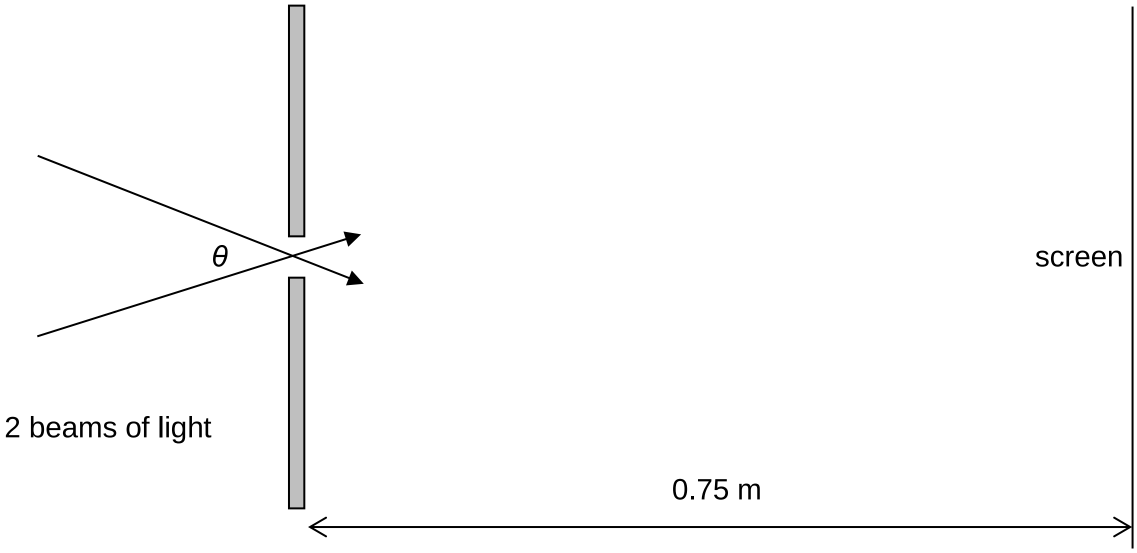


Fig. 7.4

State and explain the angle subtended between the two beams of light incident on the slit such that their diffraction patterns are just resolved. Explain your working.

L2

angle subtended = ...° [2]

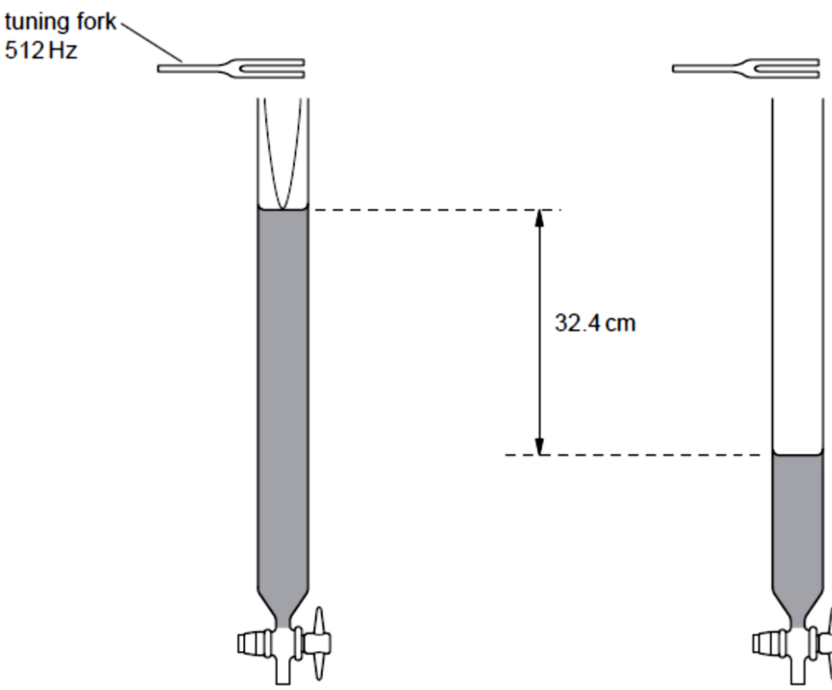
Solution:

For patterns to be just resolved, central maximum of one beam must lie on the first minimum of the other. B1

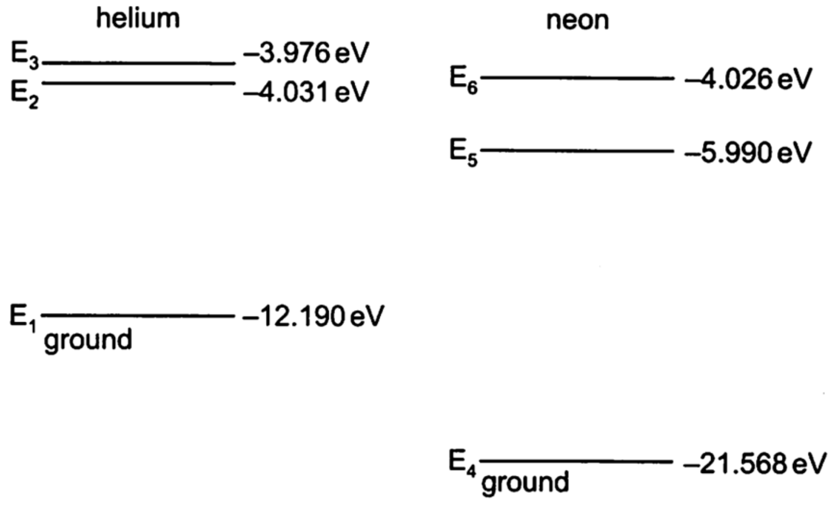
0.169° B1

Examiner's Comments:

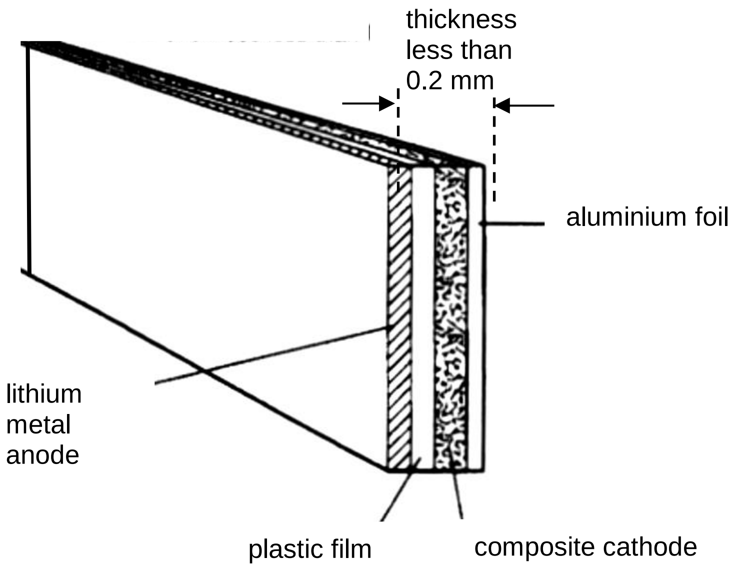
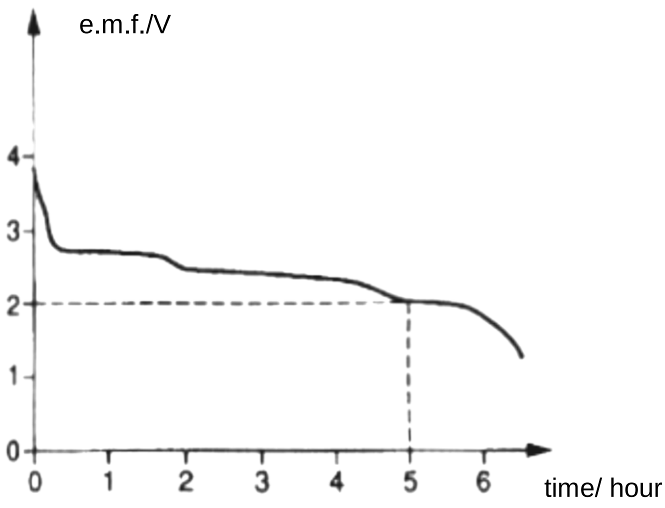
- No calculations were required for this part.
- Do note that in the graph of 7.3, angle of diffraction is given but question asks for angle subtended. As we are dealing with small angle, we can approximate it to be the same though technically they are different angles.

	(c)		In an experiment to determine the speed of sound, a long tube, fitted with a tap, is filled with water. A tuning fork is sounded above the top of the tube as the water is allowed to run out of the tube, as shown in Fig. 9.5a and Fig. 9.5b.  **Fig. 9.5a** **Fig.9.5b** A loud sound is first heard when the water level is as shown in Fig. 9.5a, and then again when the water level is as shown in Fig. 9.5b. Fig. 9.5a illustrates a stationary wave produced in the tube. The frequency of the fork is 512 Hz and the difference in the height of the water level for the two positions where a loud sound is heard is 32.4 cm. Calculate the speed of the sound in the tube.	
			speed of sound = ………………………………… $m\ s^{-1}$	[3]
	L2		Solution: (1 loop/ segment) ½ λ = 32.4 cm = 0.324 λ = 0.648 m v = f λ = 512 × 0.648 = 332 $m\ s^{-1}$ Examiner's Comments: • Students who made a mistake for this question could not recognize that it is 1 loop that fits within 32.4 cm. 1 loop is equivalent to half a wavelength.	 M1 M1 A1

8	**(a)**		A zinc plate has work function energy of 5.8 × 10^{-19} J. In a particular laboratory experiment, ultraviolet light of wavelength 120 nm is incident on the zinc plate. A photoelectric current is detected. In order to increase the photoelectric current, a student repeats the experiment with a lamp of higher wavelength of 450 nm. Show, with appropriate calculations, why he would be disappointed with the results.	
			....	**[3]**
	L2		Solution Minimum **Photon energy** for emission will be equal to the work function energy $E = \frac{hc}{\lambda_o} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{\lambda_o} = 5.8 \times 10^{-19}$ J $\lambda_o = 343$ nm threshold wavelength = 343 nm Wavelength of second lamp (=450 nm) exceeds the threshold wavelength (=343 nm), hence there is no photoelectron emitted. (Accept comparison of threshold frequency as well as the photon energy not being greater than the work function energy of the metal.) Examiner's Comments: Majority of the answers did not show the significance of the light acting as particles. The particulate nature of light could be brought out through the explicit mention of "photon" energy. Answers that mentioned "energy of the wave or light" are not credited as they have not yet shown the understanding of the particulate nature of light.	**M1** **M1** **A1**
	(b)		Fig. 8.1 shows some of the energy levels of helium and neon. The elements are the major constituents in a laser that emits red light.	

			 **Fig. 8.1**	
			Estimate the energy of a photon in the red light region of the visible spectrum	
	L2		Solutions Approximate wavelength of red light = 600nm energy of a red light photon $= hc/\lambda$ $= 6.63 \times 10^{-34} \times 3 \times 10^{8} / 600 \times 10^{-9}$ J energy of a photon in the red light = ……………………J	**M1** **A1** **[2]**
			Examiner's Comments: Many students did not realise that the estimation of energy is to be calculated from the estimation of the wavelength of red light. They were didtracted by the energy level diagrams and attempted to used the energy values to estimate the energy. Surprisingly, many students were not be able to estimate the wavelength of red light correctly.	
	L1		Determine the electronic transition between the labelled energy levels which gives rise to the emission of red laser light.	
			transition from …..……………to ……………	**[1]**
			Solutions Approximate wavelength of red light = 600nm energy of a red light photon $= (6.63 \times 10^{-34} \times 3 \times 10^{8} / 600 \times 10^{-9}) / 1.6 \times 10^{-19}$ eV = 2 eV By inspecting the difference between two energy levels Transition E_6 to E_5 give photon energy of about 2 eV	A1
			Examiner's Comments: For those students who obtained correctly the answer to part 1 were able to convert the energy to eV and deduce that the transition is from level 6 to level 5. However, a few students did not realise that transition from level 5 to level 6 corresponds to absortion of energy.	
	(c)		An electron is travelling with a speed equal to 60% of the speed of light. Assuming that the electron is moving in the *x* direction and that the uncertainty in the measurement of its speed is 0.50%, determine the.	
		(i)	Calculate the uncertinty in the momentum of the electron in the x-direction.	

			uncertainty in momentum = …………………… kg m s^{-1}	**[2]**
	L2		Solutions momentum of the electron in the x direction: $p = mv = 9.11 \times 10^{-31} \times 0.6 \times (3 \times 10^{8}) = 1.64 \times 10^{-22}$ kg m s^{-1} $\frac{\Delta p}{p} = \frac{m\Delta v}{mv} = \frac{\Delta v}{v} = \frac{0.5}{100}$ $\Delta p = \frac{0.5}{100} \text{x} 1.64 \text{x} 10^{-22} = 8.20 \text{ x} 10^{-25} \text{kg m s}^{-1}$ Examiner's Comments: There is a worrying number of answers that gave incorrect physics of accounting for the uncertainty in the momentum. Not only do candidates need to distinguish between absolute uncertainty, fractional uncertainty and percentage uncertainty in a question, they also need to know how to determine the propagation of uncertainty for calculated values.	**M1** **A1**
		(ii)	Calculate minimium uncertainty in the position of the electron along the *x* axis. uncertainty in position = …………………… m	**[2]**
	L2		Solution Applying Heisenberg's uncertainty principle, $\Delta x \Delta p \geq h$ $\Delta x \geq h / \Delta p = 6.63 \times 10\text{-}34 / 8.20 \times 10^{-25} = 8.09 \times 10^{-10}$ m Minimum uncertainty in x = 8.09×10^{-10} m Examiner's Comments: Answers that had no credit were those that did not use the Heisenberg's uncertainty principle. The key phrase "minimum uncertainty" indicates the use of the principle. It is recommended that $\Delta x \Delta p \geq h$ is used rather than h/4π	M1 A1

9			**Read the following passage and answer the questions which follow it.**	
			As early as the late 1950s, there were efforts in developing a solid state battery. Solid state means that the liquids and paste present in the ordinary battery systems are replaced by solid film which cannot leak. This film is sandwiched between a lithium metal anode (positive electrode) and a composite cathode (negative electrode) which is in contact with aluminium foil. (See fig. 11.1) The resultant cell can be constructed so that it has a large electrode area but is less than 0.2 mm thick. It is in many ways similar to a sheet of paper and can be cut and formed into almost any shape. Lithium solid-state cells such as this are rechargeable and can be incorporated into the cases of equipment or into such items as credit cards.	
				
			Fig.9.1	
			Fig. 9.2 shows the variation of the e.m.f. of one lithium solid-state cell with time. During a discharging process, the cell starts off with an initial e.m.f. of 3.4 V but it rapidly falls to about 2.8 V when it is connected across a load. Thereafter, the e.m.f. continues to fall.	
			 **Fig. 9.2**	
			The current density and charge capacity all have to be considered for a particular application.	

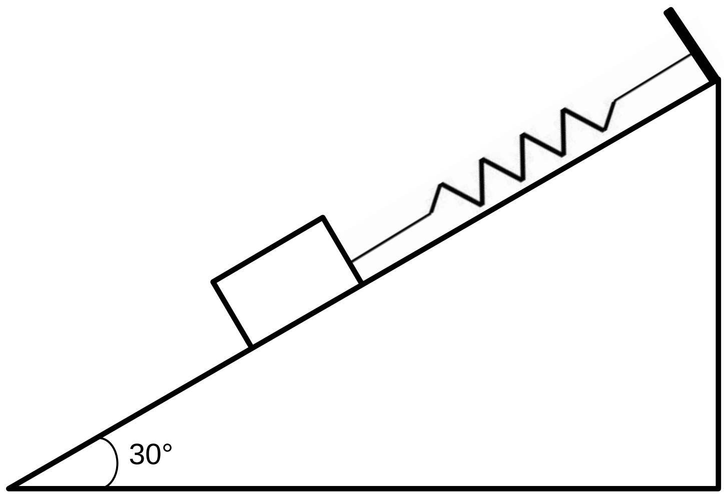
			The recommended maximum value of discharge current density is 0.15 milliamperes per square centimetre of electrode area, the charge capacity is 3.6 coulombs per square centimetre of electrode area, and the energy density is 120 watt-hours per kilogram of cell mass.	
			Questions:	
	(a)		Suggest one possible use of a lithium solid-state cell.	
			…………………………………………………………………………………………………	[1]
	L1		Solutions Pacemakers, electronic devices of low power consumption and low d.c. voltage Handphone,	B1
			Examiner's Comments: It is expected that the students noted that the cell is a d.c. source with low power output. However, quite a number of students stated in the use of heavy power consumption such as cars. Students who stated that the cell is used as a battery without mentioning its application will not gain a credit.	
	(b)		Deduce from the units, the meaning of the terms *current density* and *energy density.*	
			Current density: …………………………………………………………………………… Energy density: …………………………………………………………………………..	[2]
	L1		Solutions Current density : current per unit area of the electrode Energy density : energy per unit mass of the cell	B1 B1
			Examiner's Comments: This question was not well done. The students should be familiar with the relation between the derived units and its derived quantity. However the skill of determining quantity euation from unit equation is yet to be learnt.	
	(c)		For an electrode area 30 cm^2, calculate	
		(i)	the charge-storage capacity of this unit;	
			charge-storage capacity = …………………………C	[1]
	L2		3.6 x 30 = 108 C	B1
			Examiner's Comments: Most students understand the meaning of charge density and its application to find charge	
		(ii)	the recommended maximum value of the discharging current;	

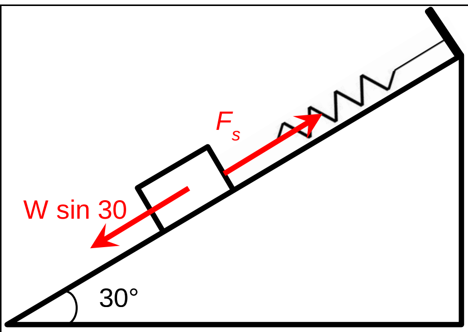
			maximum discharging current = ………………………………mA	[1]
L1			Solutions 0.15 x 30 = 4.5 mA	A1
			Examiner's Comments: Most students understand the meaning of current density and its application to find the current.	
		(iii)	the time for which this cell can supply this maximum current; and	
			time = ………… s	[1]
L2			Solutions Q= I x t 108 = 4.5 x 10^{-3} x t t = 2.4 x 10^{4} s	A1
			Examiner's Comments: Some students did not know that the time taken is actually that can be supplied by the max current. Hence Q = It should be used , where Q is the max charge that supplied I is the maximum current flow	
		(iv)	the energy it supplies in this time, assuming that the e.m.f. has a constant value of 2.5 V.	
			energy supplied = …………………………J	[1]
L2			Solutions IE t = 4.5 x 10^{-3} x 2.5 x 2.4 s x 10^{4} = 270 J	A1
			Examiner's Comments: Some students hesistated in the use of P = IE and P = E/t Some students take 120 W h as the power instead of energy	
	(d)		Design a battery of cells which could produce a current up to 300 mA at a voltage of approximately 10 V. You may illustrate your answer in a circuit diagram. In your answer, specify electrode area of the individual cell.	
			…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………	

				[2]
	L3		Solutions Max current density = 0.15 mA cm^{-2} To get a current of 300 mA Area of electrode = 300/0.15 = 2000 cm^2 To get a p.d. of 10 V Number of cells in series = 10/2.5 = 4 Connected 4 sets of cells in series. OR To get a current of 300 mA Let area of electrode = 30 cm^2 Number of cells in parallel = 300/ 4.5 = 66.6 = 67 To get a p.d. of 10 V Number of cells in series = 10/2.5 = 4 Connected 4 sets of 67 cells in series. The 4 sets of battery of cells then connected in parallel.	A1 A1 A1 A1
			Examiner's Comments: This question was poorly done. Most students left this question blank Students were not familiar with the facts that 1. Cells in series: the total emf is the sum of the individual emf **2.** Cells in parallel generates a current which is the sum of the current in each cell. Without these facts, they were not able to apply them to the question.	
	(e)		Suggest a method to prevent the cell from damage.	
			…………………………………………………………………………………… ……………………………………………………………………………………	[1]
	L2		1. Cell not short circuited 2. Max current not exceeded 3. Working temperature not exceeded 4. No water leakage into the cell. 5. Do not bend the plastic to avoid breakage 6. Any other sensible answers	B1
			Students who stated that the cell is to be covered must state the material used which should be strong and hard and made of electrical insulator) Many suggestions by students were quite trivial without details : Laminate (must state with what) Prevent over-usage (must state not exceeding max current)	

Section C

Answer **one** question from this section

10	**(a)**	Define *simple harmonic motion*.		
		....		**[2]**
	L1	**Solution:** is an oscillatory/harmonic motion in which its **acceleration is directly proportional to its displacement** from the equilibrium position and that the acceleration is always opposite in direction to the displacement. (OR The **acceleration is directed towards the equilibrium position**.) Examiner's Comments: • Majority who attempted this question had the correct definition.		**B1** **B1**
	(b)	A block of mass 1.4 kg is connected to a light spring on a frictionless plane inclined at 30° to the horizontal. The mass is gently lowered until it rests at its equilibrium position as seen in Fig. 10.1. The spring has an unstretched length of 0.45 m and a spring constant of 120 N m^{-1}.  **Fig. 10.1**		
		(i)	Determine the magnitude of the extension of the spring x_1 when the mass is at its equilibrium position.	
			x_1 = ... m	[2]
	L2		**Solution:**	



At equilibrium position, **M1**

A1

$$W \sin 30 = F_s$$
$$mg \sin 30 = kx_1$$
$$x_1 = \frac{mg \sin 30}{k}$$
$$= \frac{(1.4)(9.81)(\sin 30)}{120}$$
$$= 0.057 \text{ m}$$

Examiner's Comments:

- Majority who attempted this question had the correct calculation, although there is a number of candidates who fdid not resolve the restoring force vector correctly.

(ii) The block is pulled slightly down the incline a distance of 5.0 cm and released. As the block approaches the equilibrium position after release, the net force on the mass F_{net} can be expressed by

$$F_{net} = mg \sin 30 - kx$$

where x denotes the total extension of the spring.

1. Show that the block exhibits simple harmonic motion during the subsequent oscillations after release.

[3]

L3

Solution:

M1

$$F_{net} = mg \sin 30 - kx$$
$$ma = mg \sin 30 - k(x_2+x_1)$$
$$= mg \sin 30 - kx_2 - kx_1$$

where x_2 is the displacement of the block from the equilibrium point.

Since

$$mg \sin 30 = kx_1$$

M1

$$ma = -kx_2$$
$$a = -\frac{k}{m}x_2$$

M1

Since $\frac{k}{m}$ is a constant, $a \propto -x_2$

A0

Thus, the subsequent motion is SHM.

Examiner's Comments:

- This question was poorly attempted, with many candidates not knowing how to show a proportionality question – stating that it is the same as that of a linear equation.
- Many stidents calculated one value and used it to prove the relationship.

2. Draw the variation of the kinetic energy of the block with time on Fig. 10.2 if the slope were to be slightly rough.

Starting with the time of release at t = 0 s for at least two cycles.

[2]

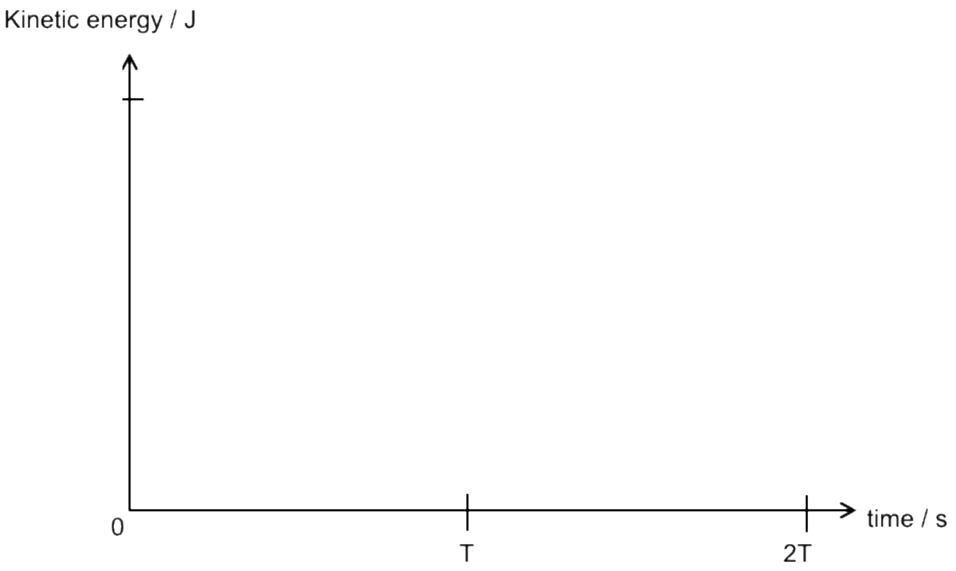
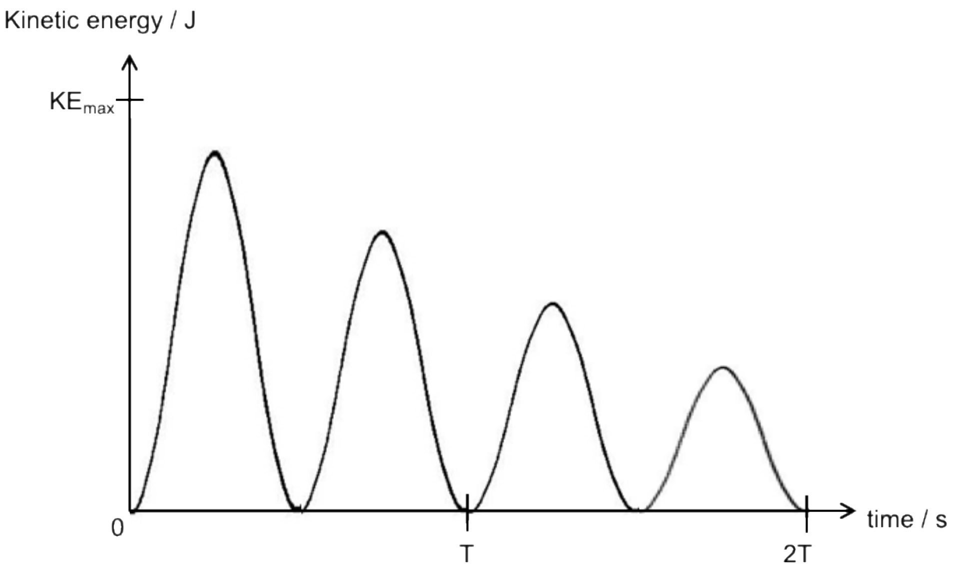


Fig. 2.2

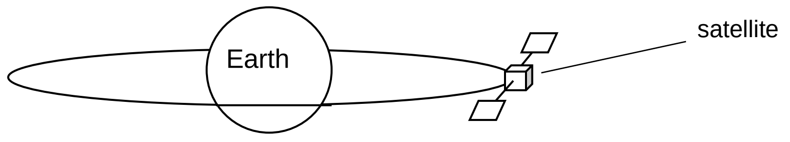
L3

Solution:



1 mark: correct shape
1 mark: correct identification number of cycles within each period
1 mark: decrease of KE over time

			Examiner's Comments: • Majority are cognizant of the smoothness of the curve, but not the other features.	

11	**(a)**	Fig. 11. 1 shows a satellite is in orbit around Earth.		
		 **Fig. 11.1**		
		The satellite orbits at a height of 1000 km above the Earth's surface. The mass of the earth is 6.0 x 10^{24} kg and the radius of the Earth is 6400 km.		
		(i)	Calculate the acceleration of the satellite	
			acceleration of satellite = ……………………… m s^{-2}	[2]
		L2	**Solution:** g = GM/R^2 = $(6.67 \times 10^{-11})(6.0 \times 10^{24}) / (7400\ 000)^2$ = 7.31 ms^{-2} Examiner's Comments: • Candidates must pay attention to the units given in the question. • Candidates must be able to visualize the scenario and deduce that the centripetal force is provided by the gravitational force acted on the satellite due to earth and from the equation solve for the acceleration of the satellite.	M1 A1
		(ii)	Show that the angular speed of the satellite is 9.94 x10^{-4} rad s^{-1}	[2]
	L1		**Solution:** a = R ω^2 7.308 = $(7400\times10^3)\ \omega^2$ ω = 9.9376 x10^{-4} = 9.94 x10^{-4} rad s^{-1} where ω is the angular speed of the satellite R is the orbital distance from the center of the Earth	M1 M1

Examiner's Comments:

- Candidates that failed to gain credit were mainly due to careless mistakes or failing to recall the formula that links angular speed to acceleration of the satellite.

(b) Space tethers are long cables which link two objects that are in orbit together in space. A 10 kg mass attached to the end of a 5.0 km tether is projected from the satellite. When fully extended from the satellite, the tether points towards the centre of the Earth as shown in Fig. 11.2.

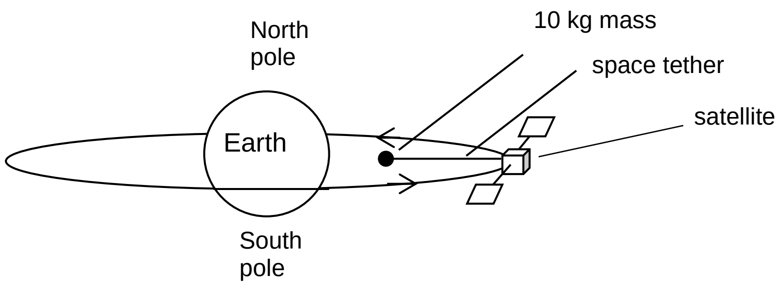


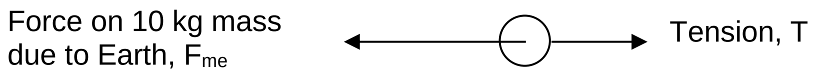
Fig. 11.2

(i) Draw a labelled free body diagram showing the forces acting on the 10 kg mass. The gravitational force on the 10 kg mass by the satellite is negligible.

[2]

L1

Solution:



A1
A1

Examiner's Comments:

- Candidates who failed to gain full credit failed to pay attention to what the question is asking. All forces must be labelled in order for credit to be given. Simply writing down a symbol that is commonly used to indicate for a certain force is NOT sufficient.
- Candidates must also be aware that weight, which is also the gravitational force due to earth is directed towards earth! Therefore, in this scenario, F_{me} must be pointed towards the left and not vertically downwards!

(ii) Assuming that the angular speed of the 10 kg mass is the same as that of the satellite, calculate the tension in the tether.

tension = …………….. N [3]

L2

Solution:

$F_{me} - T = mr\omega^2$ M1

$T = F_{me} - mr\omega^2$ M1

$= (6.67 \times 10^{-11})(6.0 \times 10^{24})(10) / (7395000)^2 - (10)(7395000)(9.94 \times 10^{-4})^2$

$= 0.116$ N A1

Examiner's Comments:

			• This was poorly attempted by majority of the candidates. • For this part, candidates are strongly advised to draw out the system of the earth, 10kg mass, satellite and tether and indicate clearly the distance/seperation apart.	
	(c)	If the tether material is a conductor it will have an e.m.f. induced across it as it passes through the Earth's magnetic field.		
		(i)	Explain why an induced e.m.f will across the tether as it passes through the earth's magnetic field.	
			....	[1]
	L3		**Solution:** As the tether moves across perpendicularly to the Earth's magnetic field, it cuts/sweeps the Earth's magnetic flux. Since there is continuous cutting of the magnetic field by the tether, by Faraday's law, there will be an induced e.m.f across the tether that is proportional to the rate of change of flux linkage. Examiner's Comments: • Candidates need to recall the possible ways in order for e.m.f. to be induced and deduce which one fits into the scenario here. In this case, the tether is sweeping/cutting the magnetic field lines created by the earth.	B1

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Catholic Junior College
JC2 Mid-Year Examinations
Higher 2

CANDIDATE NAME

CLASS **2T**

PHYSICS **9749/04**

Practical Examination

14 May 2018

2 hour

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **ALL** questions.

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 or if you do not use appropriate units or wrong significant figures.

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 end of each question or part question.

Half the candidates will start Questions 1-2 for one hour and the other half on Question 3 for one hour. There will be a changeover after that time and candidates will move to the other Question(s) for one hour.

Shift
Laboratory

For Examiner's Use	
1	/ 16
2	/ 9
3	/ 20
Total	/ 45

This document consists of **16** printed pages and **zero** blank page.

[Turn over

1 In this experiment, you will calculate the amount of charge that flows through a resistor.

(a) **(i)** You are provided with a 1.5 V battery, a component C, a 10 kΩ resistor, two digital multimeters and a switch.

Assemble the circuit of Fig. 1.1.

Ensure that the positive terminal of the battery is connected to the positive terminal of component C.

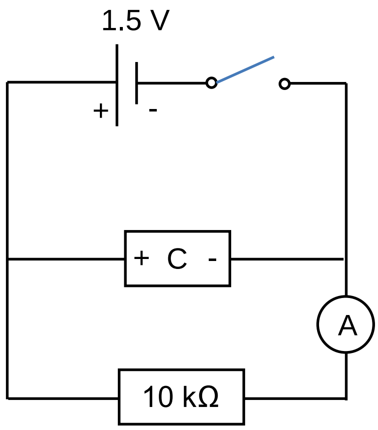


Fig. 1.1

(ii) Close the switch.
Measure and record the electrical current I_0 on the digital mutimeter.

I_0 = ... [1]

Solution:
150.4 μA

Mark Scheme:

- precision to 0.1 μA
- include units

(iii) Estimate the percentage uncertainty in your value of I_0.

percentage uncertainty = ... [1]

Solution:

$\Delta I_0 \geq 0.1 \mu A$

$$\% = \frac{\Delta I_0}{I} \times 100 = \frac{0.1}{150.4} \times 100 = 0.066\%$$

Mark Scheme:

- $\Delta I_0 \geq 0.1$ μA
- Correct calculation of percentage uncertainty
- At most 2 s.f.
- has unit "%"

(iv) *V* is the potential difference across the resistor at the start before opening the switch.

Determine *V* with the use of another digital multimeter.

V = ... [1]

Solution:

1.638 V

Mark Scheme:

- precision to 0.001 V
- include units

(b) When the switch is opened, the current in the resistor will gradually decrease to zero with time.

In this experiment, you are required to determine how the current in the resistor changes with time.

(c) Open the switch and start the stopwatch simultaneously.

Measure and record the current I in the resistor at suitable times t up to a value of t = 60 s, while the switch remains open. Include t = 0 s in your table of measurements.

You may need several attempts before you have a satisfactory set of results.

[5]

Solution:

t / s	**I_1 / μA**	**I_2 / μA**	**$\langle I \rangle$ / μA**
0.0	150.4	150.4	150.4
10.0	93.2	93.8	93.5
20.0	59.9	59.0	59.5
30.0	38.2	37.4	37.8
40.0	24.4	22.4	23.4
50.0	15.3	15.1	15.2
55.0	12.0	12.0	12.0
60.0	10.0	9.9	10.0

Mark Scheme:

- Each column heading contains an appropriate quantity and unit. Quantity and unit are distinguished with a solidus. (1 mark)
- Consistency of no. of d.p. for time reading, to 0.1 s. (1 mark)
- Consistency of no. of d.p. for current reading, to 0.1 μA (1 mark. Allow ecf from (a) and (b), but mark for consistency)
- Methods (2 marks)
  - At least 8 sets of readings with t = 0.0 s (2 marks)
  - At least 7 sets of readings with t = 0.0 s (1 mark)
  - At least 8 sets of readings without t = 0.0 s (1 mark)
  - Others (0 mark)
  - -1 if student requires some assistance in the data collection
  - -2 if student requires full assistance to collect data

(c) Plot your values from **(b)(i)** on Fig. 1.2.

Draw a line of best-fit of plotted points in Fig. 1.2. The graph obtained should be a curve.

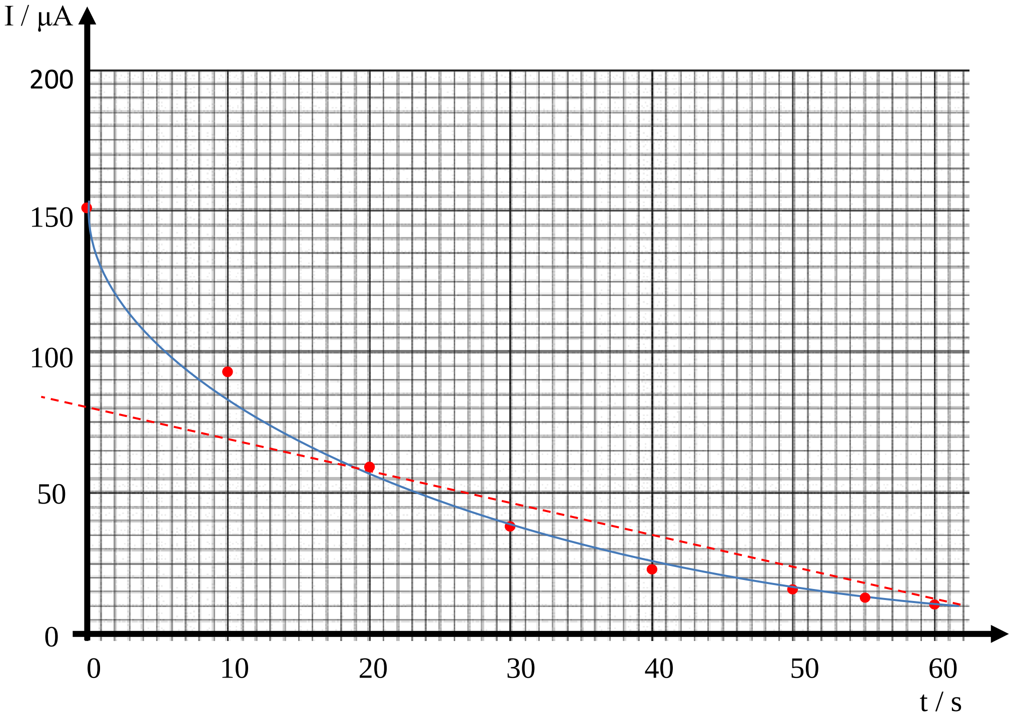


Fig. 1.2

[2]

Mark Scheme:

- Plot at least 3 data points accurately to ½ the smallest division, all data points plotted. (1 mark)
- Good scatter of points about the line of best fit. (1 mark)

(d) Estimate the amount of charge *Q* that has flowed through the resistor during the 60 s from your graph in **(c).**

Q = ... [3]

Solution:

Method 1: Count Squares

Method 2: Draw Straight Line

The total amount of charge Q during the 60 s is represented by the area under the current-time graph.

Estimated area:

$$Q = \frac{1}{2}(80 + 13)(10^{-6})(60) = 2.79 \times 10^{-3}\ \text{C}$$

Mark Scheme:

- Method (1 mark)
  - Evidence of determining *Q* from the area under graph.
- Accuracy (1 mark)
  - Correct determination of Q, ± 250 C variance
- Presentation (1 mark)
  - Includes unit
  - Presented to 3 s.f.

(e) State one significant source of error or limitations of taking the readings for this experiment. Give a reason.

.... [1]

Solution:
It is difficult to read off the stopwatch timing and the ammeter **reading simultaneously** with just our bare eyes, thus affecting the readings of t and I significantly.

The change in the current is too fast such that the reading on the ammeter might not be reading the exact current at the exact time.

Mark Scheme:
- 1 mark for each reasonable sources of error

(f) State one improvement that could be made to this method of determining Q using other equipment or components.

[1]

Solution:
Use a current sensor connected to a datalogger to log in the time and current, t and I, simultaneously.
(The reason for using datalogger is to log in timing simultaneously for post experiment analysis)

Mark Scheme:
- 1 mark for the improvement suggested to answer the sources of error identified in (e).

(g) Theory suggests that the total charge that flows through the resistor $Q = kV$ where V is the potential difference across the resistor at the start before opening the switch, and k is a constant equal to 2.2×10^{-3} CV^{-1}.

Determine Q using the answer obtained in **(a)(iv).**

$Q =$ .... [1]

Solution:
$Q = kV$

$Q = 2.2 \times 10^{-3}(1.638) = 3.60 \times 10^{-3}$ C

Mark Scheme:
- Correct calculation of Q
- 3 s.f.
- Include unit

[Total:14 marks]

2 When scientists were thinking about measuring temperature, they reasoned that if they mixed equal volumes of water at 0 °C and 100 °C, the final temperature of the mixture would be 50 °C, as illustrated in Fig. 2.1.

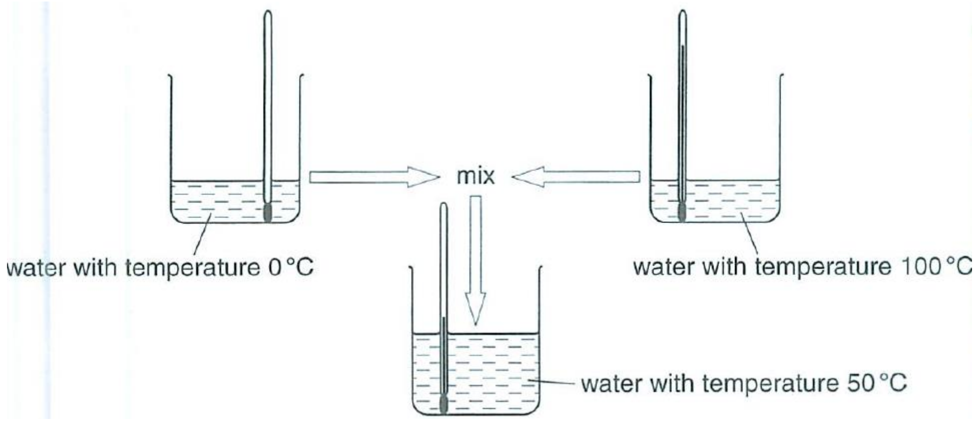


Fig. 2.1

In the eighteenth century, scientists did not know which liquid to use in their thermometers. One physicist, De Luc, performed this experiment testing several liquid-in-glass thermometers and concluded that mercury was the most satisfactory.

You are going to perform a similar experiment using the cold water in the beaker provided and hot water from the kettle.

In this experiment, you will measure the final temperature of a mixture of two equal volumes of water.

(a) Measure and record the temperature of the cold water.

temperature of the cold water = [1]

Solution:

30.0 °C

Mark Scheme:

- precision to 0.1 °C
- include unit

(b) State the volume of hot water that you will need.

volume = ...

Solution:

50 cm^3

Mark Scheme:

- precision to 1 cm^3
- include unit

(c) Carefully pour this volume of hot water from the kettle into an empty beaker.

Measure and record the temperature of this hot water.

temperature of the hot water = ...

Solution:

70.0 °C

Mark Scheme:

- precision to 0.1 °C
- include unit

(d) Carefully mix the hot water and cold water into the plastic cup.

Measure and record the final temperature of the mixture of water.

final temperature = ... [1]

Solution:

48.0 °C

Mark Scheme:

- precision to 0.1 °C
- include unit

(Marks to share with 2(a). 1 mark in 2(a) is not awarded if the temperature of hot water is not represented correctly.)

(e) Calculate the expected final temperature of the mixture.

calculated final temperature = ... [1]

Solution:

Expected temperature = (70.0+30.0) / 2 = 50.0 °C

Mark Scheme:

- Correct calculation of the final temperature.
- 3 s.f.
- include units

(f) The values of **(d)** and **(e)** should be different. One of the reasons is due to the thermal energy loss during the mixing of the hot and cold water.

Suggest another reason why the values in **(d)** and **(e)** are different.

[1]

Solution:

The masses for the hot water and cold water used might be different as there exist a large uncertainty when reading off volume from a beaker, which has an absolute uncertainty.

Temperature difference is high.

Mark Scheme:

- 1 mark for the improvement suggested to answer the sources of error identified in (e).

(g) In order to account for the thermal energy loss, one theory suggests that

$$100m_H = (m_H + m_C)T - \frac{h}{c}$$

where m_H is the mass of hot water used at initial temperature of 100 °C, m_C is the mass of cold water used at initial temperature of 0 °C, T is the temperature after mixing the water, h is the thermal energy loss which is a constant for a fixed time duration of mixing and c is the specific heat capacity of water which is a known constant.

Plan an investigation to determine the thermal energy loss after mixing the cold water at 0 °C and hot water at 100 °C.

You are provided with water at room temperature and apparatus generally found in a science laboratory.

Your account should include:

- your experimental procedure;
- details of measurements with appropriate units;
- how you would find the thermal energy loss for 30 s after mixing the cold and hot water.

[5]

Solution:

1. Heat water to boiling using a Bunsen Burner and a tripod stand. Stir the water with a stirrer to ensure homogeneous heating.
2. Cool water to melting point in a beaker using an ice and water bath.
3. Measure the volumes of hot water at 100 °C and cold water at 0 °C using respective measuring cylinders.
4. Quickly transfer the hot water and cold water into separated insulated container with a lid, to minimise heat loss to the surrounding.
5. Measure the hot water temperature T_H and cold water temperature T_C using a mercury-in-glass thermometer respectively. Record the temperatures.
6. Mix the hot water and cold water in a separate insulated container with a lid. Cover the mixture immediately after the mixing. Start a

stopwatch and measure the temperature of the mixture with a thermometer at the same time.

7. When the stopwatch shows 30 s, read off the temperature T of the mixture from the thermometer.
8. Repeat step 1 to 5 to obtain another set of temperatures of hot water, cold water and the equilibrium temperature of the mixture after 30 s.
9. The table of measurements are as follow,

m_H / kg	m_C / kg	T / °C

10. $100m_H = (m_H + m_C)T - \frac{h}{c}$

$$100cm_H = (m_H + m_C)cT - h$$

$$h = (m_H + m_C)cT - 100cm_H$$

with 2 sets of data, calculate for *h* and take an average value of the heat loss.

Mark Scheme:

1 mark – methods of heating water and cooling water to 100 °C and 0 °C respectively with the appropriate apparatus

1 mark - method for measuring volume with appropriate instruments

1 mark - method for measuring temperature with appropriate instruments

1 mark - method of determining / calculating h with evidence of repeated readings.

1 mark – additional details or indication of addressing better precision and accuracy such as the evidence of controlled variable

[Total:9 marks]

3 In this experiment, you will time the oscillations of a loaded spring.

(a) **(i)** You are provided with a metre rule which has a 300 g slotted mass attached at the 50 cm mark and a string loop tied to one end of a spring.

Set up the apparatus as shown in Fig. 3.1.

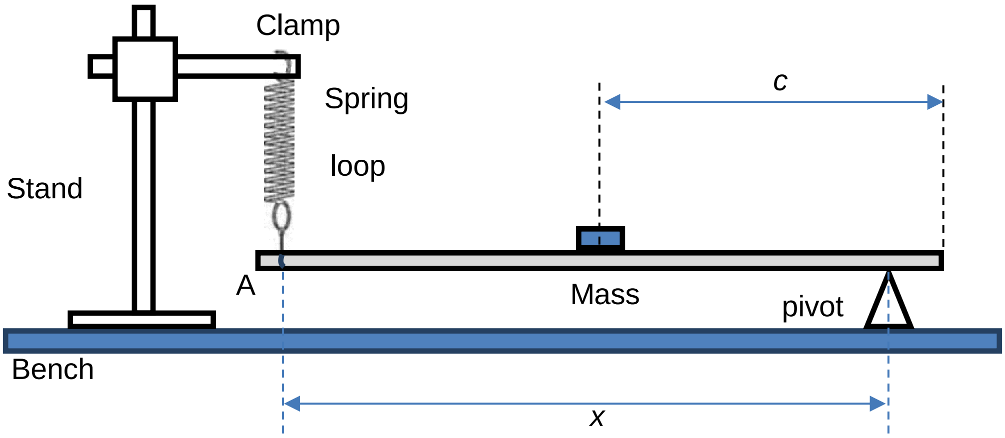


Fig. 3.1

The string loop should be secured at 1 cm from one end of the metre rule.

(ii) Adjust the position of the pivot such that the distance between the pivot and the other end of the metre rule is about 5 cm.

(b) Adjust the clamp so that the metre rule is horizontal and the spring is vertical.

Measure and record the distance x between loop and the pivot as shown in Fig. 3.1.

x = ... [1]

Solution:
94.0 cm
Mark Scheme:
- precision to 0.1 cm
- include unit

(c) **(i)** c is the distance between the attached mass and the end of the metre rule as shown in Fig. 3.1.

Calculate and record L, where $L = x - c$.

L = ... [1]

Solution:
$L = x - c$
$L = 94.0 - 50 = 44.0$ cm
Mark Scheme:
- Correct determination/calculation of L
- precision to 0.1 cm
- include unit

(ii) Estimate the percentage uncertainty in your value of L.

percentage uncertainty = ... [1]

Solution:

$\Delta L \geq 0.2$ cm

$$\% = \frac{\Delta L}{L} \times 100 = \frac{0.2}{44.0} \times 100 = 0.45\%$$

Mark Scheme:

- $\Delta L \geq 0.2$ cm
- Correct calculation of percentage uncertainty
- At most 2 s.f.
- has unit "%"

(d) Gently depress end A of the metre rule and allow it to oscillate.

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

T = ... [1]

Solution:

For 30 oscillations, total time, t_{30},

$t_{30,1} = 12.8$ s

$t_{30,2} = 12.8$ s

$$\langle t \rangle = \frac{t_1 + t_2}{2} = \frac{12.8 + 12.8}{2} = 12.8 \text{ s}$$

Mark Scheme:

- each raw timing t_n taken to be more than 10 s
- s.f. of *T* to follow the s.f. of $\langle t_n \rangle$

(e) Move the position of the pivot and repeat **(b)**, **(c)** and **(d)** for values of *x* such that *x* > c.

[7]

Solution:

x / cm	n	$t_{n,1}$ / s	$t_{n,2}$ / s	<t> / s	T / s	*L* / cm	T^2L / s^2 m	L^2 / m^2
94.0	30	12.8	12.8	12.8	0.427	44.0	0.0802	0.194
91.0	30	12.4	12.4	12.4	0.413	41.0	0.0699	0.168
89.0	30	12.2	12.1	12.2	0.407	39.0	0.0646	0.152
86.0	30	11.8	11.8	11.8	0.393	36.0	0.0556	0.130
84.0	30	11.5	11.4	11.5	0.383	34.0	0.0499	0.116
79.0	35	12.2	12.6	12.4	0.354	29.0	0.0363	0.0841

Mark Scheme:

- Each column heading contains an appropriate quantity and unit. Quantity and unit are distinguished with a solidus. (1 mark)
- Consistency of no. of d.p. for time reading, to 0.1 s. (1 mark. Allow ecf from (d) but mark for consistency)
- Consistency of no. of d.p. for length reading, to 0.1 cm (1 mark. Allow ecf from (c) but mark for consistency)
- Consistent least s.f. of calculated values, T, T^2L and L^2 according to the least s.f. of raw measurements
- Calculate T^2L and L^2 correctly. Allow at most 2 slips in calculation.
- Methods (2 marks)
    - At least 6 sets of readings without assistance (2 marks)
    - At least 5 sets of readings without assistance (1 mark)

- Other number of sets of readings (0 marks)
- -1 if student requires some assistance in the data collection
- -2 if student requires full assistance to collect data

(f) It is suggested that *T* and *L* are related by the expression

$$T^2L=PL^2+Q$$

where *P* and Q are constants.

Plot a suitable graph to determine the values of *P* and *Q*.

P = ...

Q = ... [4]

Solution:

Plot a graph of T^2L against L^2. A straight line graph with gradient P and y-int Q is expected.

Gradient = $\dfrac{0.0890-0.0375}{0.216-0.086}=0.4023$

Hence, P = 0.402 $s^2\ m^{-1}$

Taking point (0.216, 0.0890),

$$Q=0.0890-0.402\times0.216=0.002168$$

Hence, Q = 0.00217 s^2 m

Mark Scheme:

- 1 mark - Gradient correctly determined. Read of ½ smallest division accuracy, hypotenuse of gradient triangle to be more than ½ of the line of best fit.
- 1 mark - vertical intercept read off or calculated correctly.
- 1 mark - Correct linearization of the equation. (be it seen in graph or relating P and Q to the gradient and y-int of the line of best fit drawn)
- 1 mark - correct calculations of P and Q, as well as correct unit of P and Q. (1 mark)

(g) Comment on any anomalous data or results that you may have obtained. Explain your answer.

....

....

.... [1]

Solution:

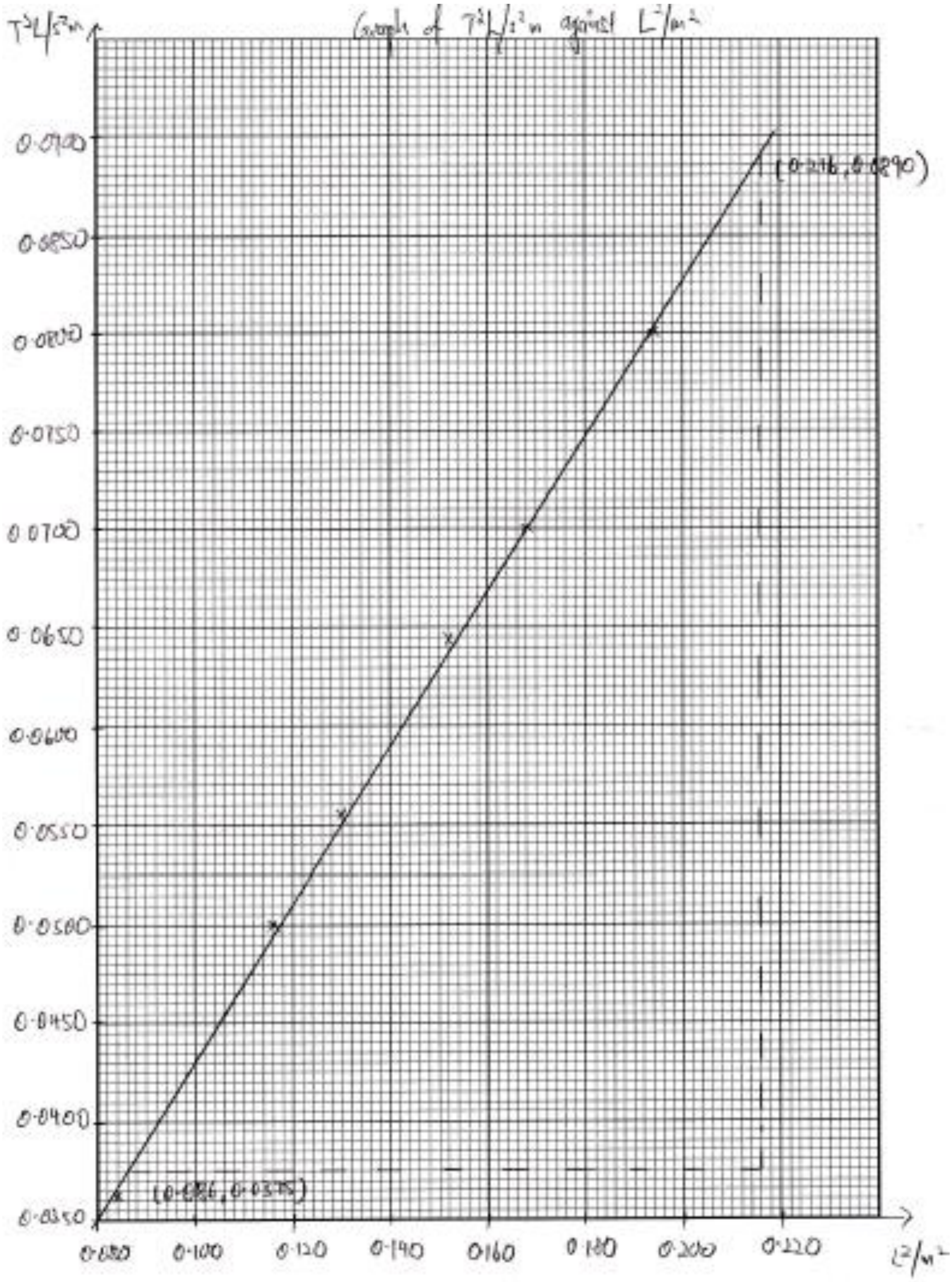
There is no anomalous data as none of the points are out of trend from one another and there is a good scatter of points about the line of best fit.

OR

The data points (x_1, y_1) is an anomalous data as this point is out of trend with the rest of the points.

Mark Scheme:

- Appropriate identification of anomalous data.
- At most two anomalous points



Mark Scheme:

- Good line of best fit with good scatter of plotted points. [3]
- Plot at least 3 data points accurately to ½ the smallest division, all data points plotted. (1 mark)

- Appropriate scale. Odd scales are not allowed and scale to allow plotted points to cover at least ½ of the graph paper provided.

(h) (i) Determine a value for *k*, where $k = \sqrt{\dfrac{Q}{P}}$.

$k =$ .... m [1]

Solution:

$$k = \sqrt{\frac{Q}{P}} = \sqrt{\frac{0.00217}{0.402}} = 0.232\,\text{m}$$

Mark Scheme:

- Correct determination of *k* according to the unit m provided.
- 3 s.f.

[Total: 20 marks]

– END OF PAPER –