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)

	Class	Reg No
Candidate Name: ______________________		

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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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
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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

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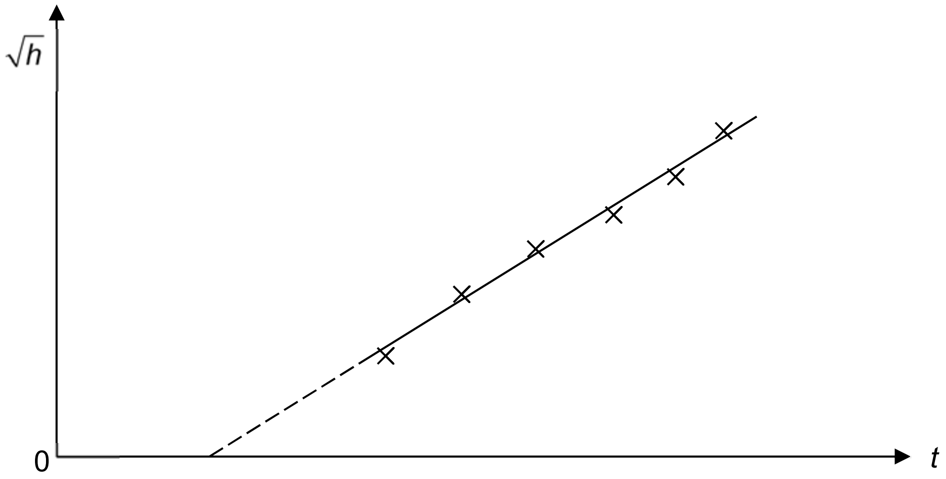

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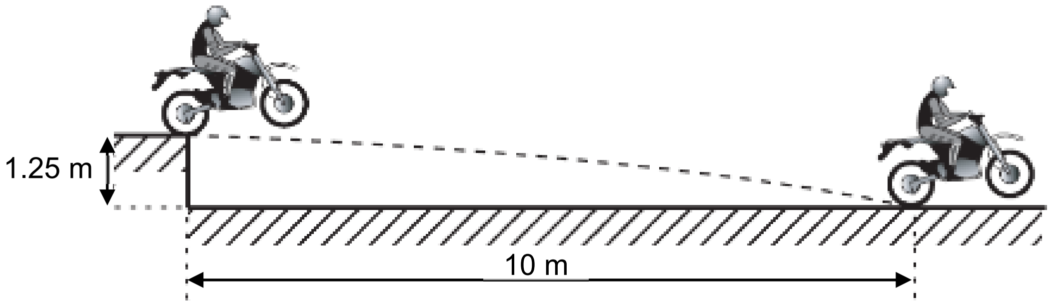
2 The experimental measurement of the heat capacity of a solid as a function of temperature *T* is found to fit the following expression

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

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?

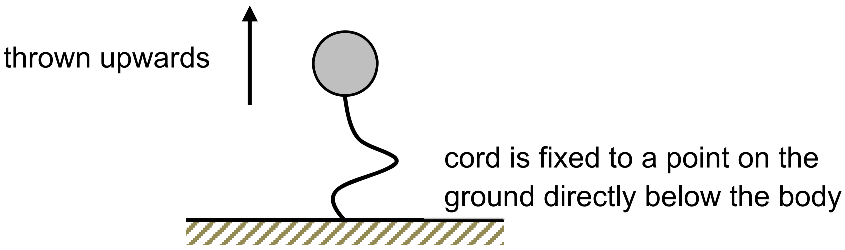
A zero **B** 17 kg m s^{-2} **C** 29 kg m s^{-2} **D** 33 kg m s^{-2}

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?

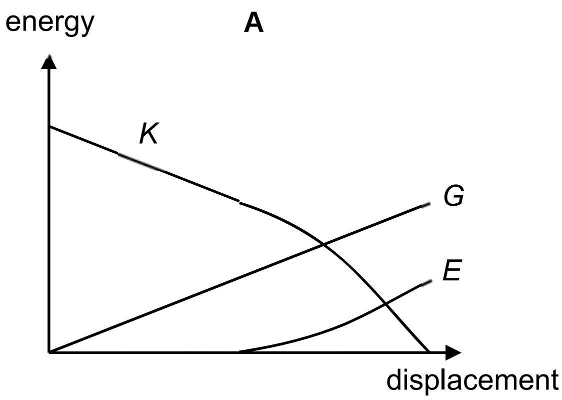
	velocity of P after collision	velocity of Q after collision
A	+0.5 m s^{-1}	+0.5 m s^{-1}
B	+0.0 m s^{-1}	+3.0 m s^{-1}
C	–1.0 m s^{-1}	+2.0 m s^{-1}
D	–0.6 m s^{-1}	+1.8 m s^{-1}

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.

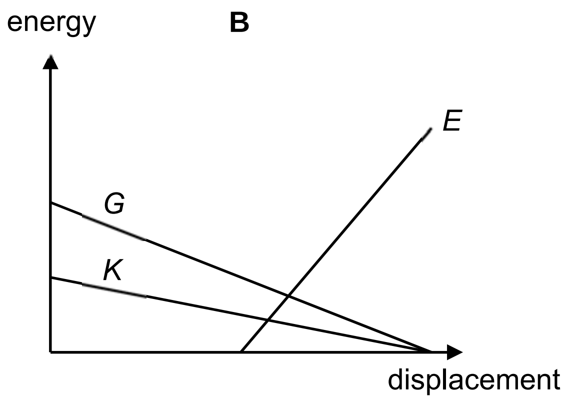


Which of the following shows the variation with displacement of the kinetic energy *K*, gravitational potential energy *G* and elastic potential energy *E*?

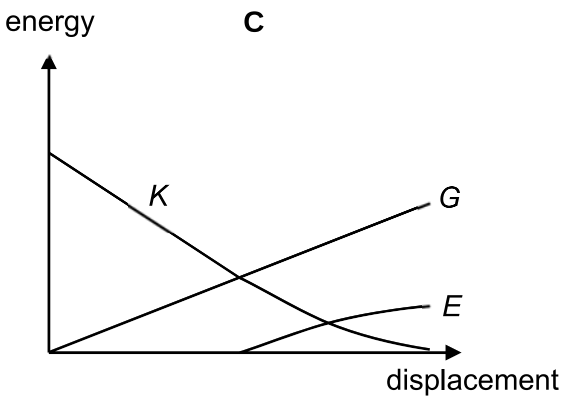
A



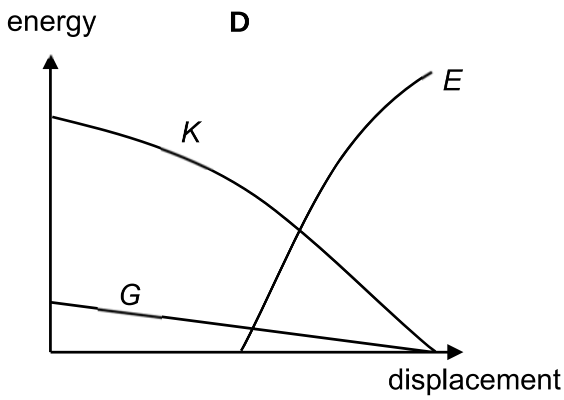
B



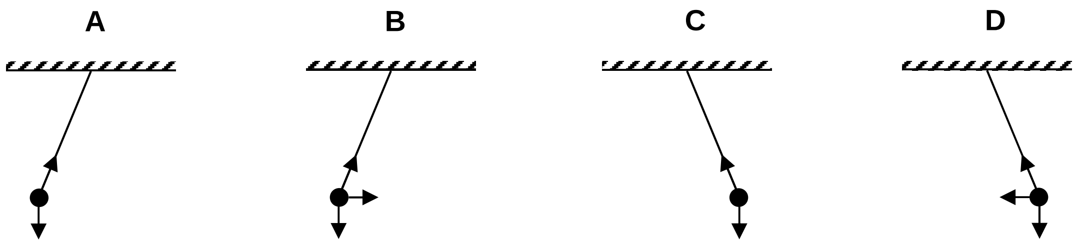
C



D



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

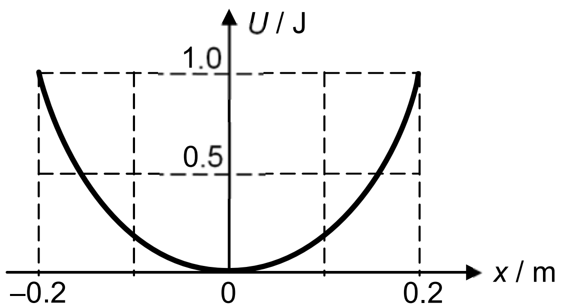
A $S_1 = S_2$ and $M_1 = 0.25\ M_2$

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.



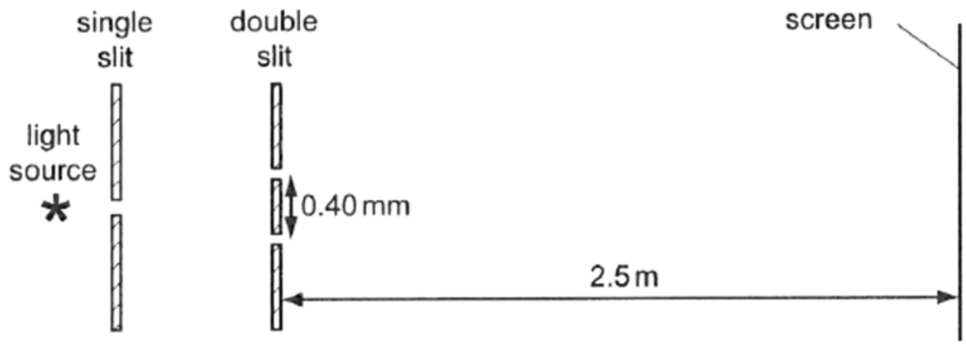
What is the period of oscillation of the mass?

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

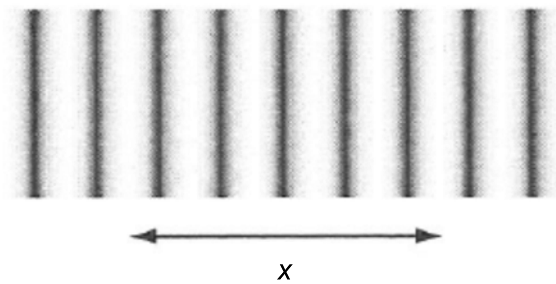
10 A toy car moving along a horizontal plane in simple harmonic motion starts from the amplitude at time t = 0 s. If the amplitude of its motion is 5.0 cm and frequency is 2.0 Hz, the magnitude of the acceleration of the toy car at 1.7 s is

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.



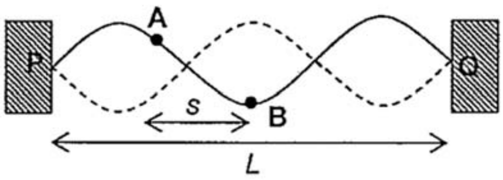
The source emits light of wavelength 600 nm. The interference pattern on the screen is shown below.



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.

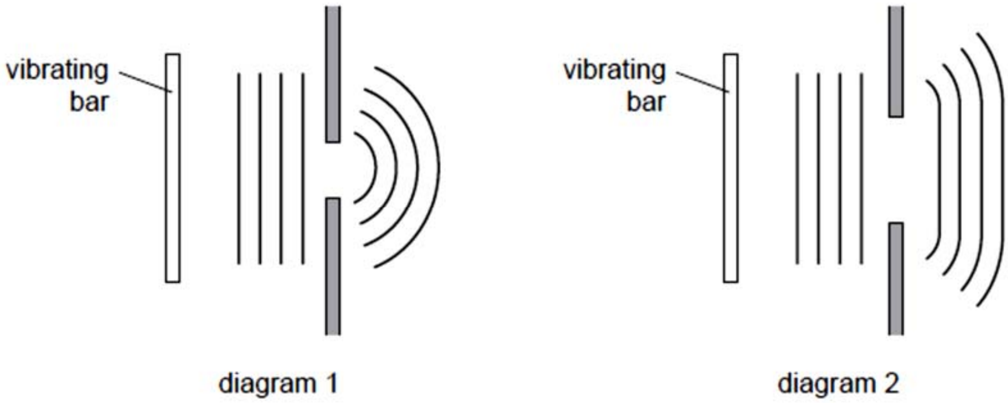
Which of the following gives the correct phase difference and maximum kinetic energies of the particles?

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

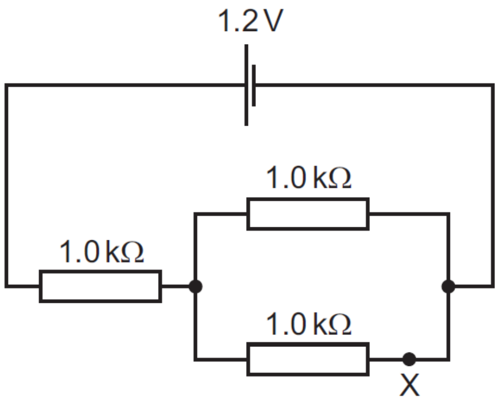
D 450 V m^{-1} towards P

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*

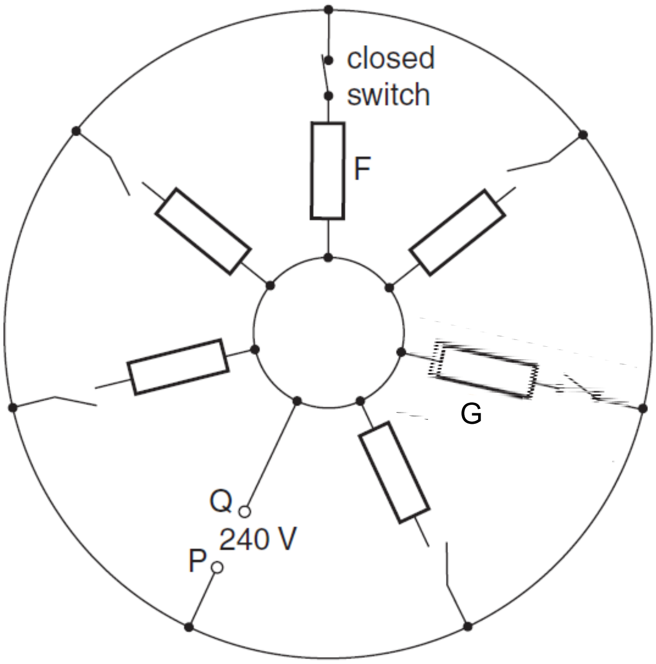
20 In the circuit below, 3 identical resistors of resistance 1.0 kΩ are connected to a cell of 1.2 V with negligible internal resistance as shown.



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.

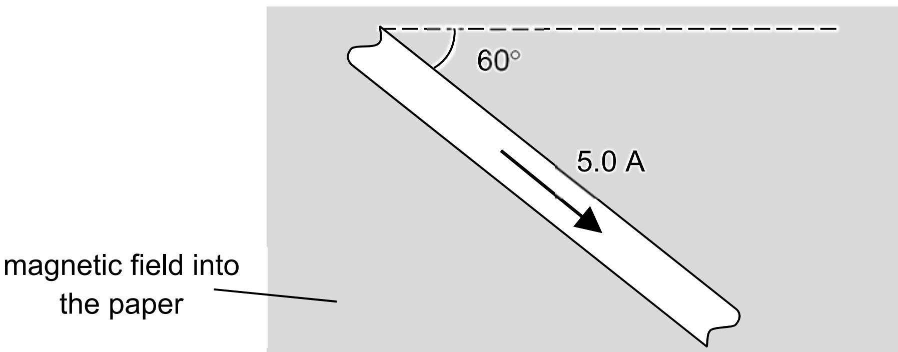


Two devices, F and G, are currently switched on. They have resistances of 1200 Ω and 1700 Ω respectively.

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?

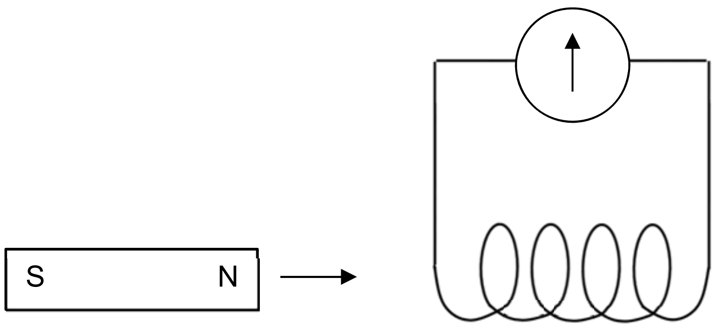
A No force acts on the electron.

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

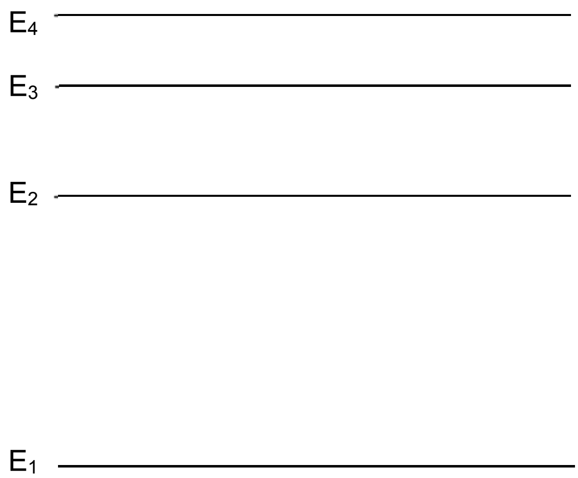
D more than 10 units to the right

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"?

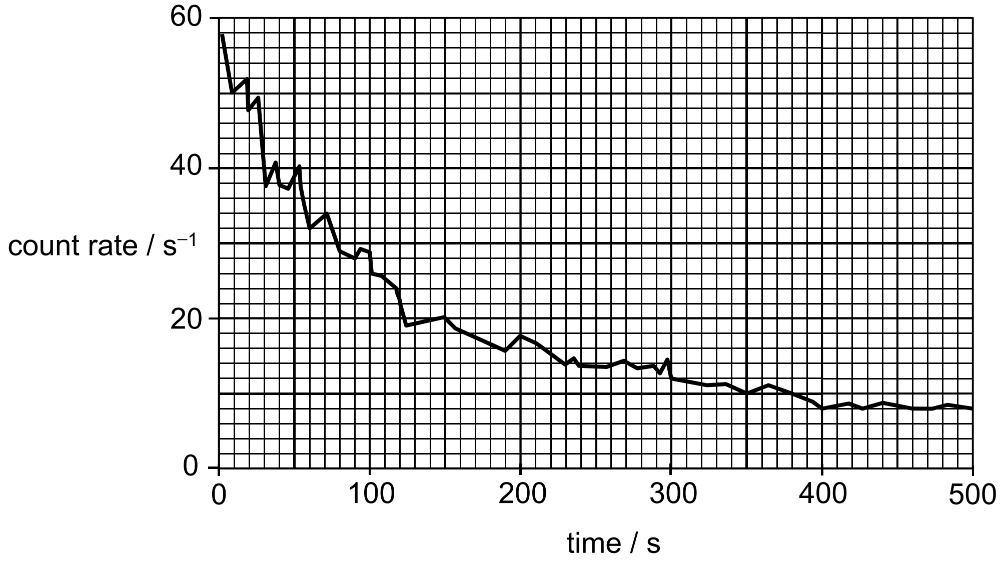
${}^{28}_{8}O$	${}^{40}_{20}Ca$	${}^{56}_{26}Fe$	${}^{50}_{28}Ni$	${}^{126}_{50}Sn$

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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1 hour

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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	=	$v_o \cos \omega t$
	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	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
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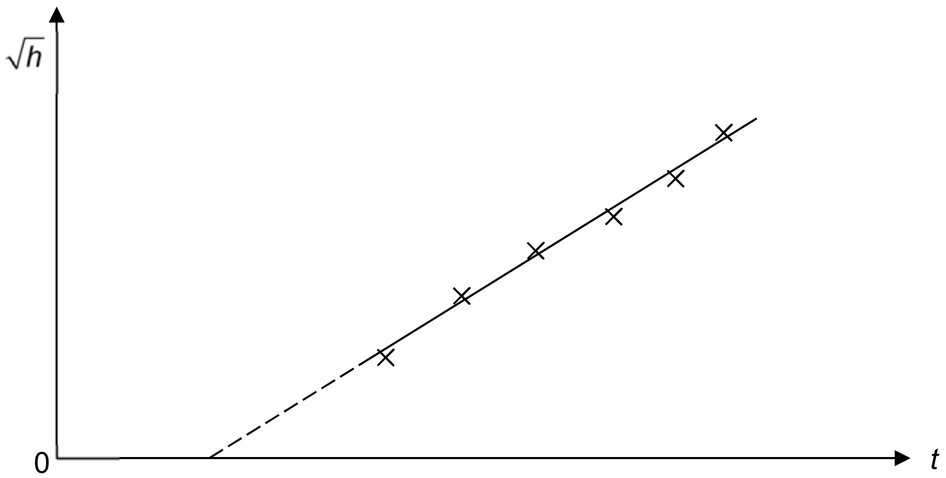
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

[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

1 A student measures the time *t* for a ball to fall from rest through a vertical distance *h*. The student plots his results and best-fit line in the graph shown.



Which of the following statement is true?

A The result is accurate as the line is close to the data points

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)

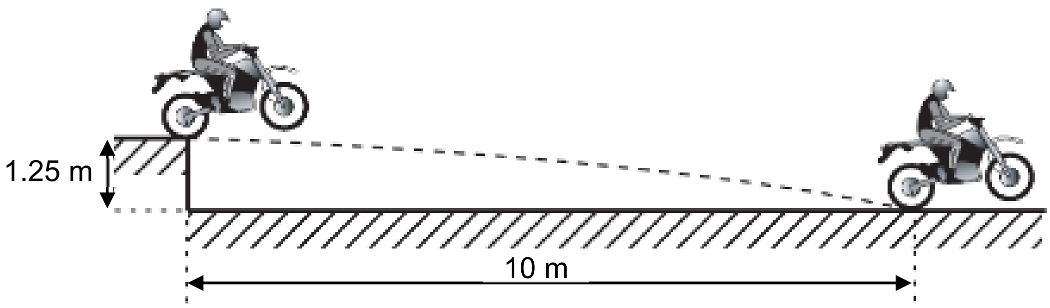
$C = \alpha T^3 + \beta T$

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

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

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

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

$\downarrow s_y = u_y t + ½ a_y t^2 \Rightarrow 1.25 = 0 + ½ (9.81) t^2 \Rightarrow t = 0.50$ 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 × 20 sin 60°) / 1.8 = –29 kg m s^{-2}

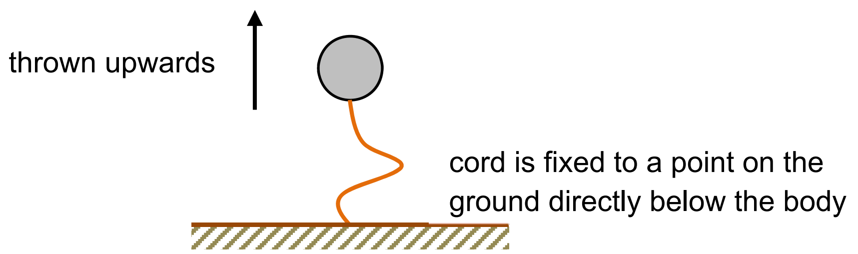
5 A body P of mass 2.0 kg and moving with velocity +3.0 m s^{-1} makes a head-on inelastic collision with a stationary body Q of mass 4.0 kg.

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

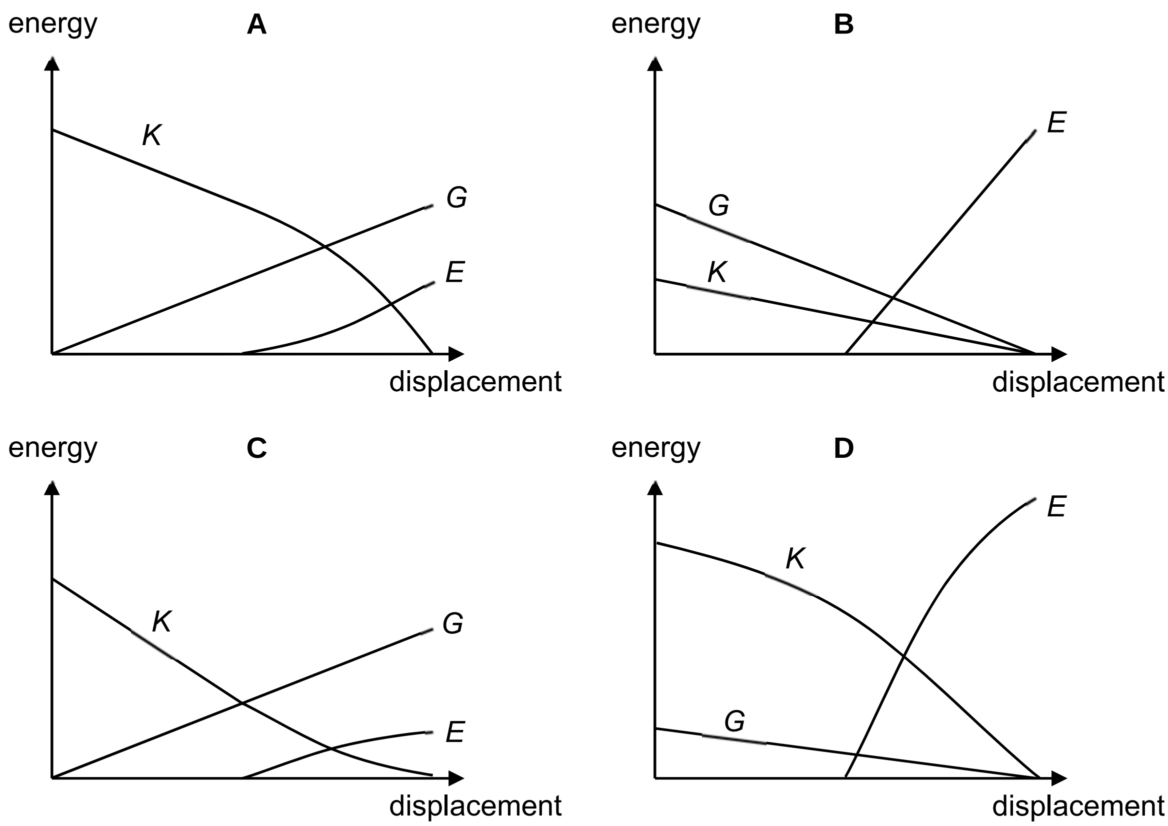
	velocity of P after collision	velocity of Q after collision
A	+0.5 m s^{-1}	+0.5 m s^{-1}
B	+0.0 m s^{-1}	+3.0 m s^{-1}
C	–1.0 m s^{-1}	+2.0 m s^{-1}
D	–0.6 m s^{-1}	+1.8 m s^{-1}

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.

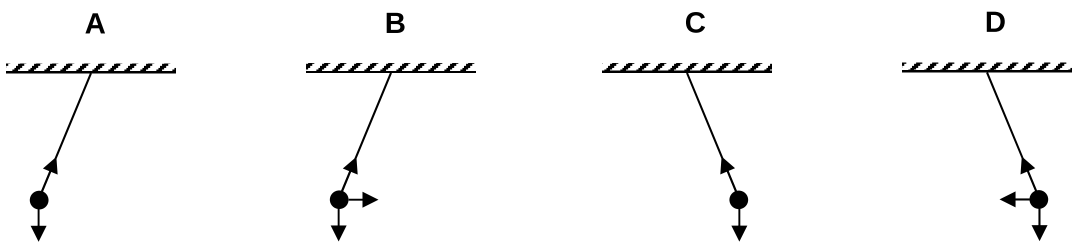


Which of the following shows the variation with displacement of the kinetic energy *K*, gravitational potential energy *G* and elastic potential energy *E*?



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 $M_1 = 0.25\,M_2$

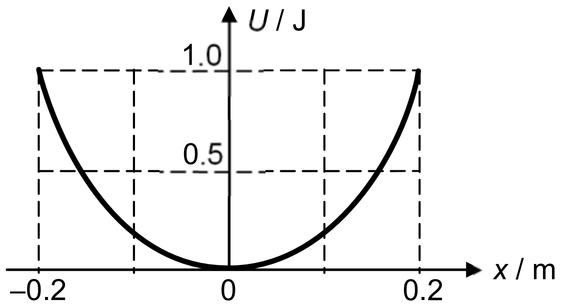
B $S_1 = 4S_2$ only

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

Ans B

Total energy of system is constant.

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

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

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

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

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

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

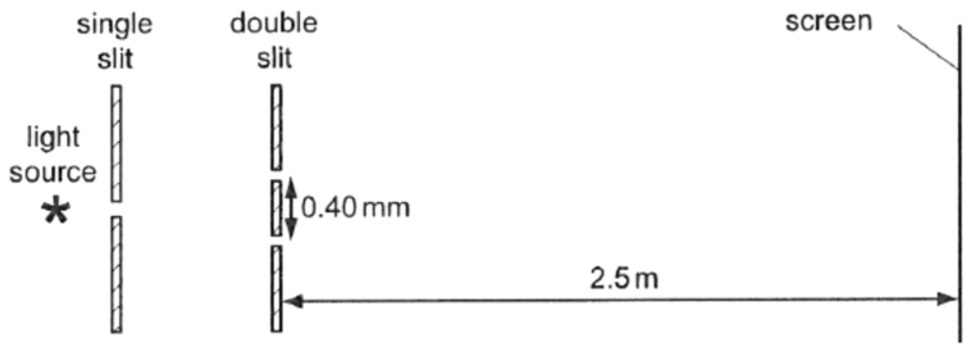
10 A toy car moving along a horizontal plane in simple harmonic motion starts from the amplitude at time *t* = 0 s. If the amplitude of its motion is 5.0 cm and frequency is 2.0 Hz, the magnitude of the acceleration of the toy car at 1.7 s is

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

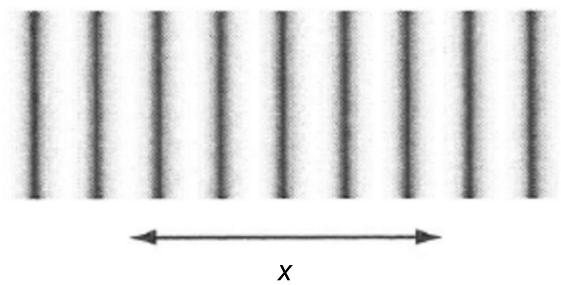
Ans C

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

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*?

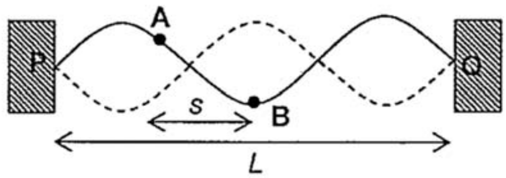
A 3.8×10^{-4} m **B** 1.9×10^{-3} m **C** 3.8×10^{-3} m **D** 1.9×10^{-2} m

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?

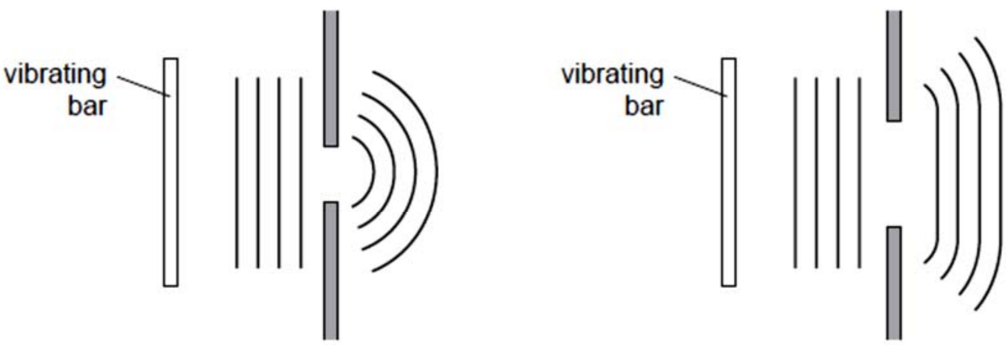
	Phase difference	Maximum kinetic energy
A	$\left(\frac{3s}{2L}\right)\times 360°$	$K_A < K_B$
B	$\left(\frac{3s}{2L}\right)\times 360°$	same
C	180°	$K_A < K_B$
D	180°	same

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.



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 m³ has a pressure of 3.0 x 10⁵ 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 10⁵ Pa and at a room temperature of 300 K?

A 0.500 m³ **B** 2.00 m³ **C** 2.25 m³ **D** 4.50 m³

Ans C

$$n_1 = \frac{p_1V_1}{RT_1} = \frac{3.0\times10^5(1)}{8.31(200)} = 180.5 \text{ mol}$$

$$n_2 = \frac{p_2V_2}{RT_2} = \frac{3.0\times10^5(1)}{8.31(400)} = 90.25 \text{ mol}$$

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

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

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*

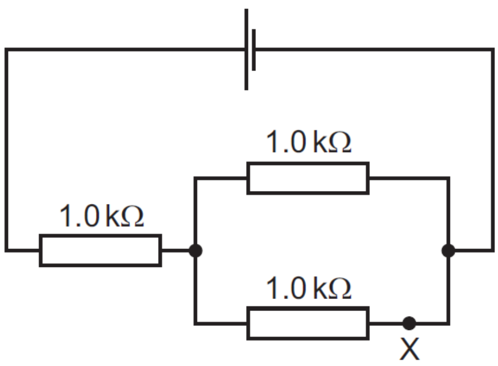
Ans: D
Since volume remains constant,

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

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

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

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

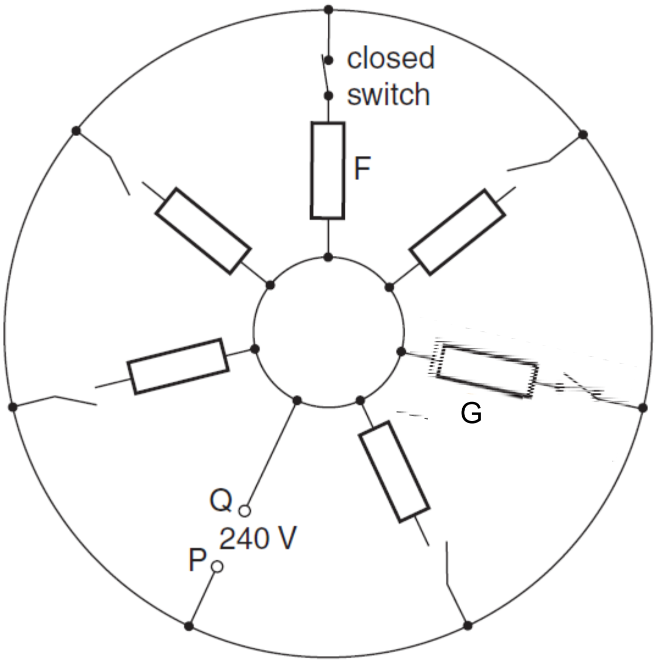
$$V_{parallel} = \frac{0.5}{1.5}(1.2) = 0.4 \text{ V}$$

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

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

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

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

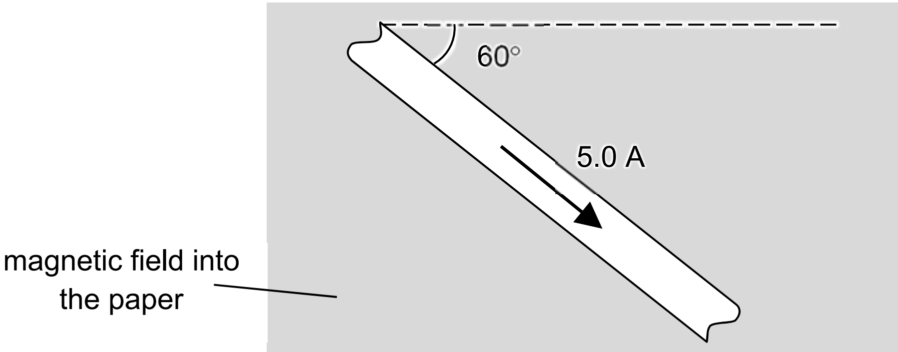
Ans: D
F and G are connected in parallel to the power supply.

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

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

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

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.

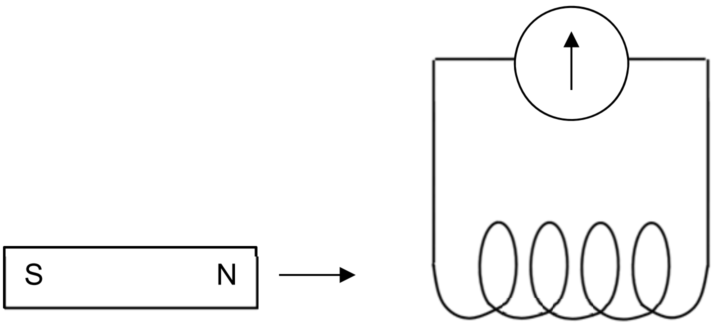
B The force acts in the direction of motion.

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

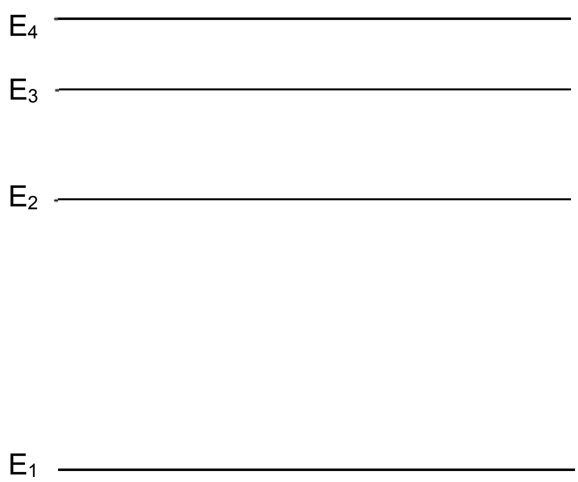
alt: $V_s = RI = 10 \times 1.5 = 15$ V

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

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

$= 4.5$ 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, $E = \frac{hc}{\lambda}$ 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)

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

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

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

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

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

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)

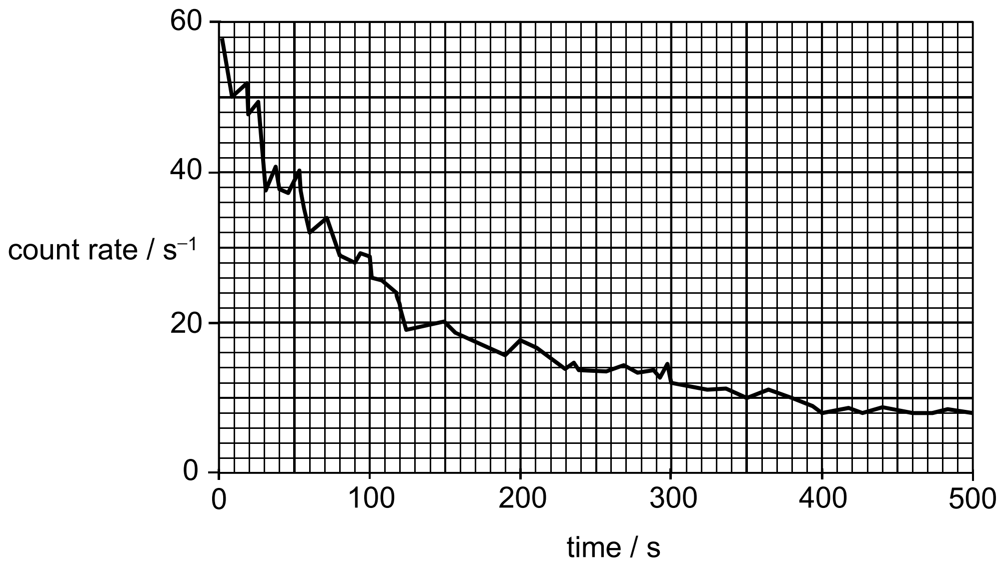
$^{126}_{50}Sn$: 50 protons, 76 neutrons (not)

29 Radon-222, ${}^{222}_{86}\text{Rn}$ decays to Lead-210, ${}^{210}_{82}\text{Pb}$ 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 ${}^{214}_{82}\text{Pb}$ **B** ${}^{214}_{83}\text{Bi}$ **C** ${}^{218}_{84}\text{Po}$ **D** ${}^{216}_{85}\text{At}$

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}
		=	$\left(1/(36\pi)\right) \times 10^{-9}$ 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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
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.

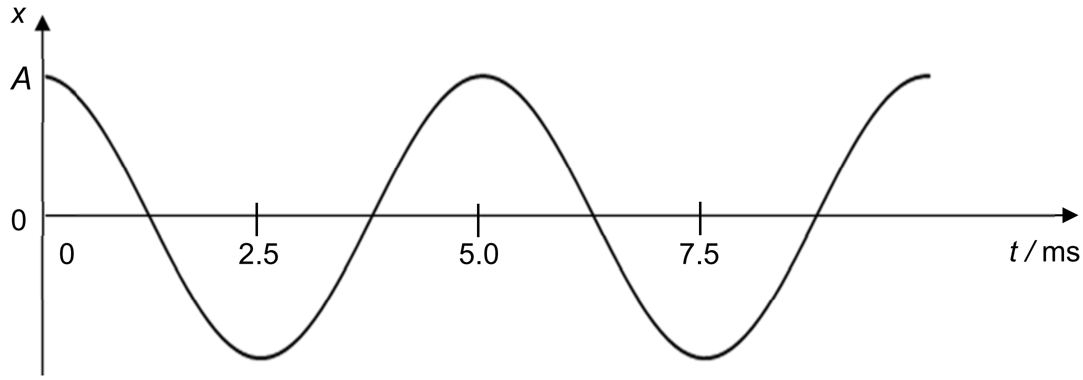


Fig. 2.1

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.

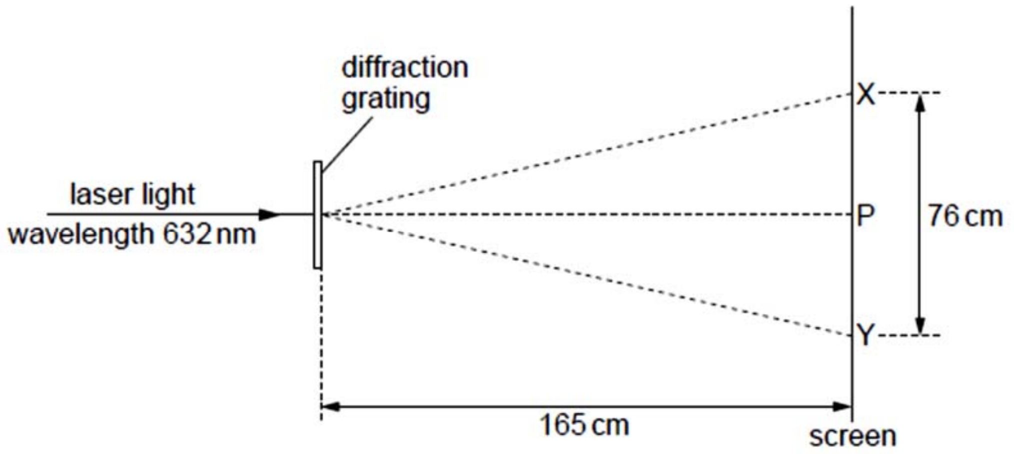


Fig. 3.1 (Top view)

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.

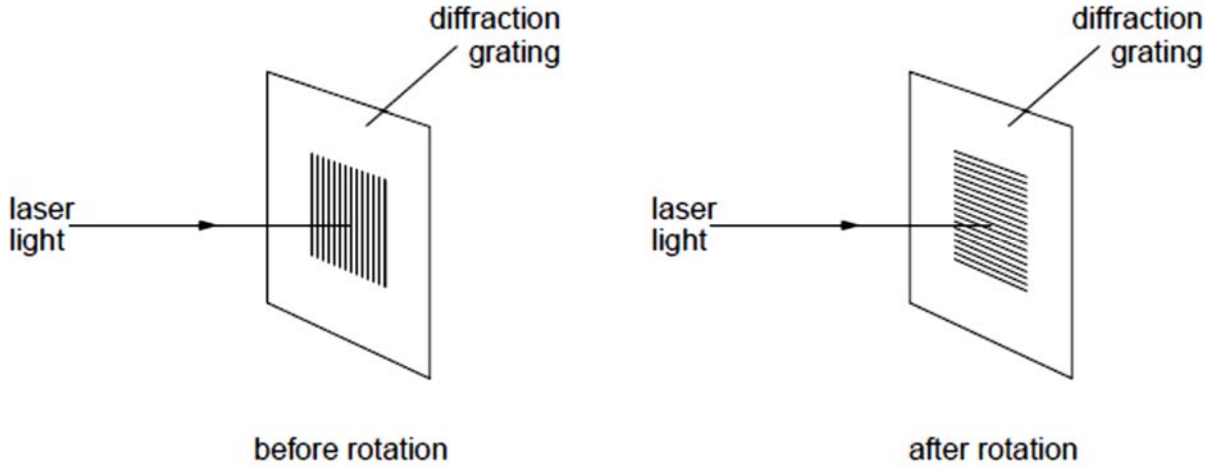


Fig. 3.2

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.

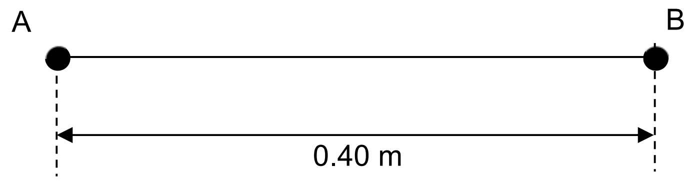


Fig. 3.3

(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.

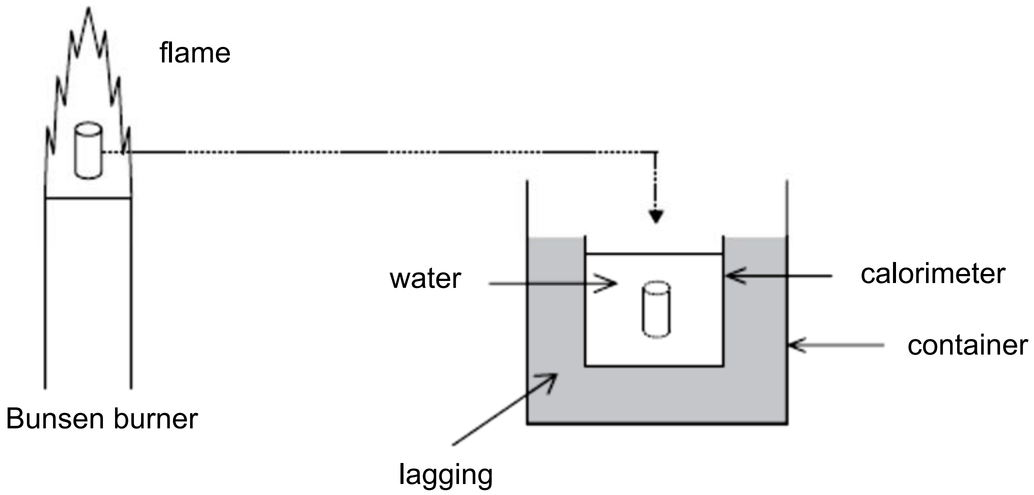


Fig. 4.1

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.

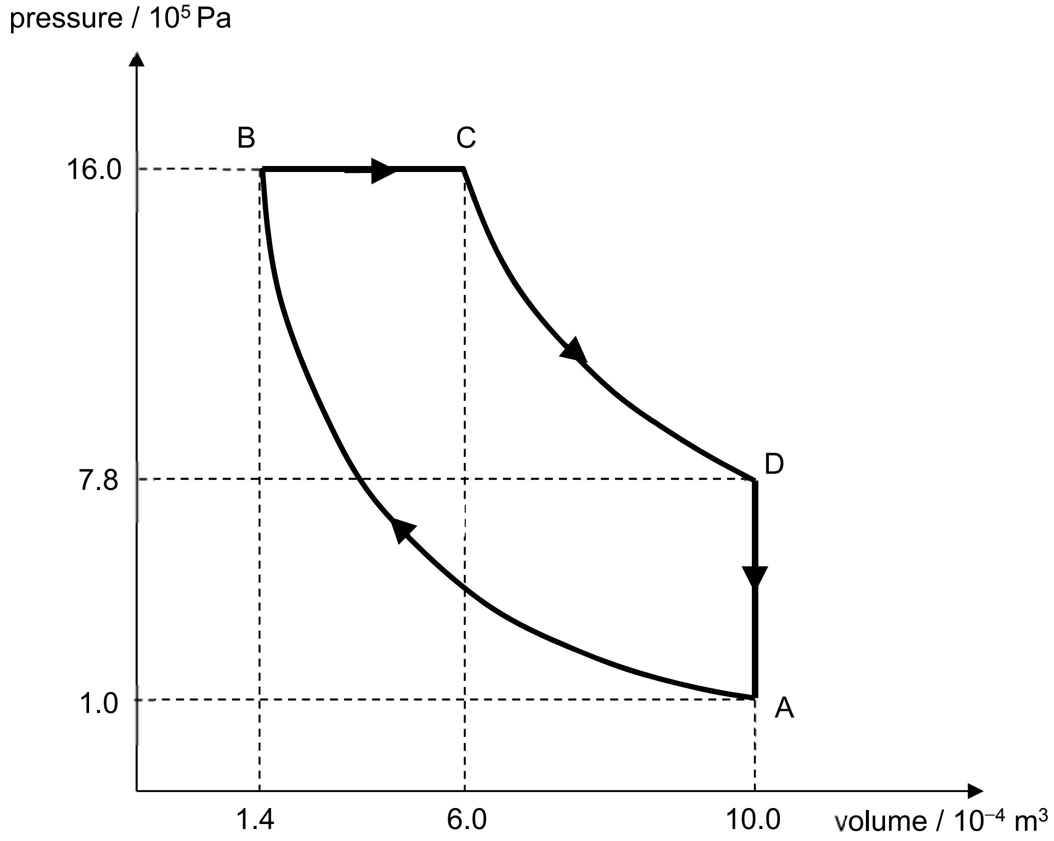


Fig. 4.2

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.

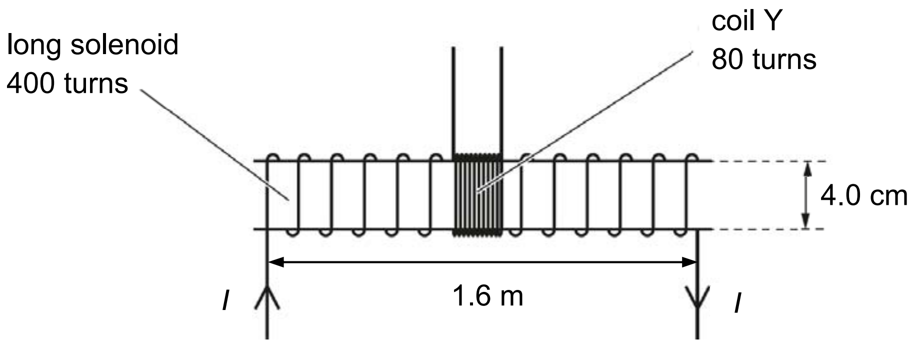


Fig. 5.1

(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.

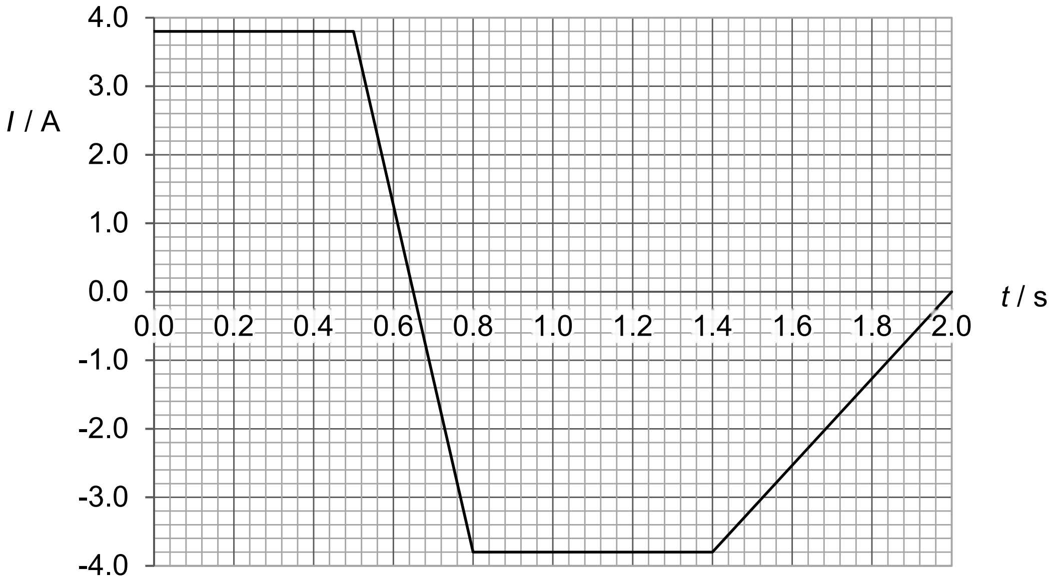
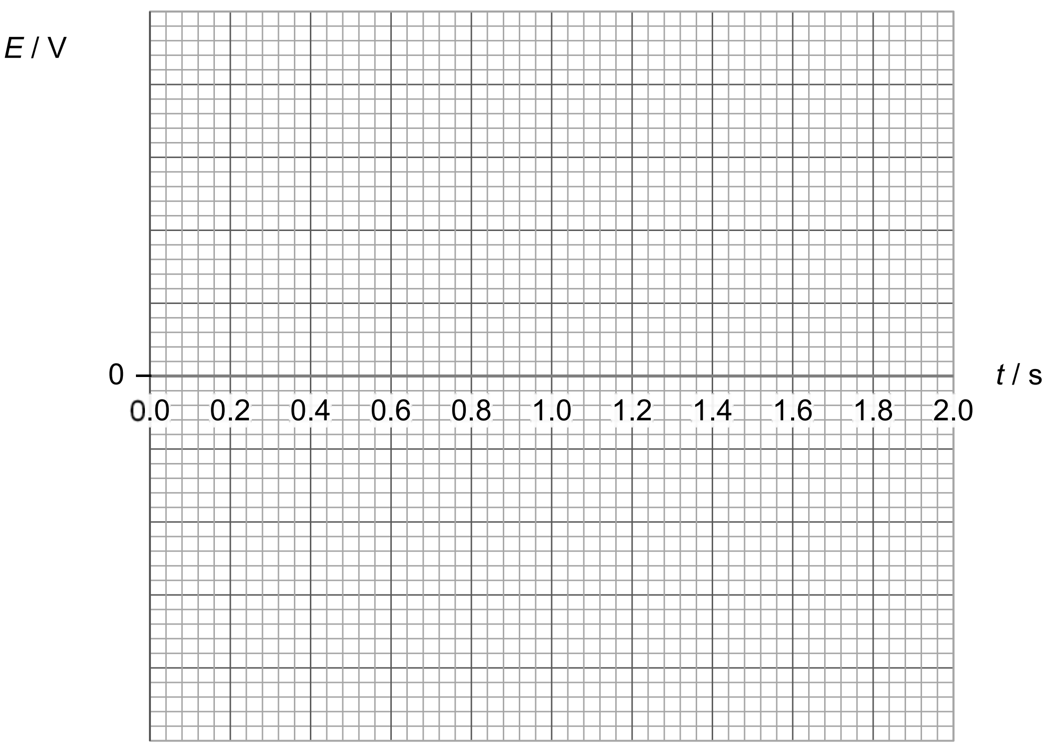


Fig. 5.2

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.

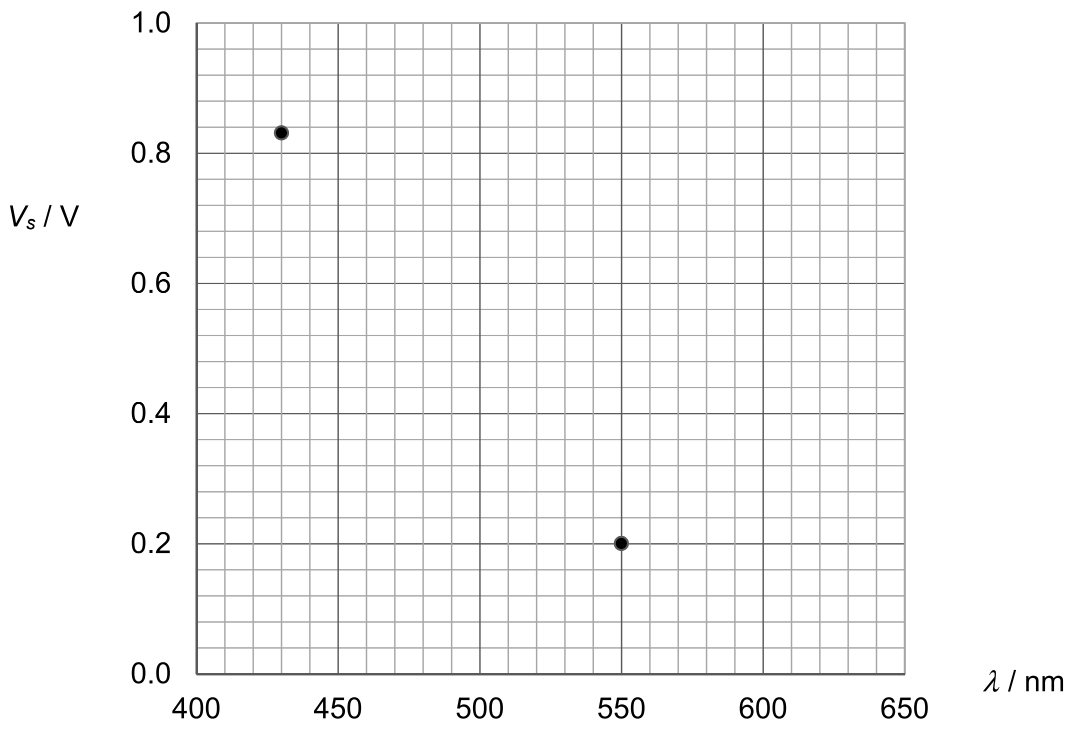


Fig. 6.1

(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.

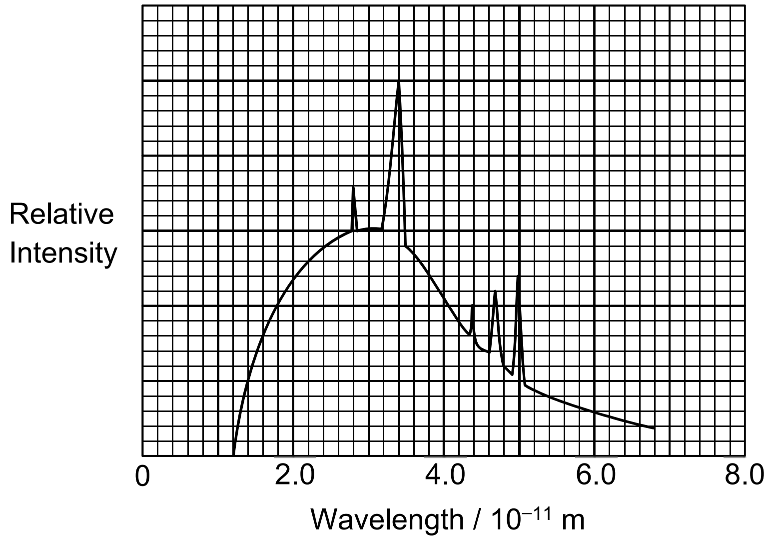


Fig. 7.1

(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*.

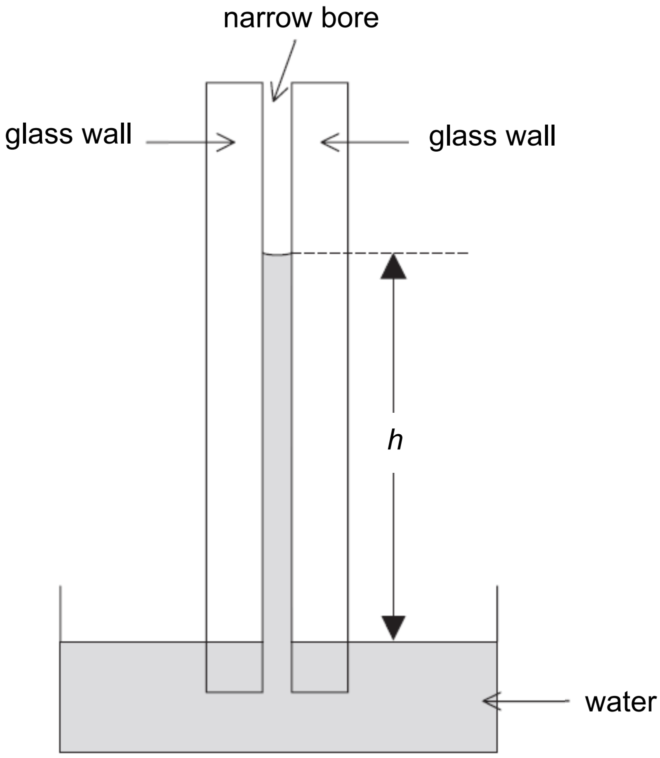


Fig. 8.1
(not to scale)

(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.

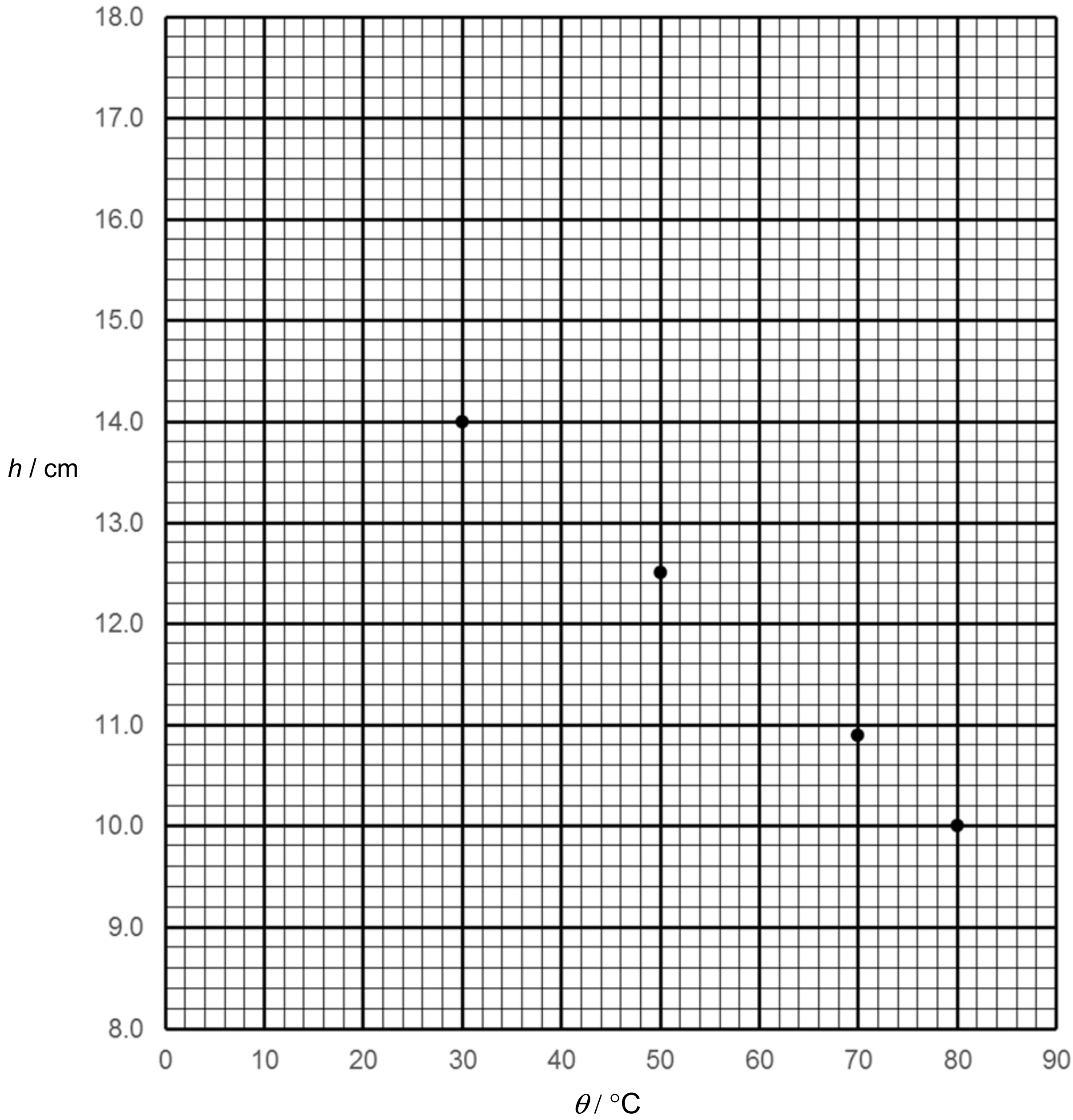


Fig. 8.3

(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.

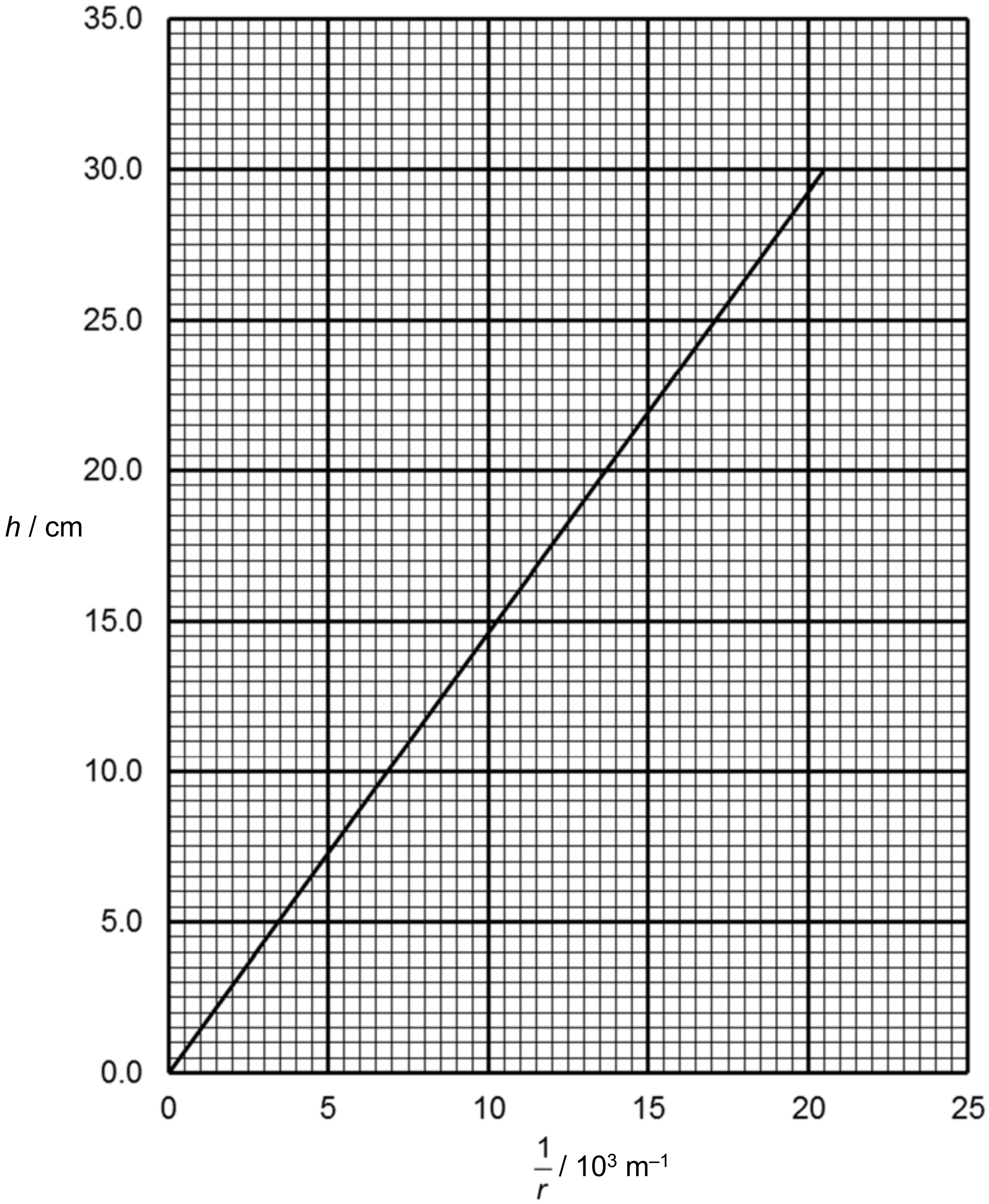


Fig. 8.4

(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	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
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.

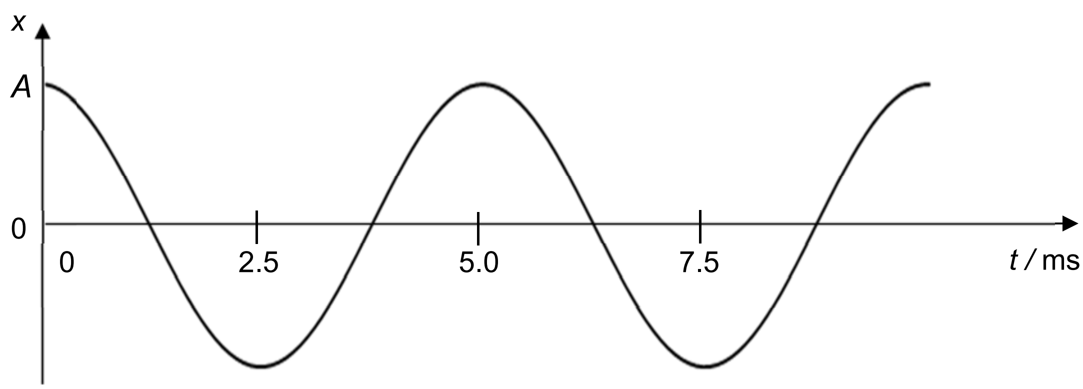


Fig. 2.1

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,

$$f = \frac{1}{T} = \frac{1}{5.0 \times 10^{-3}} = 200 \text{ Hz}$$ [B1]

[Turn over

frequency = ... Hz [1]

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

Intensity $\propto$ Amplitude^2

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

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

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

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]

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

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

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.

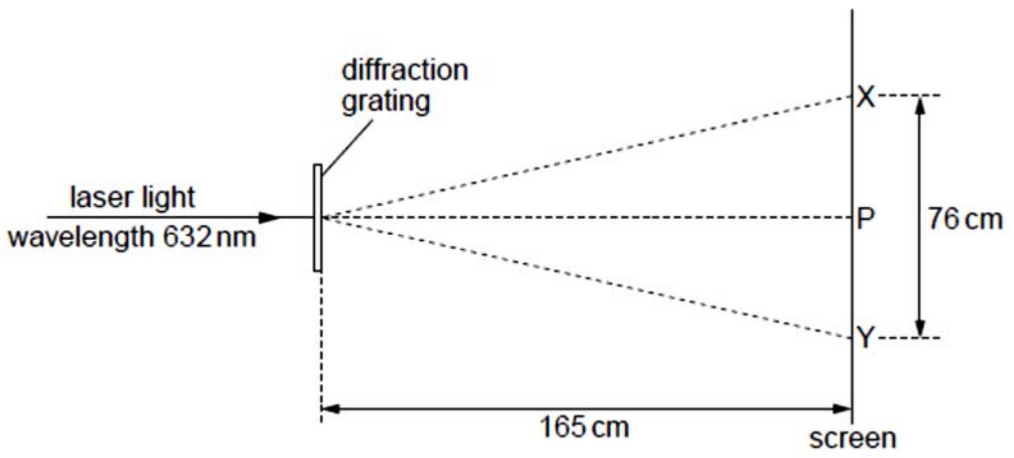


Fig. 3.1 (Top view)

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.

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

$$\theta = 12.97° \ (13°)$$

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

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

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

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.

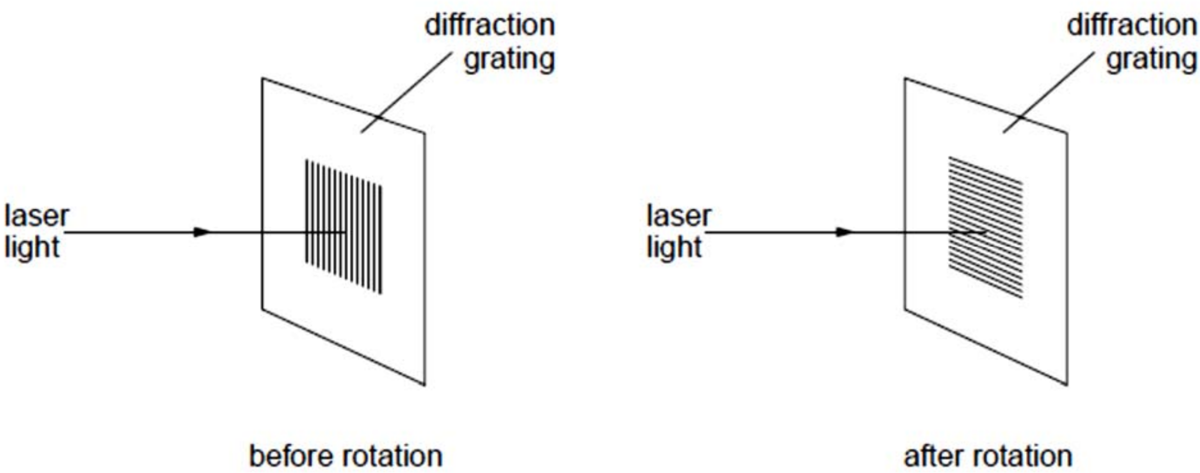


Fig. 3.2

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.

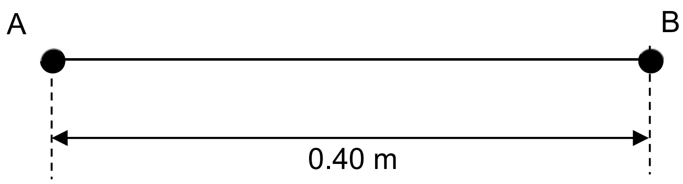


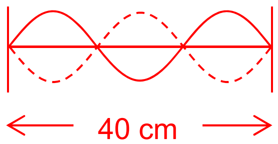
Fig. 3.3

(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.

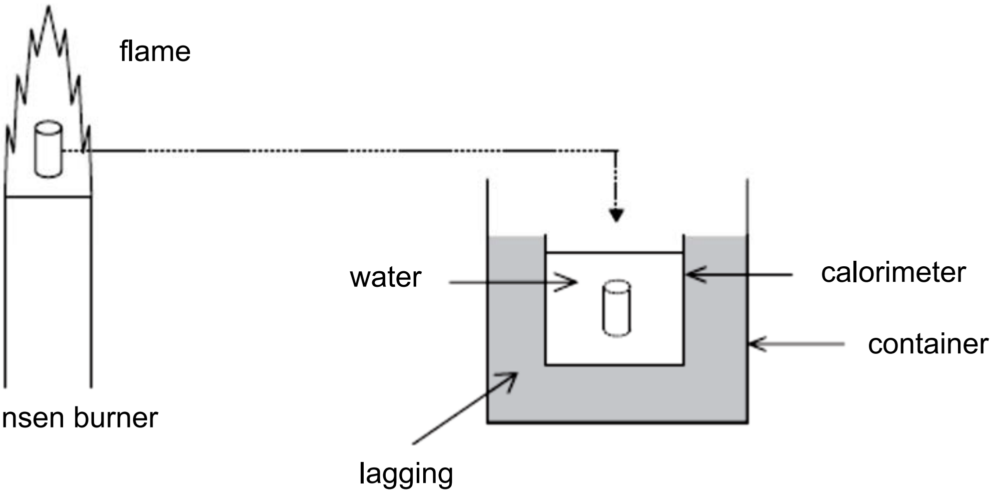


Fig. 4.1

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	$4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$
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

$$82.7(T-90) = (0.130 \times 4.2 \times 10^3)(90-25) + 54.6(90-25)$$ [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.

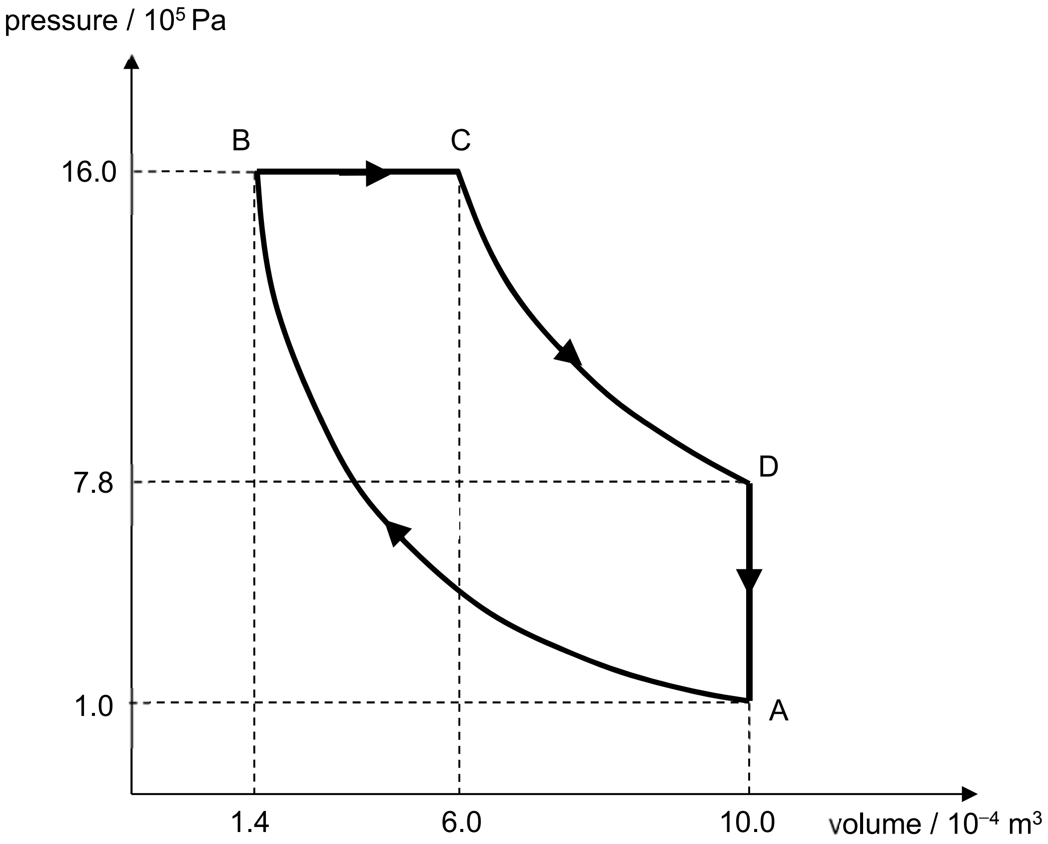


Fig. 4.2

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 <u>product of the flux density normal to the surface</u> and the <u>area of the surface</u>

....[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.

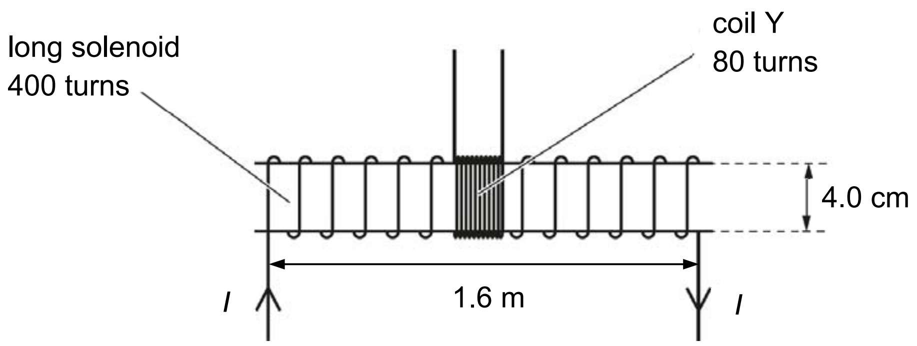


Fig. 5.1

(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.

$B = \mu_0 nI = 4\pi \times 10^{-7}\left(\frac{400}{1.6}\right)3.8$ [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.

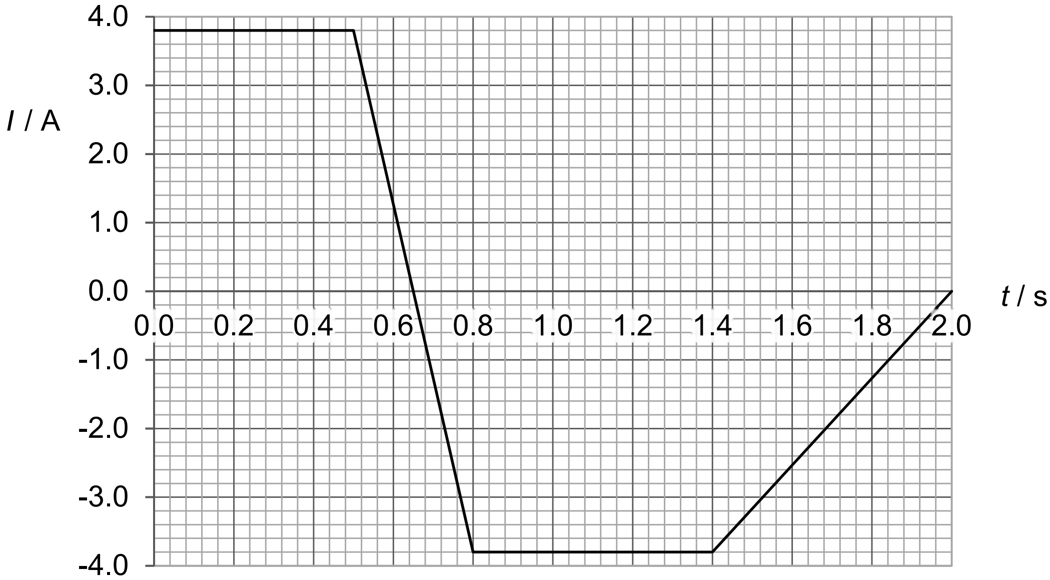
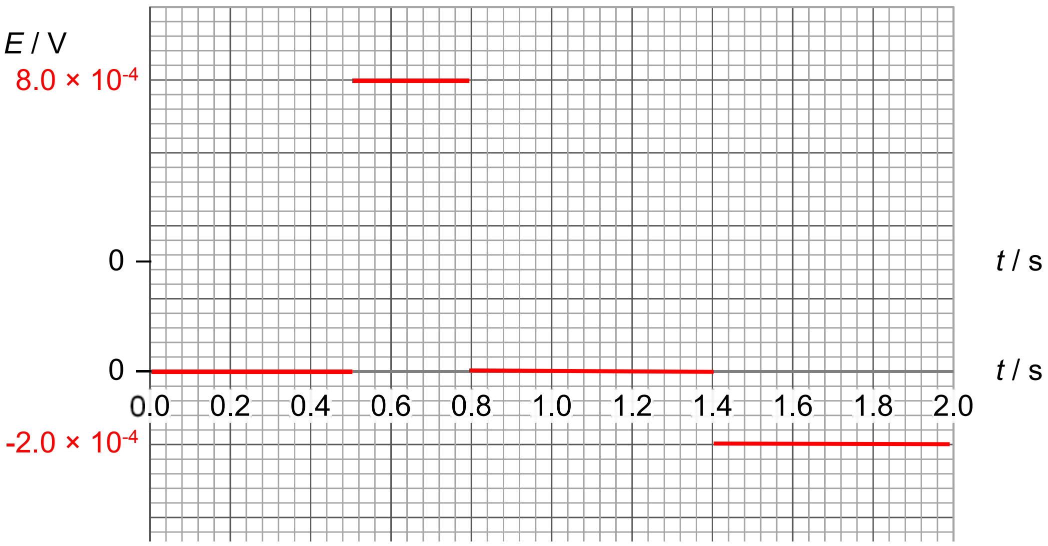


Fig. 5.2

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 <u>larger</u> (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.

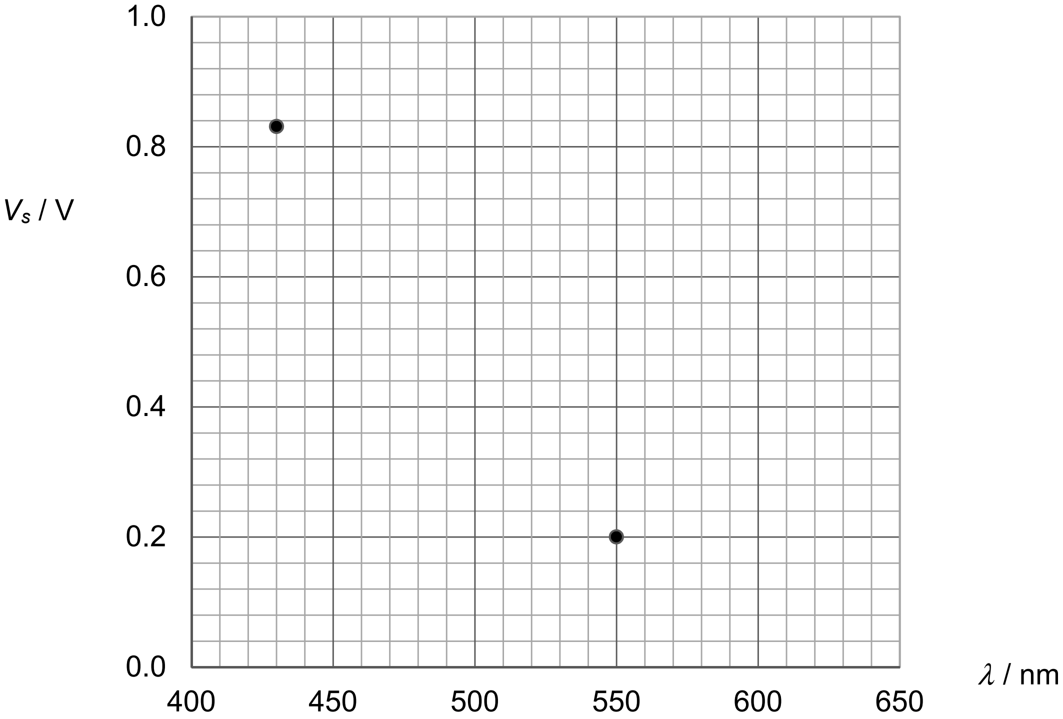


Fig. 6.1

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

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

maximum kinetic energy = ...J [1]

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

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

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

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

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.

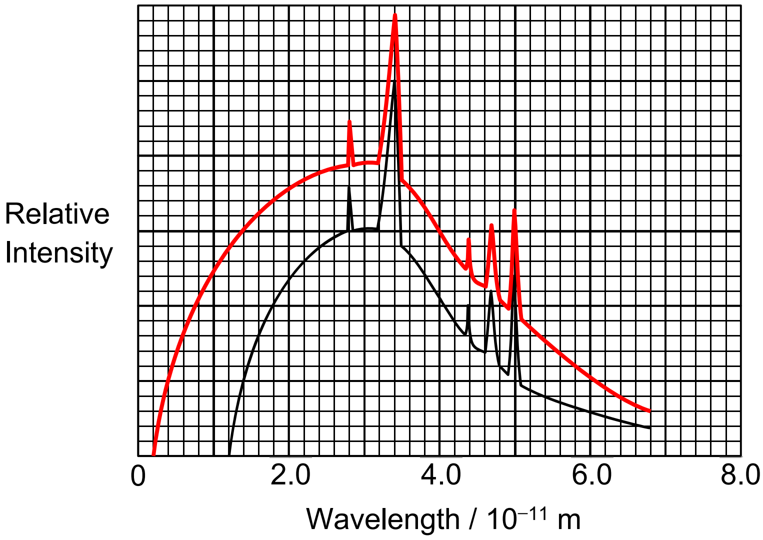


Fig. 7.1

(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]

[Turn over

(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*.

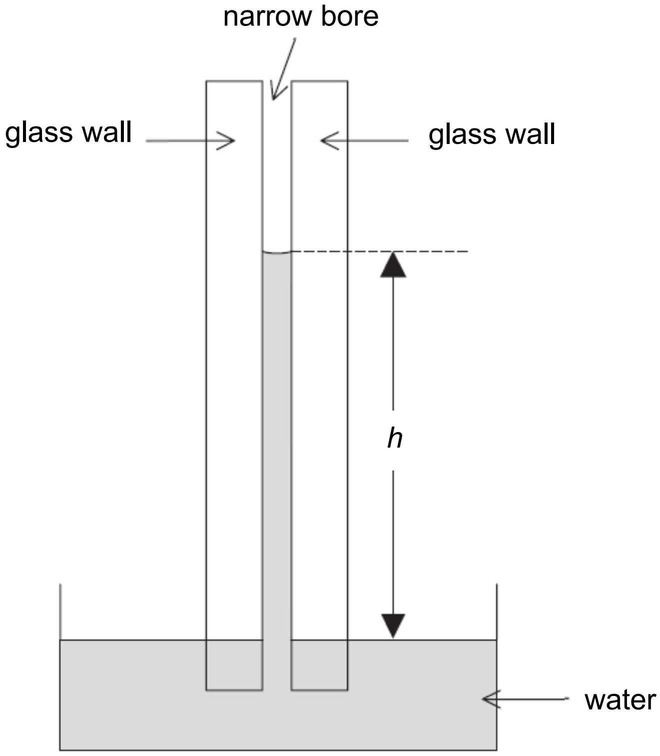


Fig. 8.1
(not to scale)

(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.

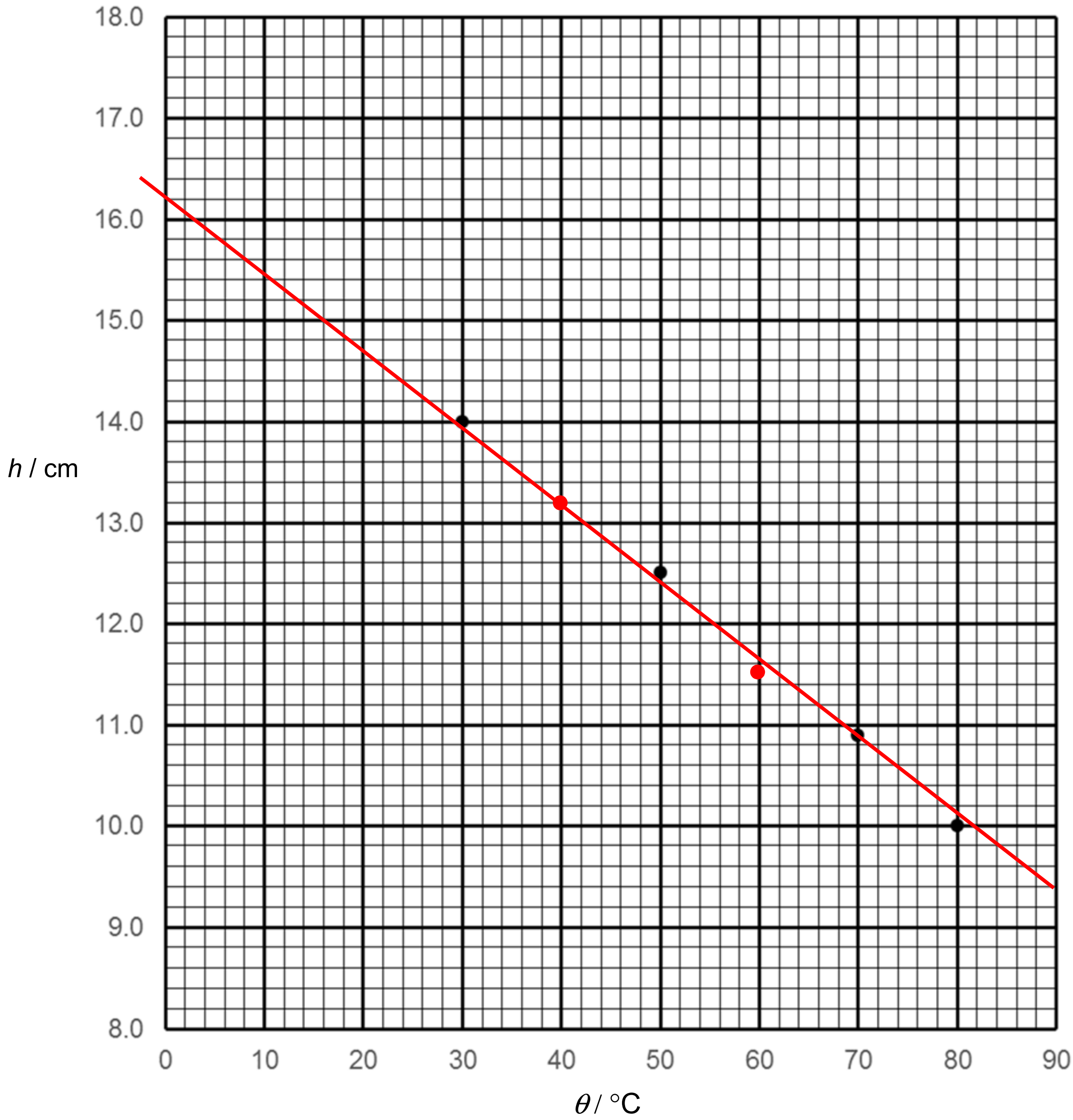


Fig. 8.3

(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.

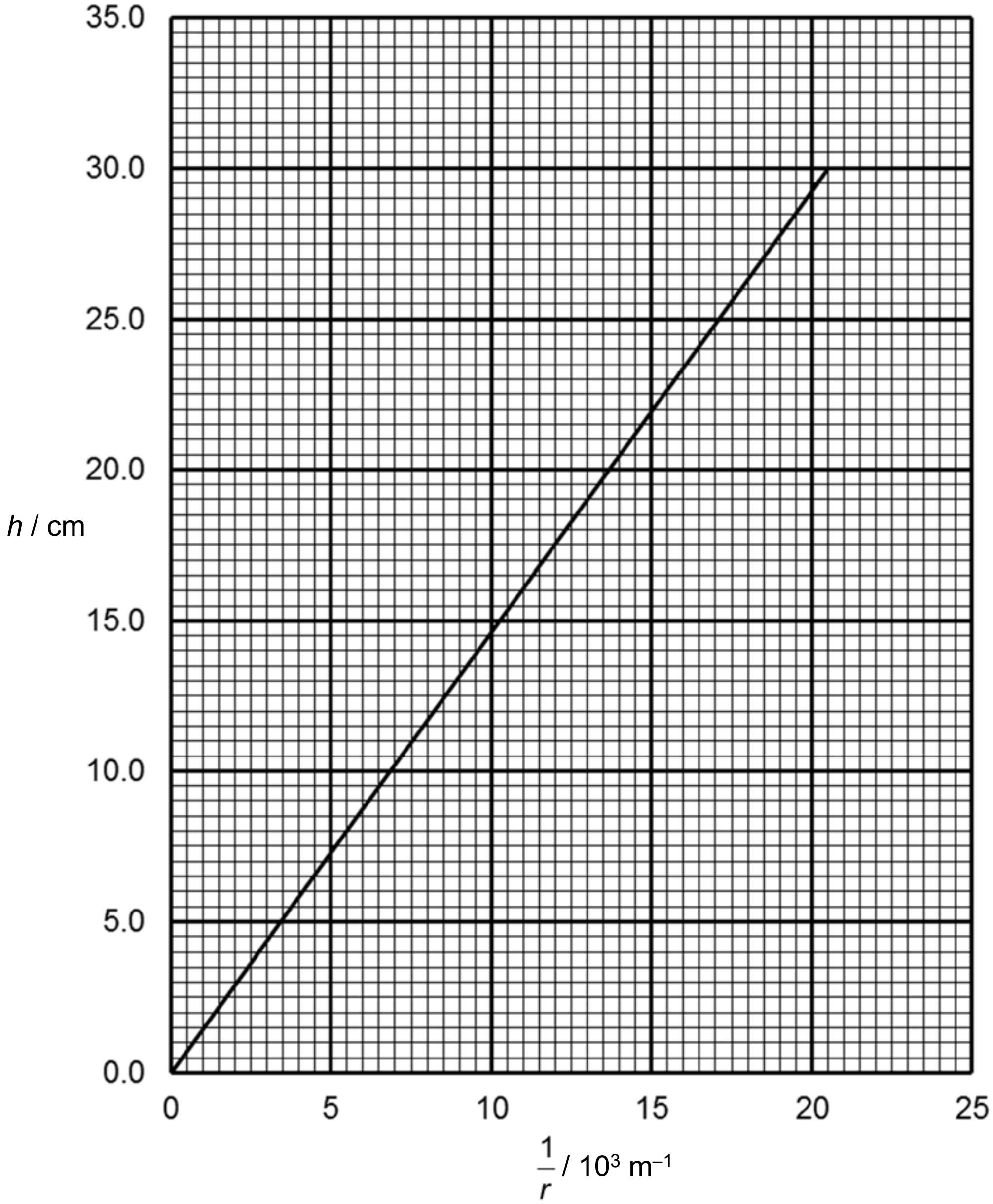


Fig. 8.4

(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.

Evaporation 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	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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.

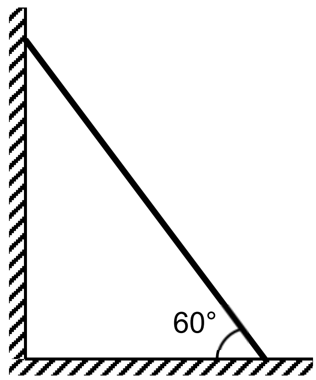


Fig. 1.1

(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.

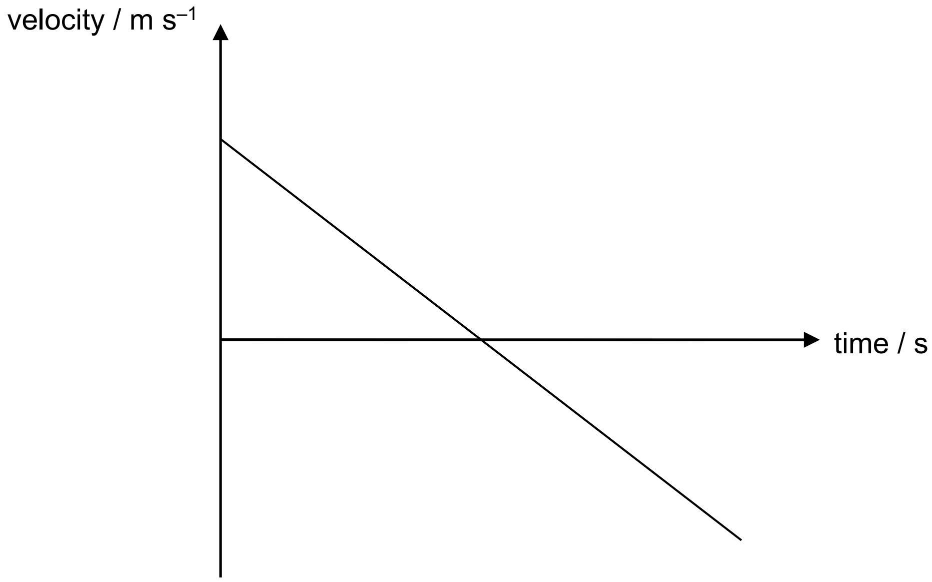


Fig. 4.1

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.

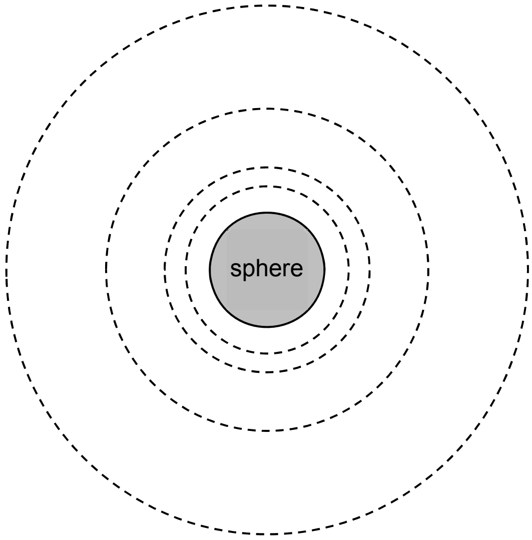


Fig. 6.1

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]

[Turn over

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.

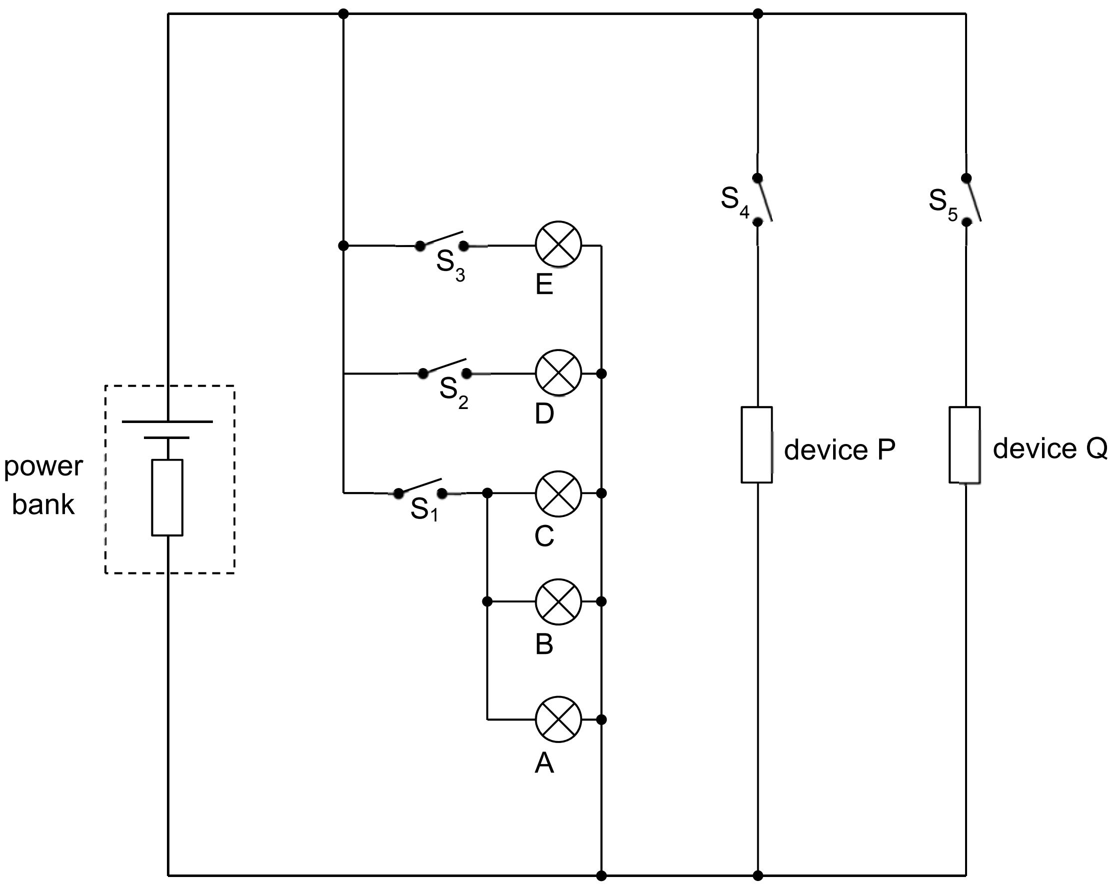


Fig. 7.1

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.

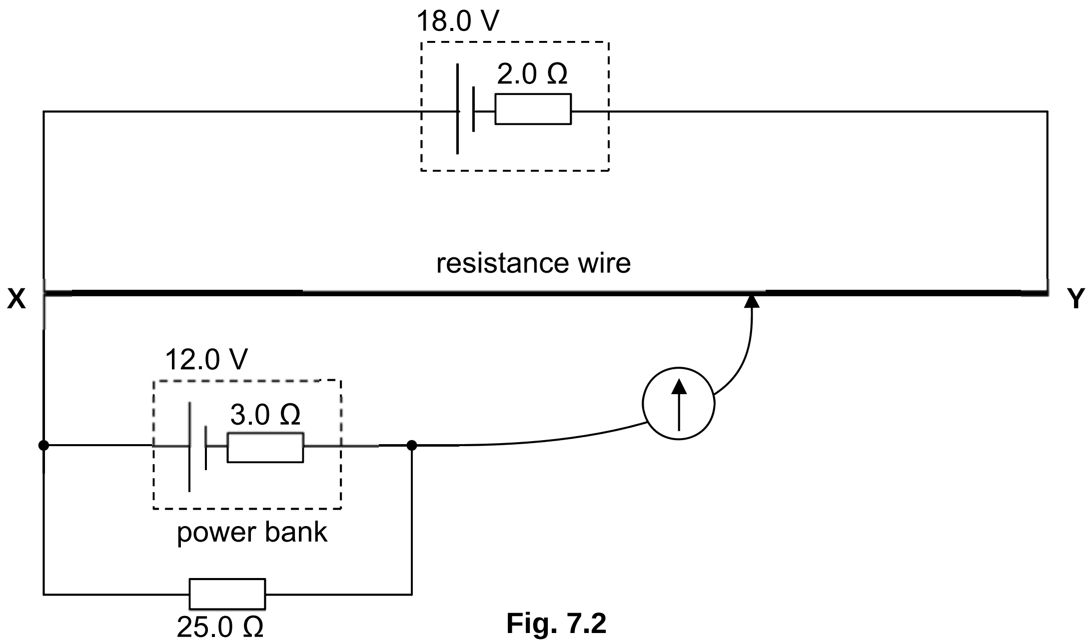


Fig. 7.2

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.

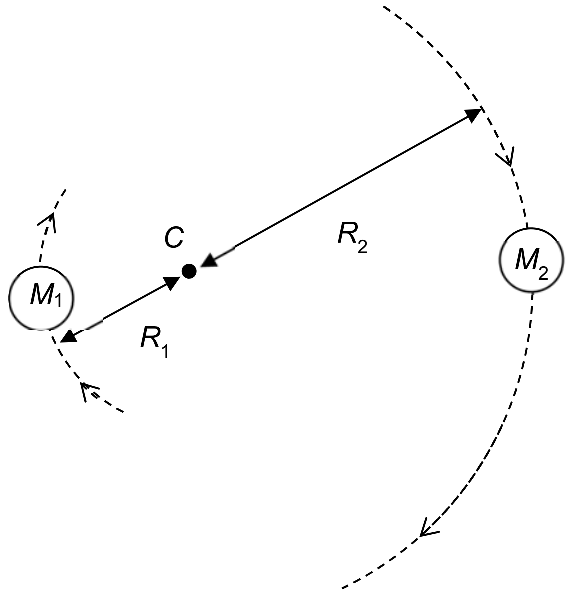


Fig. 8.1

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]

[Turn over

(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.

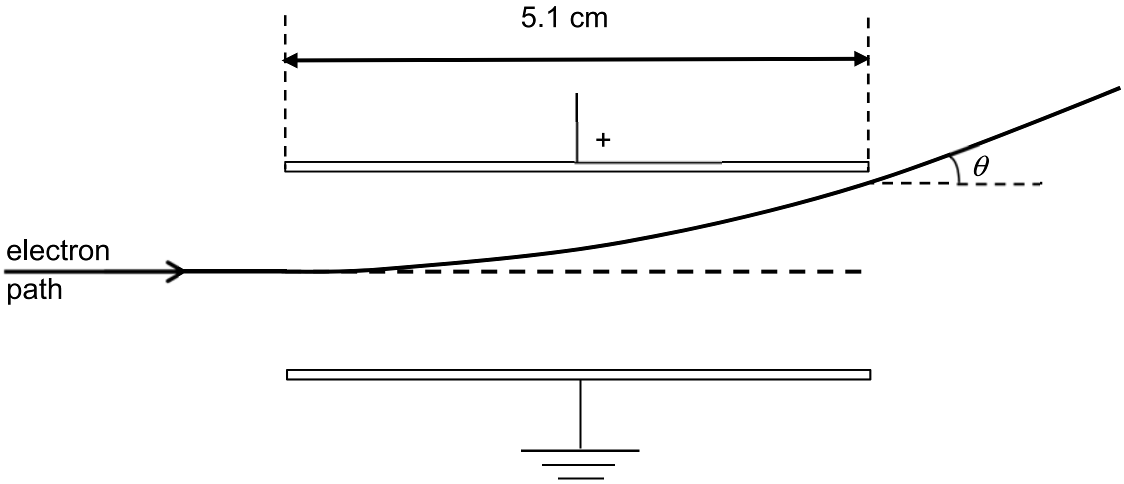


Fig. 8.2

(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.

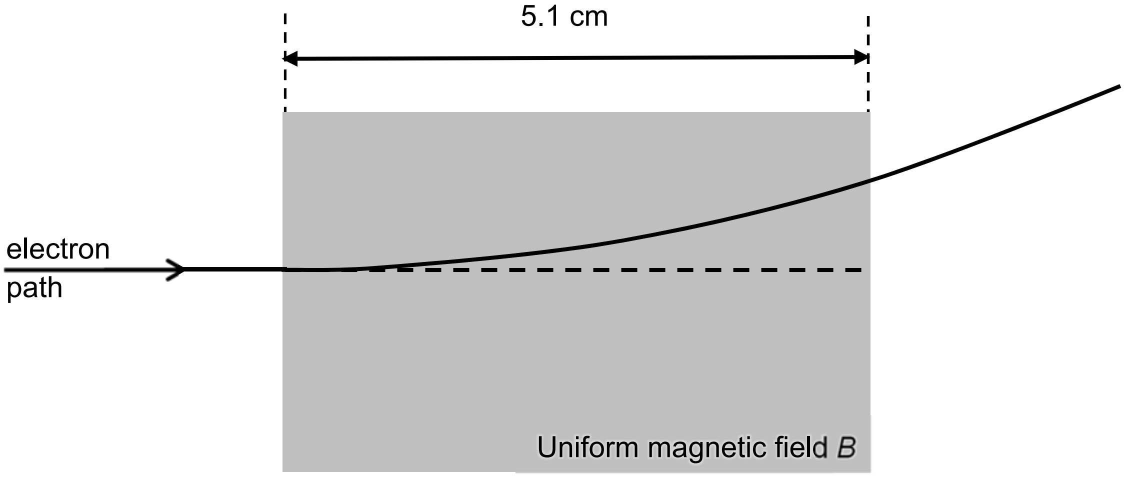


Fig. 8.3

(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}
		=	$\left(1/(36\pi)\right) \times 10^{-9}$ 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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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.

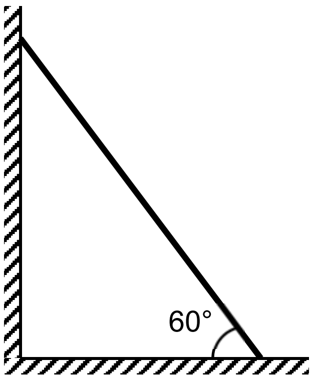


Fig. 1.1

(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,

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

$$= 672 \text{ m} \quad \text{[A1]}$$

distance = ...m [2]

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

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

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

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

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

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

$$\text{work} = Fs = (4800)(672) \quad \text{[M0]}$$

$$= 3.23 \times 10^6 \text{ J} \quad \text{[A1]}$$

work done = ...J [1]

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

$$\text{work} = \text{gain in KE}$$

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

$$= 3.23 \times 10^6 \text{ J} \quad \text{[A1]}$$

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.

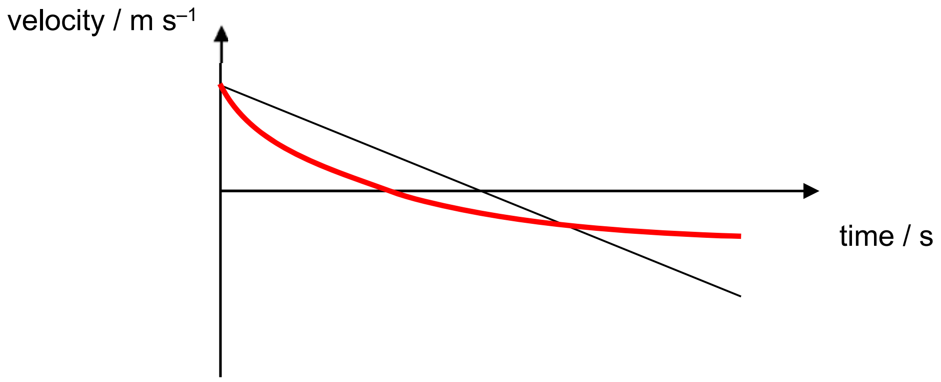


Fig. 4.1

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: $\rightarrow$ (0.800)(9.2) + 0 = (3.200) V $\Rightarrow$ 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: $\frac{1}{2}m_{\text{A\&B}}v^2 = \frac{1}{2}kx^2$

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

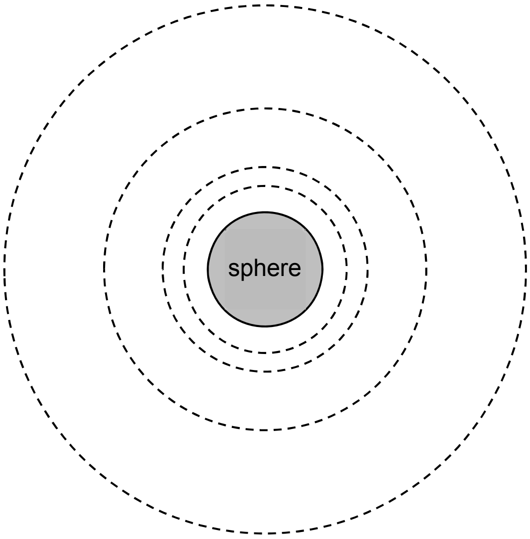


Fig. 6.1

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.

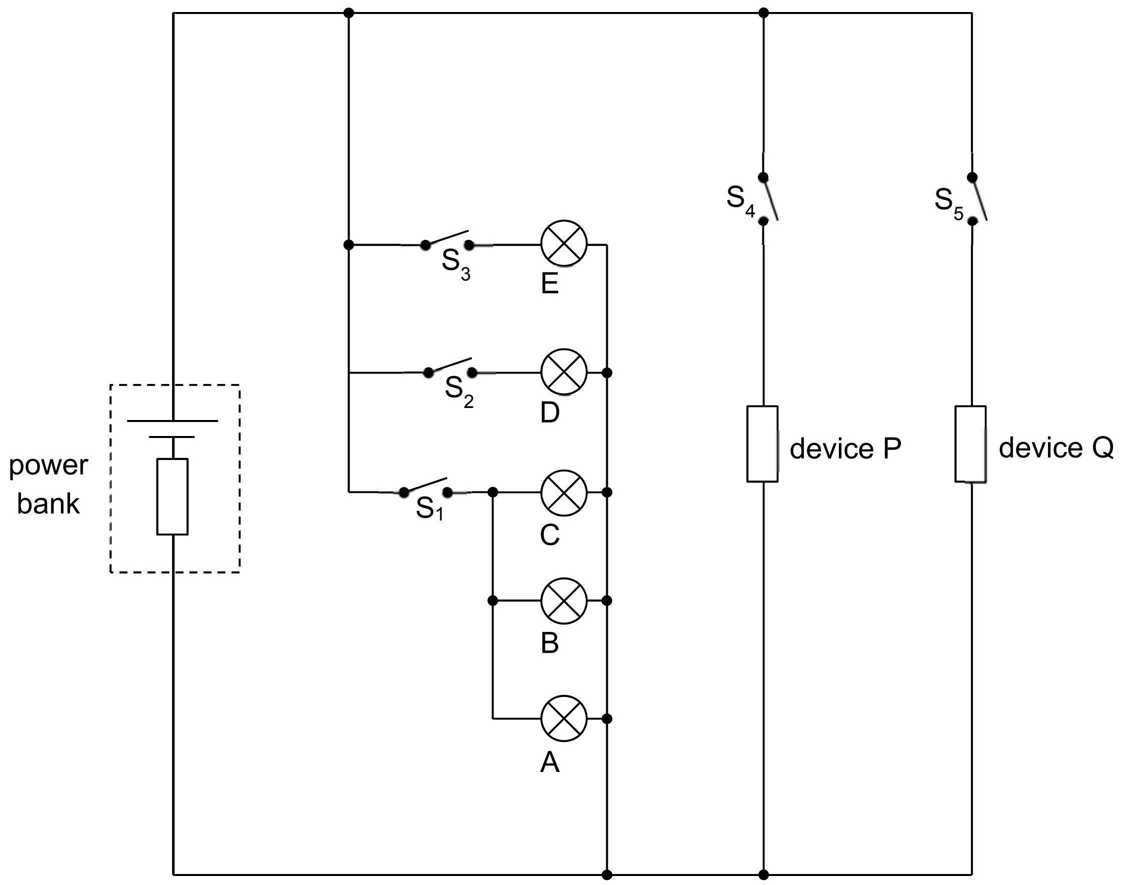


Fig. 7.1

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.

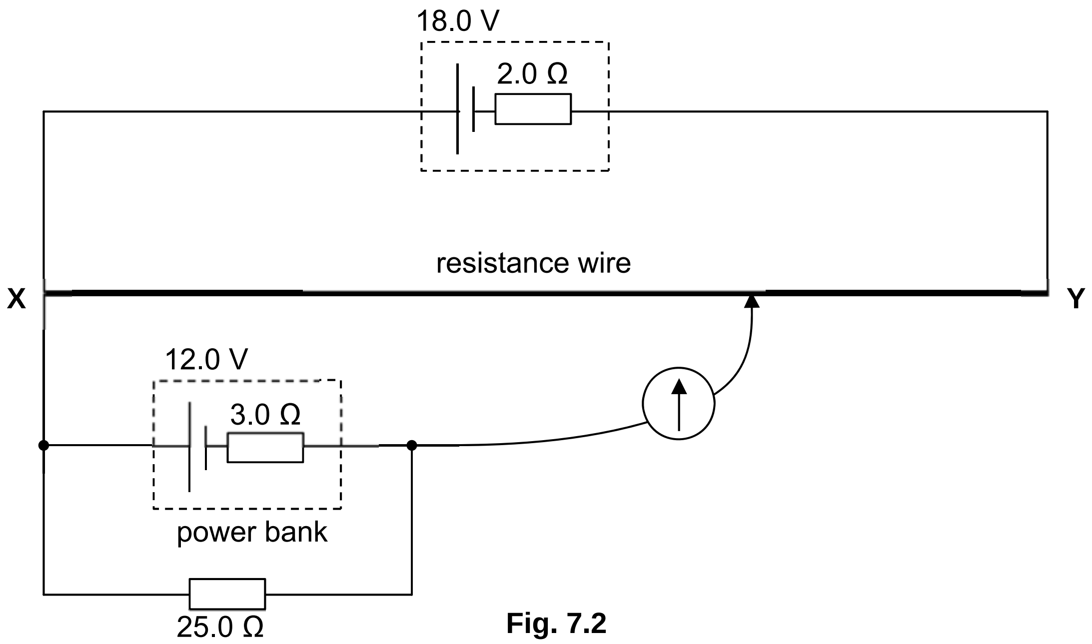


Fig. 7.2

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.

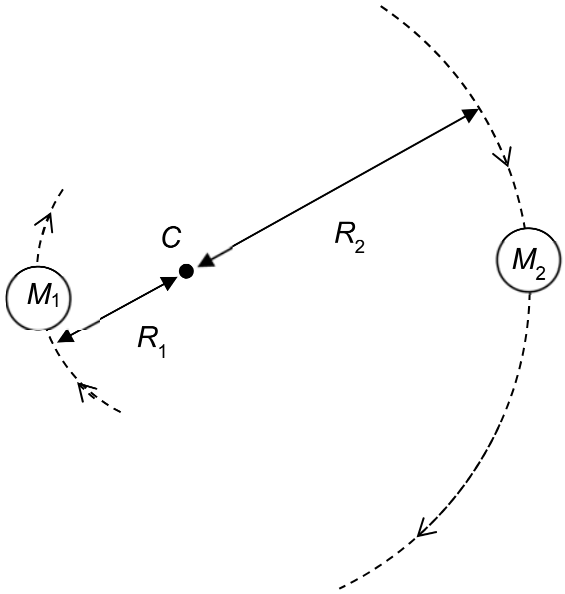


Fig. 8.1

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 × 10^{11} m
R_2= 2.4 × 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.

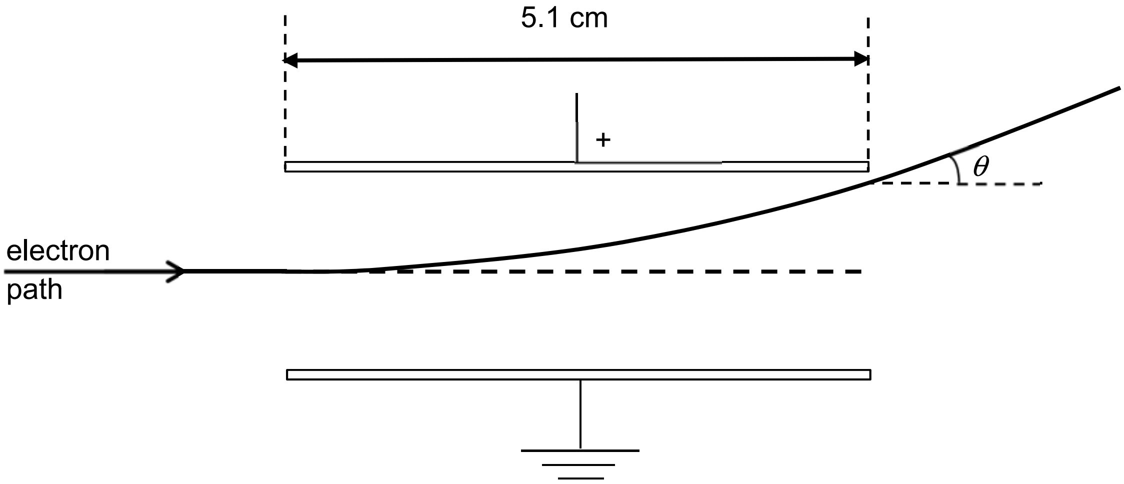


Fig. 8.2

(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 = $(5.1\times10^{-2}) / 1.7 \times 10^7 = 3.0\times10^{-9}$ s[C1]
Final vertical component of velocity $v_y = u_y + a_y t = 0 + (7.025 \times 10^{14})(3.0\times10^{-9}) = 2.1\times10^6$ 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]

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

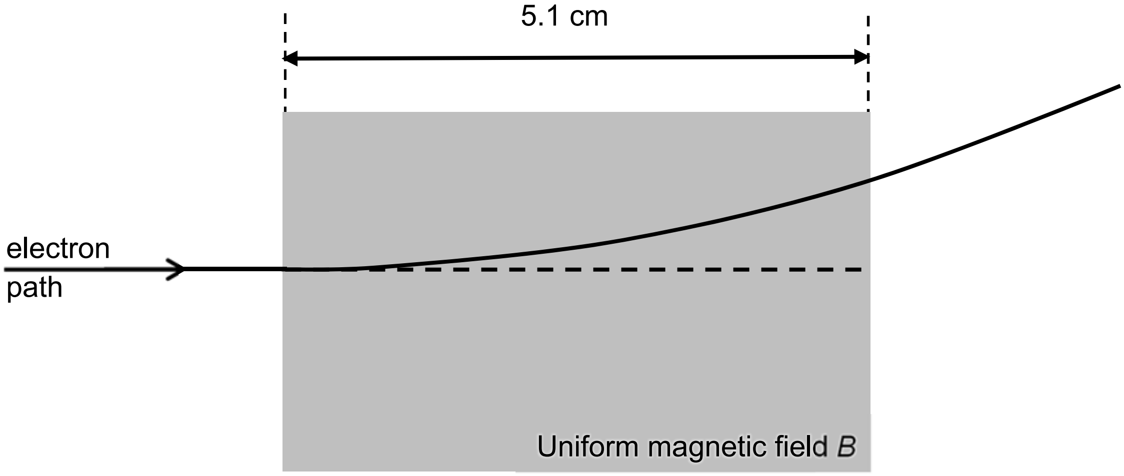


Fig. 8.3

(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]

[Turn over

(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 <u>same as initial speed</u> = 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]
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]