Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	MARK SCHEME
CLASS	2T

PHYSICS — 9749/03

Paper 3 Longer Structured Questions

September 2025

2 hours

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

FOR EXAMINER'S USE	
SECTION A	
Q1	/ 8
Q2	/ 8
Q3	/ 11
Q4	/ 6
Q5	/ 10
Q6	/ 7
Q7	/ 10
SECTION B	
Q8	/ 20
Q9	/ 20
PAPER 3	/ 80
PAPER 2	/ 80
PAPER 1	/ 30
PAPER 4	/ 55
TOTAL (WEIGHTED)	%

DATA

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ 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} mol^{-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	=	$u t + \frac{1}{2} a t^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p \Delta V$
hydrostatic pressure	p	=	$\rho g h$
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T / K	=	$T / ^\circ C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2} kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A solid iron sphere of density 8000 kg m^{-3} and volume 4.50 × 10^{-4} m^3 is completely submerged in a liquid of density 800 kg m^{-3}. The iron sphere is resting on a spring, as shown in Fig. 1.1. The spring is compressed by 10.2 cm.

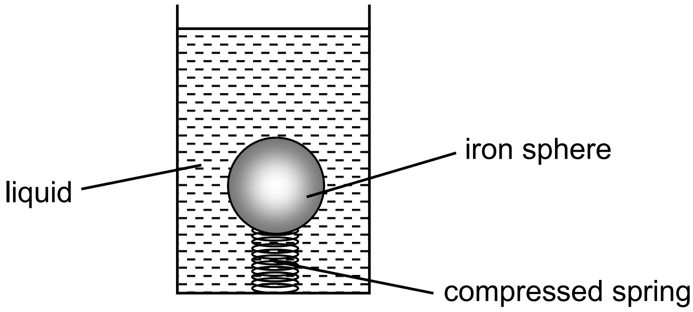


Fig. 1.1

(a) Show that the upthrust on the iron sphere is 3.53 N.

[1]

Solution

Upthrust

$= \rho V g$

$= 800(4.50 \times 10^{-4})(9.81)$ M1

$= 3.5316$ N A0

$= 3.53$ N (Shown)

(b) Hence, calculate the force constant of the spring.

force constant = ... N m^{-1} [2]

Solution

At equilibrium, considering forces on the iron sphere

$kx + U = mg$

$k = \dfrac{mg - U}{x} = \dfrac{8000(4.50 \times 10^{-4})(9.81) - 3.5316}{0.102}$ M1

$= 312$ N m^{-1} A1

(c) A string of breaking strength 32.0 N is used to lift the iron sphere vertically upwards, as shown in Fig. 1.2. The iron sphere is then lifted partially out of the liquid as shown in Fig. 1.3.

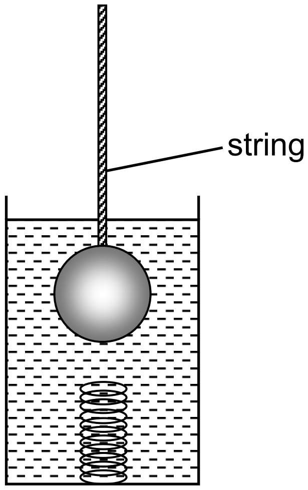


Fig. 1.2

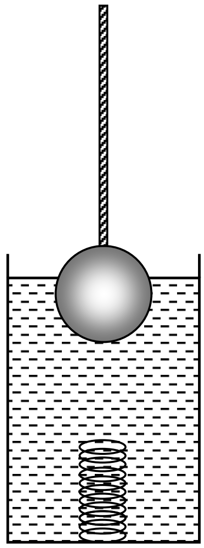


Fig. 1.3

(i) Explain why the string breaks as the sphere emerges from the liquid.

....

....

....

.... [2]

Solution

When the sphere is lifted out of the liquid, the volume of liquid displaced is reduced. This causes the upthrust acting on sphere to decrease. B1

To maintain equilibrium, the tension will increase and the string breaks when the tension exceeds the maximum allowable value. B1

(ii) Calculate the volume of the fluid displaced at the instant when the string breaks.

volume = ... m^3 [3]

Solution

At breaking point,

$T + U = mg$ C1

$32.0 + 800(V)(9.81) = 8000(4.50 \times 10^{-4})(9.81)$ M1

$V = 4.23 \times 10^{-4}$ m^3 A1

[Total: 8]

[Turn over

2 **(a)** A satellite S of mass *m* is in a stable circular orbit at an altitude of 2*R* above the surface of a planet of mass *M* and radius *R*, as shown in Fig. 2.1.

Assume the planet has no atmosphere and that all its mass is concentrated at its centre.

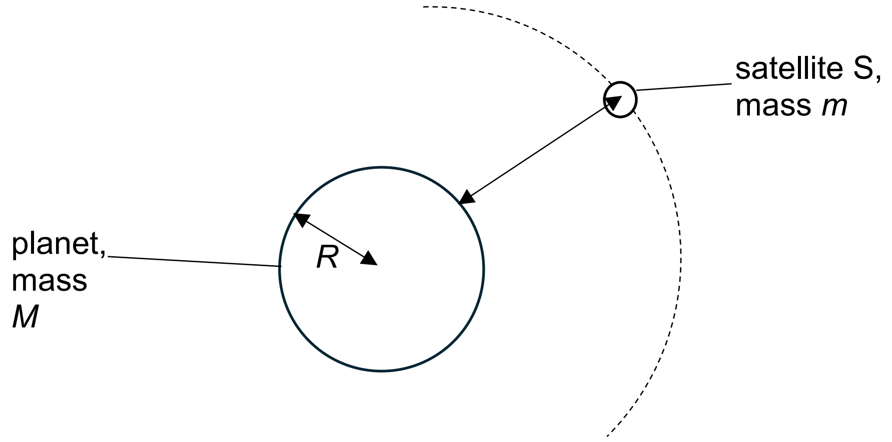


Fig. 2.1

(a) Show that the kinetic energy E_k of the satellite S in orbit is given by the expression:

$$E_k = \frac{GMm}{6R}$$

where *G* is the gravitational constant.

[2]

Solution:

The gravitational force provides the centripetal force.

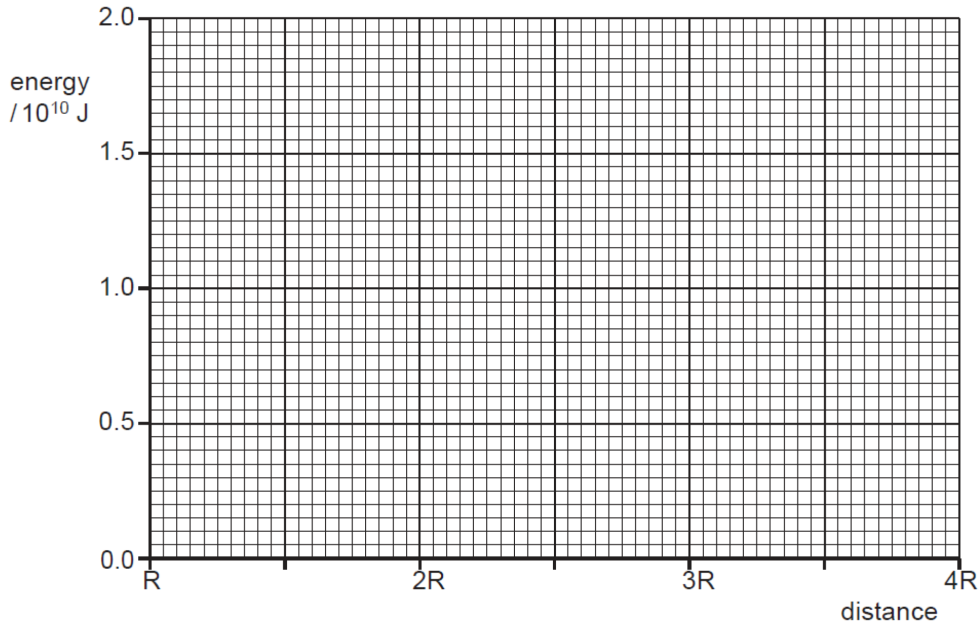
$F_G = F_C$

$$\frac{GMm}{(3R)^2} = \frac{mv^2}{3R}$$ B1

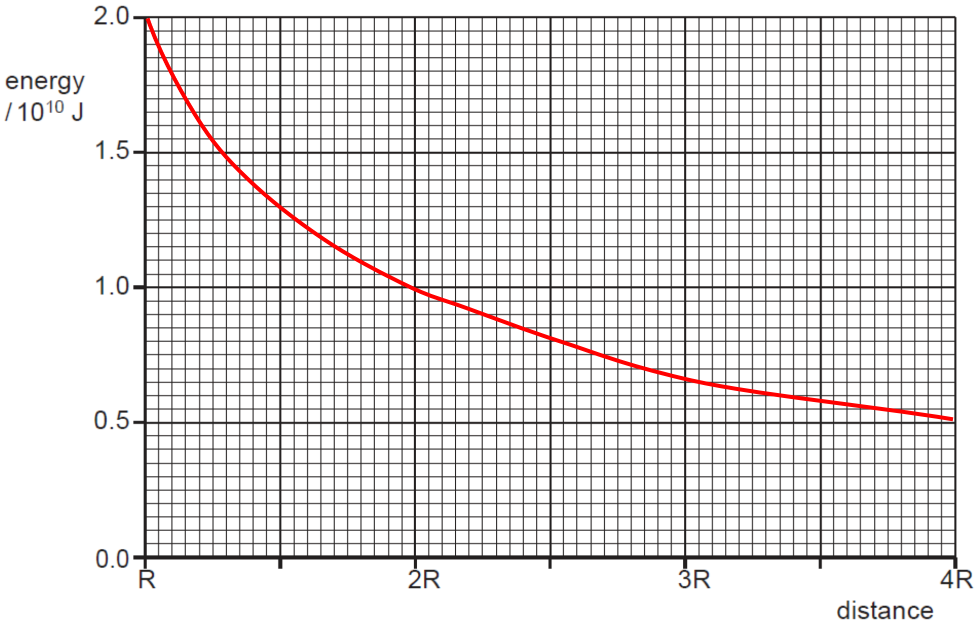
$$v^2 = \frac{(3R)Mm}{(3R)^2 m} = \frac{GM}{3R}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\frac{GM}{3R}$$ B1

$$= \frac{GMm}{6R}$$

	(b)	The planet has mass 4.5×10^{24} kg and radius of 5.5×10^{3} km. The satellite has a mass of 1500 kg. Determine the total energy of satellite S in orbit.	
		total energy = ... J	[2]
		Solution: Total energy = $-\frac{GMm}{2r}$ where r is the orbital radius and is equal to 3R for this Q $= \frac{(6.67 \times 10^{-11})(4.5 \times 10^{24})1500}{2 \times 3(5.5 \times 10^{3} \times 10^{3})}$ $= -1.36 \times 10^{10}$ J (negative sign to be included) If students equate E_k to E_T, there must be some derivation shown to get M1 marks.	M1 A1
	(c)	A second satellite P is launched into orbits from the surface of the same planet with an initial kinetic energy of 2.0×10^{10} J. It rises to a distance of 4R from the centre of the planet. On the axes provided in Fig 2.2, sketch a graph to show how the satellite's orbital kinetic energy varies with distance from the centre of the planet as it moves from R to 4R.	
		 **Fig 2.2**	[2]

Solution:



B1 – Shape of graph:

- Smooth curve decreasing with increasing r (concave upwards)

1 mark – Correct key points labelled or plotted:

- Correctly labels or plots the following values:

Since $E_k \alpha \frac{1}{r}$

r	E_K / 10^{10} J
R	+2.0
2R	+1.0
3R	+0.67
4R	+0.5

(d) A third satellite Q is to be launched vertically from the surface of the same planet. Determine the minimum speed that satellite Q must be given at the surface to escape the planet's gravitational field.

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

		Solution: By conservation of energy, Energy of satellite Q at the surface of the planet = energy of satellite Q at infinity $\frac{1}{2}mv^2+\left(\frac{-GMm}{r}\right)=0$ $v=\sqrt{\frac{2GM}{r}}=\sqrt{\frac{2(6.67\times 10^{-11})(4.5\times 10^{24})}{5.5\times 10^{3}\text{x}10^{3}}}$ $v = 1.04 \times 10^4$ m s^{-1}	M1 A1

[Total: 8]

3 A student sets up the apparatus illustrated in Fig. 3.1 in order to observe two-source interference fringes. The double slit with slit separation 0.800 mm, situated 2.50 m from the screen, is illuminated with coherent red light of wavelength 690 nm. Fringes are observed on the screen.

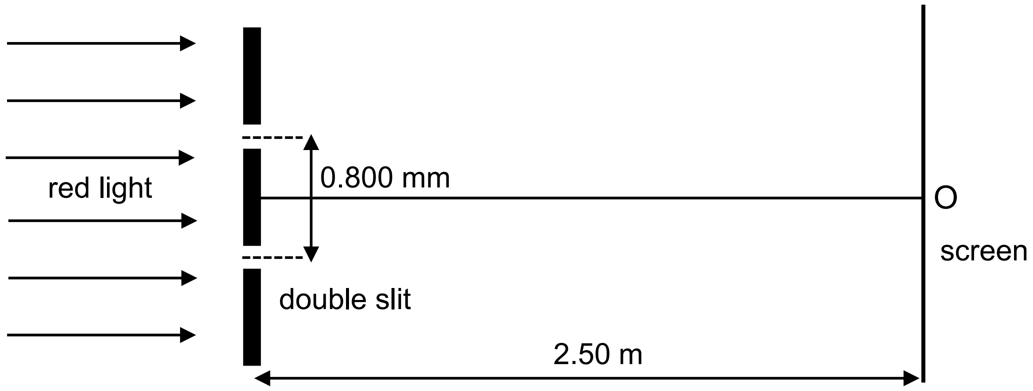


Fig. 3.1

(a) State two conditions necessary for two source interference fringes to be observed.

....

....

....

.... [2]

Solution

Waves must be of the same nature and must overlap. B1

Sources must be coherent, i.e. the phase difference between them remains constant. B1

Amplitudes of the two waves must be approximately equal.

For transverse waves, they must be either unpolarized or, if polarized, polarized in the same direction.

(b) Explain why a maxima is always observed at Point O.

....

....

....

.... [2]

Solution

The two sources are in phase and there is no path difference of the waves at Point O as it is equidistant from the two sources. B1

Therefore, constructive interference must occur as the two waves are in phase with each other at point O, giving rise to a maxima at point O. B1

(c) Calculate the distance from O to the second minima observed on the screen.

separation = …………..…………………..…………… m [3]

Solution

$x = \dfrac{\lambda D}{a}$

$= \dfrac{(690 \times 10^{-9})(2.50)}{0.800 \times 10^{-3}}$ M1

$= 2.15625 \times 10^{-3}$ m

Distance from O to the second minima observed on the screen

= 1.5x

= 1.5 × (2.15625 × 10^{-3}) M1

= 3.23 ×10^{-3} m A1

(d) Describe the changes, if any, that occur in the separation of the fringes and the difference in the brightness between bright and dark fringes observed on the screen, when each of the following changes is made separately.

(i) increasing the intensity of the red light incident on the double slit,

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

Solution

There is no change in the spacing. B1

The maxima is brighter and thus the difference in the brightness is higher. B1

(ii) increasing the distance between the double slit and the screen.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

Solution

Since D is larger, x will be larger. The separation of the fringes will increase. B1

The maxima is dimmer/ less intense/ less bright due to the longer distance travelled by the waves. Thus, the difference in the brightness is lower. B1

[Total: 11]

4	A 3.00 g copper coin at 20.0 °C drops 50.0 m to the ground.		
	(a)	The copper is said to possess internal energy. Explain what is meant by the internal energy.	
		....	
		....	
		....	
		....	[2]
		Solution The internal energy of a system is the sum of its kinetic energy due to the random motion of its molecules and potential energy due to intermolecular forces of attraction.	B1 B1
	(b)	The coin does not undergo a change in volume after it landed on the ground. Determine the gain in temperature of the coin given that the specific heat capacity of copper is 385 $\text{J kg}^{-1}\text{K}^{-1}$. Assuming that 10.0 % of the change in gravitational potential energy of the coin goes to increasing the internal energy of the coin.	
		gain in temperature = ... K	[2]
		Solution By principle of conservation of energy, decrease in G.P.E. → increase in internal energy $0.10mg\Delta h = mc\Delta\theta$ $\Delta\theta = \frac{0.10mg\Delta h}{mc} = \frac{0.10(9.81)(50.0)}{385}$ = 0.13 K	M1 A1
	(c)	The first law of thermodynamics for a system can be expressed as $\Delta U = q + w$ where ΔU is the increase in internal energy of the system, q is the heat supplied to the system and w is the work done on the system. Use the words **positive**, **negative** and **zero** to complete Table 4.1 for the three terms in the equation for each of the processes shown. You may use each word once, more than once, or not at all.	

Process	ΔU	q	w
Copper coin drops and lands on the ground			

Table 4.1

[2]

Solution
ΔU: positive
q: positive (B1 for both delta U and q) B1
w: zero – B1 one mark here B1

As the coin's temperature rises, its average molecular kinetic energy increases. Thus, the increase in internal energy of the system ΔU is positive.
As the coin does not undergo any change in volume, the work done on the system w is zero.
By the First Law, since ΔU is positive and w = 0, the heat supplied to the system q must be positive.

[Total: 6]

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

....

....

.... [2]

Faraday's law of electromagnetic induction states that the magnitude of the induced e.m.f. in a conductor **[B1]** is directly proportional to the rate of change of magnetic flux linkage **[B1]** of the conductor.

(b) Two coils of insulated wire are wound on an iron bar, as shown in Fig. 5.1.

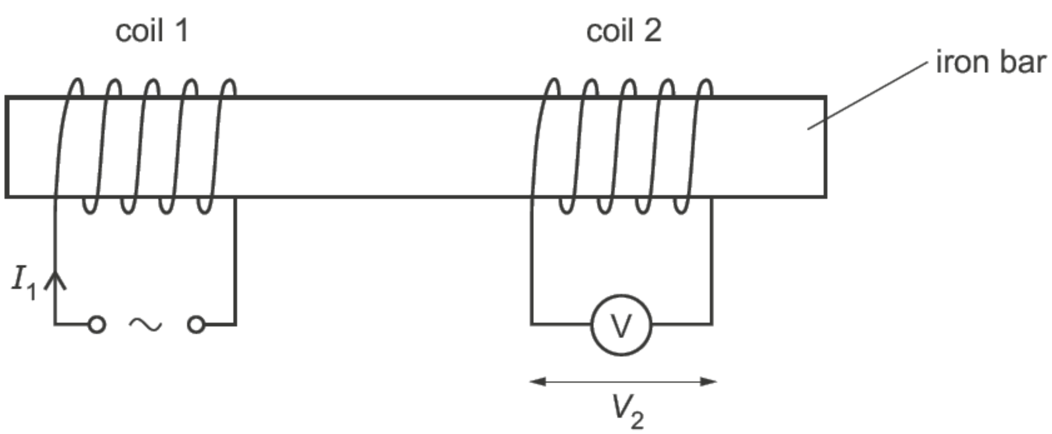


Fig. 5.1

There is a current I_1 in coil 1 that varies with time t as shown in Fig. 5.2.

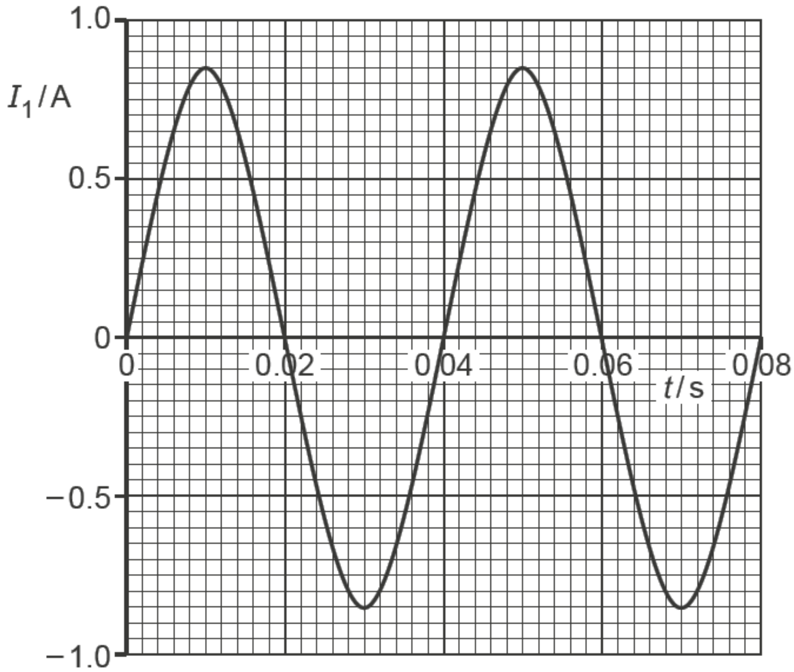


Fig. 5.2

(i) The variation with t of I_1 can be represented by the equation

$$I_1 = A \sin B(t)$$

where A and B are constants.

Use Fig. 5.2 to determine the values of A and B. Give units to your answers.

A = ... unit ....

B = ... unit .... [2]

From Fig. 5.2, A = 0.85 A **[A1]**

$B = 2\pi / T = 2\pi / 0.040$

= 160 (or 157) rad s^{-1} **[A1]**

(* Answers must include appropriate units)

(ii) The current in coil 1 gives rise to a magnetic field with a flux density that is proportional to I_1.

An electromotive force (e.m.f.) is induced across coil 2. The potential difference (p.d.) across coil 2 is measured using a voltmeter that gives a root-mean-square (r.m.s.) value of 4.6 V.

On Fig. 5.3, sketch a graph to show the variation with t of V_2 between t = 0 and t = 0.08 s.

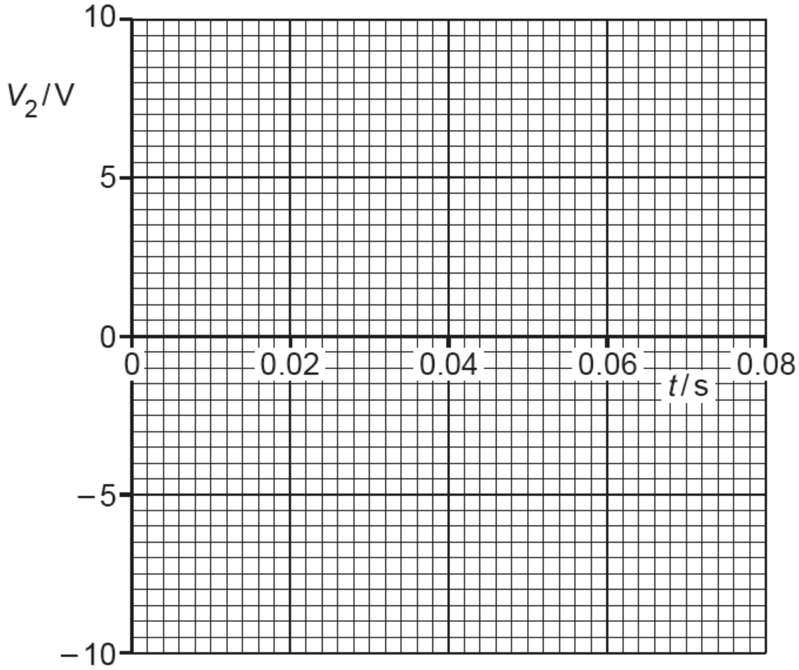


Fig. 5.3

[3]

[B1] – 2 cycles of a negative cosine graph (starting at (0, - 6.5)) with a

[B1] – Minimum e.m.f of zero at t = 0.01, 0.03, 0.05 and 0.07 s
- Maximum (magnitude) e.m.f. at t = 0, 0.02, 0.04, 0.06 and 0.08 s.
- period of 0.040 s.

[B1] - $V_0 = \sqrt{2}(4.6)$ = +/- 6.5 V at peak e.m.f. times.

(iii) Use the laws of electromagnetic induction to explain the shape of your graph in **(b)(ii)**.

....

....

....

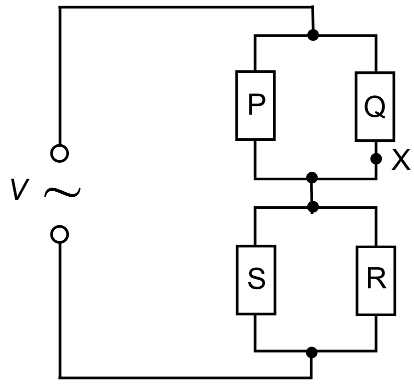
....

.... [3]

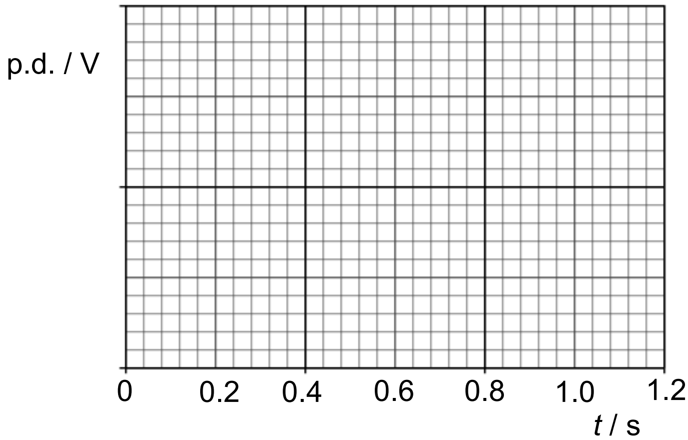
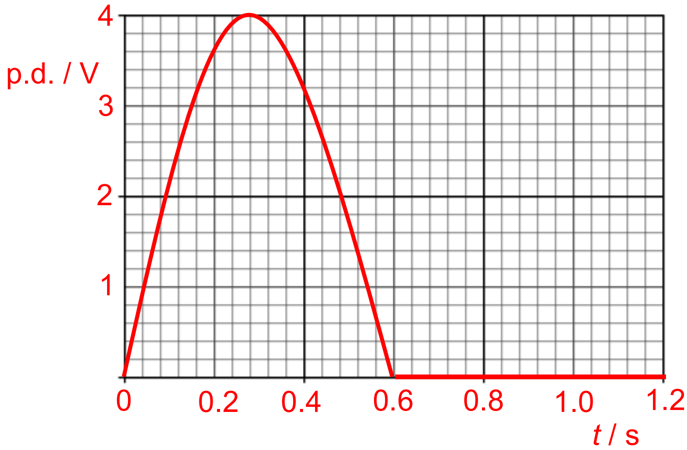
According to Faraday's law,
- Magnitude of V_2 is proportional to gradient of the $I_1 - t$ graph (Fig. 5.2)
- V_2 has maximum magnitude when gradient of the $I_1 - t$ graph is the steepest.

			- V_2 is zero when $I_1 - t$ graph is horizontal momentarily at its peak and minimum points. **2 x [B1] – Any 2 points above, 1 mark each** According to Lenz's law, - The induced e.m.f produces effects that opposes the magnetic flux linkage that causes it. - Hence, V_2 changes sign when the sign of the gradient of the $I_1 - t$ graph changes. **[B1] – 2nd point above**

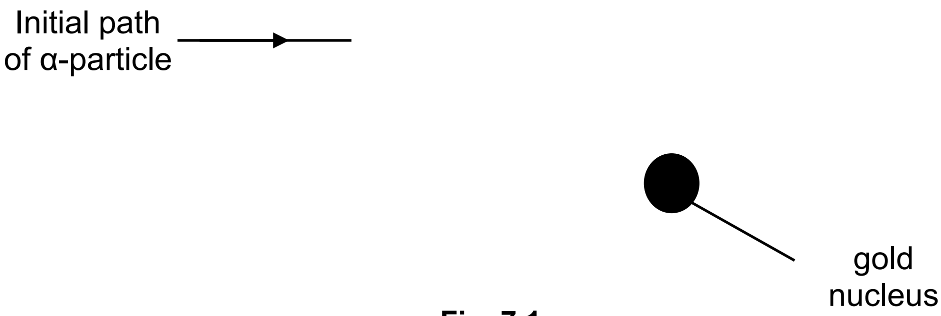
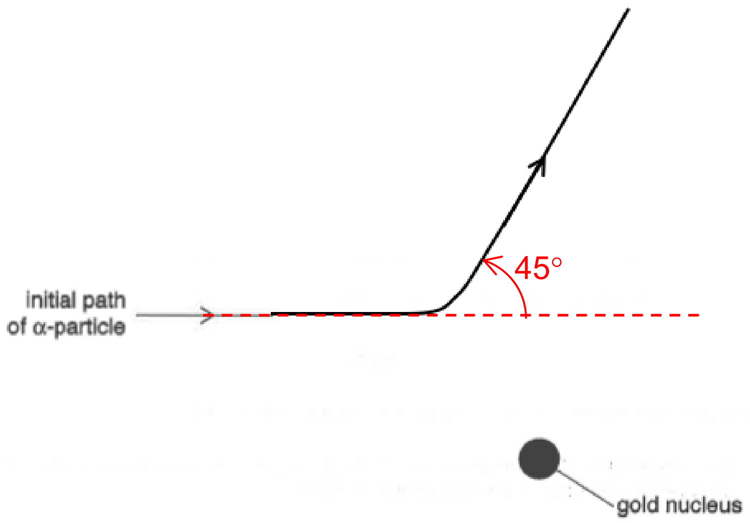
[Total: 10]

6	A sinusoidal voltage supply of peak voltage 8 V and period of 1.2 s is connected to a circuit as shown in Fig. 6.1. The circuit consists of four resistors P, Q, R and S, which has a resistance of 10 Ω each.  **Fig. 6.1**		
	(a)	Calculate the maximum potential difference across resistor P.	
		potential difference = ... V	[3]
		Solution Total resistance = $\left(\frac{1}{10}+\frac{1}{10}\right)^{-1}+\left(\frac{1}{10}+\frac{1}{10}\right)^{-1}=10\ \Omega$ Using potential divider principle, Maximum potential difference across P = $\frac{5}{10}(8)$ = 4 V	C1 M1 A1
	(b)	Determine the peak power dissipated across resistor P.	
		peak power = ... W	[2]
		Solution Peak power $=\frac{V_o^2}{R_p}=\frac{4^2}{10}$ (ecf allowed) = 1.6 W	M1 A1

[Turn over

	(c)	An ideal diode is connected in series with resistor Q at point X. On Fig. 6.2, sketch the variation with *t* of the p.d. across resistor Q for a time of 1.2 s. Add a scale to the y-axis.  **Fig. 6.2** [2]	
		Solution  Correct shape of graph. (accept cosine) Correct labelling of graph.	B1 B1

[Total: 7]

7	**(a)**	In the Rutherford α-particle scattering experiment, α-particles are emitted from a source and travel towards a thin gold foil.	
		(i)	An α-particle is deflected through an angle of approximately 45° as it passes near a stationary gold nucleus. On Fig. 7.1, sketch the path of the α-particle as it passes the gold nucleus.  **Fig. 7.1** [1]
			Solution:  Marking points: (B1 - both have to be present) - Deflect away from the nucleus, since like charges repel. - Deviation through 45°.
		(ii)	Only a small proportion of the α-particles incident on the metal foil are deflected through large angle deflections greater than 90°. Explain the following phenomenon.
			....

			....[2]	
			Solution: The atom contains a **small**, **positively charged nucleus** that is **very small compared to the overall size of the atom**, so only a **small proportion of alpha particles** come close enough to it. These alpha particles experience **strong electrostatic repulsion**, which can cause deflections greater than 90° since **alpha particles are also positively charged**.	B1 B1
		(ii)	In the α-particle scattering experiment, a large number of alpha particles are directed at the metal foil. Explain why a large number of alpha particles is necessary.	
			....[2]	
			Solution: Large angle deflections are rare / occur for only a small proportion of alpha particles. A large number ensures that enough deflections are observed to draw reliable conclusions / obtain statistically significant results.	B1 B1
	(b)	An α-particle with kinetic energy 7.7×10^{-13} J is directed at a stationary gold nucleus ($^{197}_{79}$Au). Determine the minimum separation possible between this α-particle and the gold nucleus.		
		separation = ... m		[3]
		Solution: Given: • Charge of α-particle: $Q_1 = 2e = 2 \times 1.60 \times 10^{-19}$ C • Charge of gold nucleus: $Q_2 = 79e = 79 \times 1.60 \times 10^{-19}$ C		

		At the start of the alpha particle's motion, when it is far away from the nucleus, the electric potential energy is taken to be zero. By conservation of energy, Gain in EPE = loss in KE $\frac{Q_1Q_2}{4\pi\varepsilon_0 r} = E_k$ $r = \frac{Q_1Q_2}{4\pi\varepsilon_0 E_k} = \frac{(2 \times 1.60 \times 10^{-19}) \times (79 \times 1.60 \times 10^{-19})}{4\pi(8.85x10^{-12})7.7 \times 10^{-13}}$ *[correct substitution]* $r = 4.7 \times 10^{-14}$ m	B1 M1 A1
	(c)	The metal foil is changed from gold ($^{197}_{79}Au$) to carbon ($^{12}_{6}C$), while the α-particle energy is kept the same. State and explain how the number of large-angle deflections would change.	
		....[2]	
		Solution: As carbon nuclei have a smaller positive charge (atomic number 6) compared to gold (atomic number 79), the electrostatic repulsion between the α-particle and the carbon nucleus is weaker. As a result, fewer α-particles are deflected through large angles, so the number of large-angle deflections decreases.	M1 A1

[Total: 10]

Section B

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

8 (a) Define *simple harmonic motion*

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

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

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

Simple harmonic motion is a periodic motion in which the **acceleration is proportional to the displacement from the equilibrium position** **B1**

And **directed towards the equilibrium position** OR **in the opposite direction to the displacement.** **B1**

(b) **Fig. 8.1** shows the force–extension graph for a light spring.

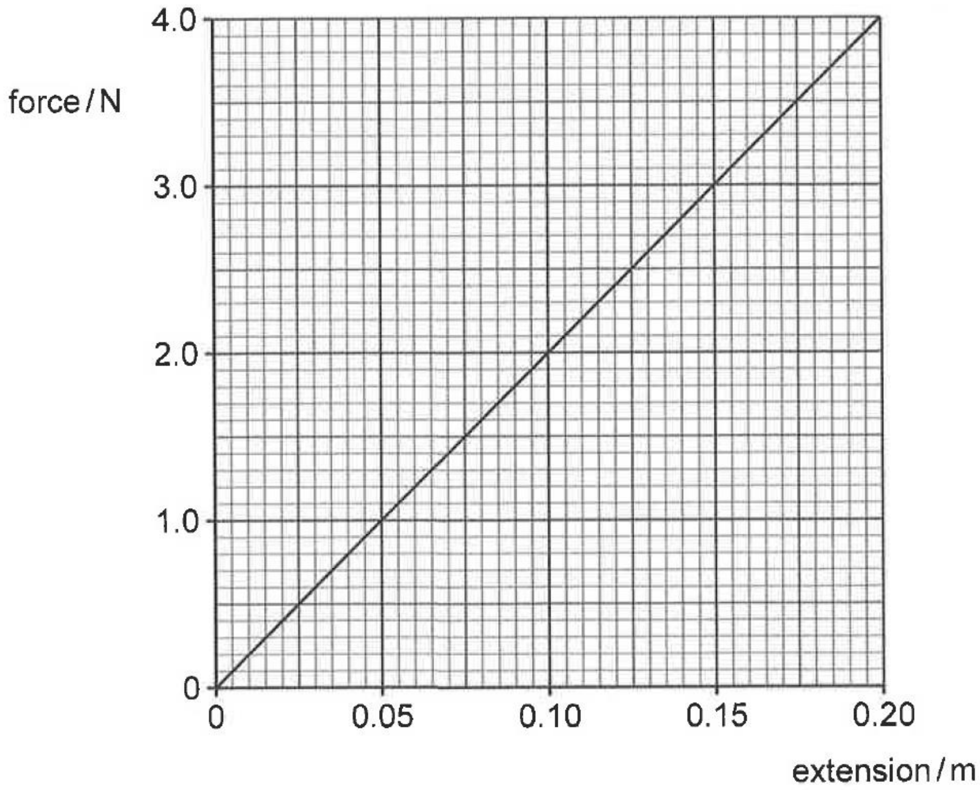


Fig 8.1

The spring described by Fig. 8.1 is attached to a fixed point on the ceiling and a mass of 2.0 N is hung on the spring.

Once the mass reaches its equilibrium position, it is displaced a further 0.15 m downward and released, such that it oscillates with simple harmonic motion.

		(i)	Determine the force constant k of the spring.	
			k = ………………………………. N m^{-1}	[2]
			Solution: $k = \frac{F}{x} = \frac{4.0\text{N}}{0.20\text{m}}$ $k = 20.0\ \text{N m}^{-1}$	**M1** **A1**
		(ii)	Show that the maximum acceleration of the mass when it is oscillating in simple harmonic motion is 14.7 m s^{-2}.	
				[3]
			Solution: *At amplitude position* $F_{net} = kx - mg$ [*mark for setting up* F_{net} *correctly*] $F_{net} = (20.0)(0.10 + 0.15) - 2.0$ $F_{net} = 3.0\ N$ [*mark for the correct value*] $ma = 3.0\ N$ $\frac{2.0}{9.81}a = 3.0$ [*mark for correct substitution in ma*] $a = 14.7 m\ s^{-2}$	**M1** **C1** **M1** **A0**
		(iii)	Hence, determine the period of the oscillation.	

			period = …………………….. s	[3]
			Solution: using $a = -\omega^2 x$ $a_0 = -\omega^2 x_0$ $-14.7 = -\omega^2 (0.15)$ $\omega^2 = \frac{14.7}{0.15} = 98$ $\omega = 9.90 \text{ rad s}^{-1} = \frac{2\pi}{T}$ $T = 0.63 \text{ s}$	**M1** **M1** **A1**
	(c)	On Fig. 8.2, sketch the variations with time of the displacement *x*, the velocity *v* and the acceleration *a* of the object for two complete oscillations, starting at *t* = 0. Take upwards as positive. Include an appropriate scale on the axes.		

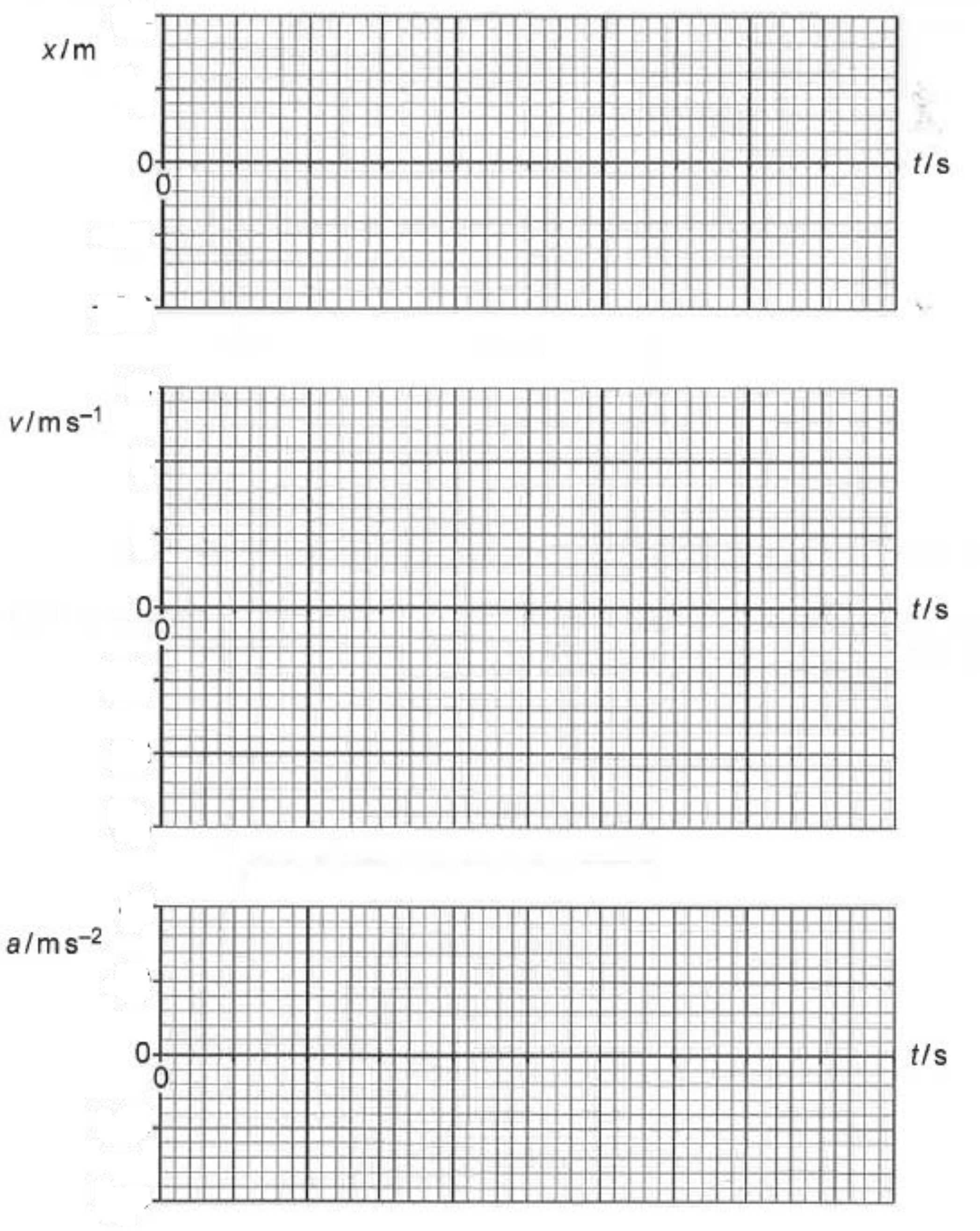
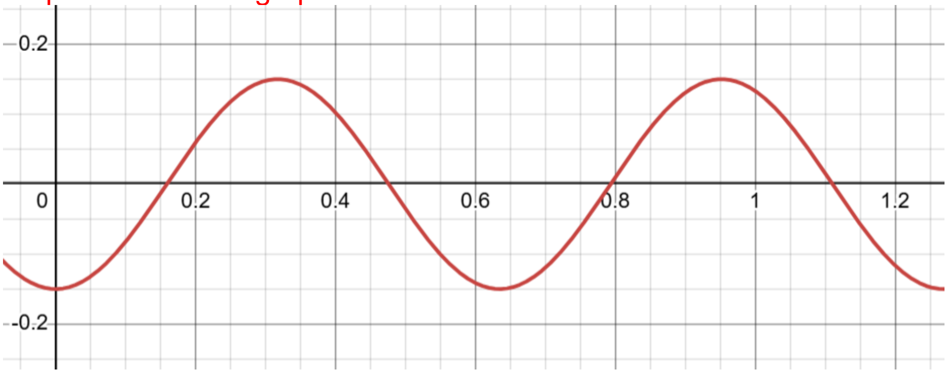


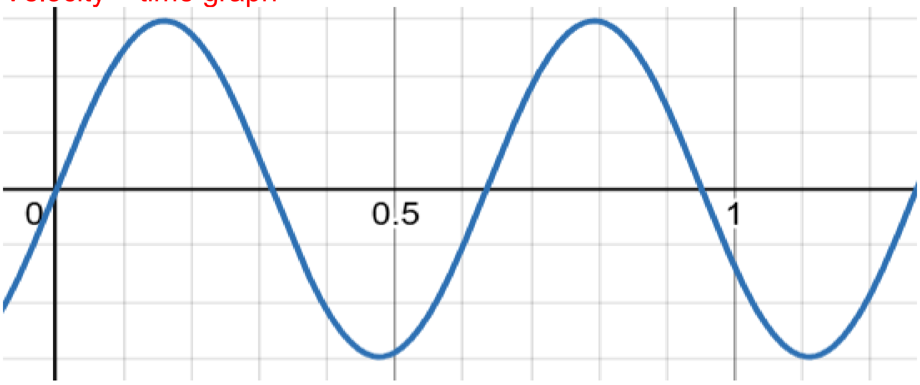
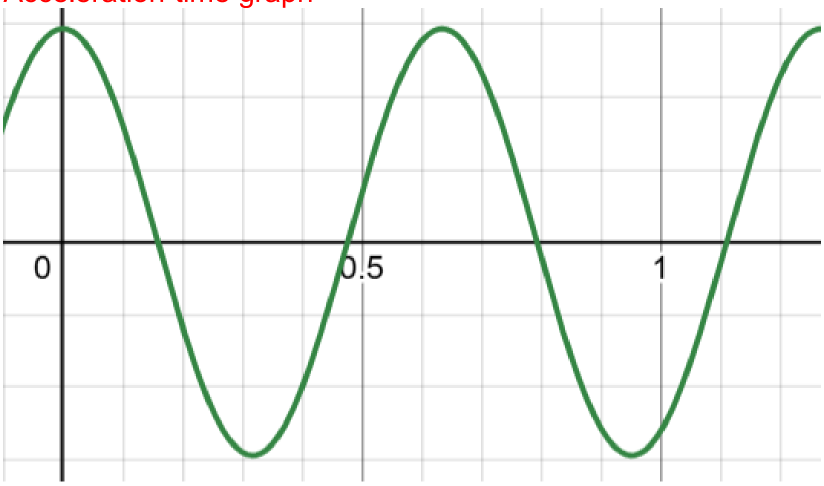
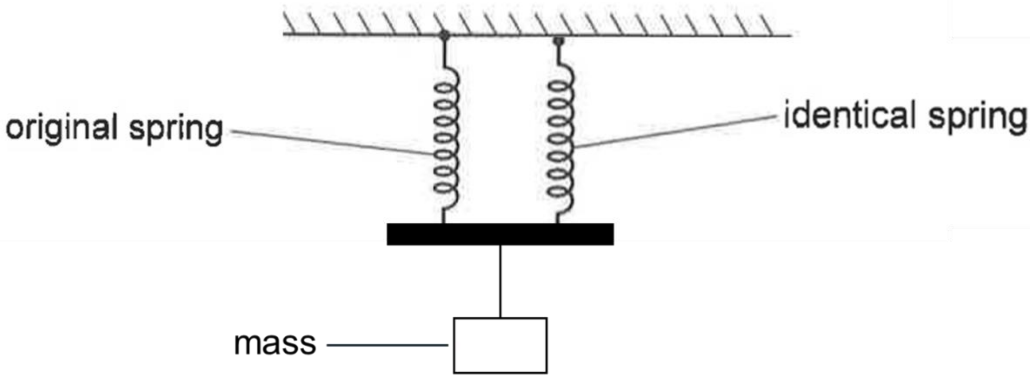
Fig. 8.2

[6]

Solution:

Displacement-time graph



		1 mark: negative cos curve for 2 cycles (regardless of period value) 1 mark: amplitude = 0.15 m (ecf), period = 0.63 s (ecf) Velocity – time graph  1 mark: positive sin curve for 2 cycles (regardless of period value) 1 mark: max v = 1.5 m s^{-1}(from $v_0 = \omega x_0 = \frac{2\pi}{0.63} \times 0.15$), period = 0.63 s (ecf if wrong value but same as x-t graph) Acceleration-time graph  1 mark: positive cos curve for 2 cycles (regardless of period value) 1 mark: max a = 14.7 m s^{-2}, period = 0.63 s (ecf if wrong value but same as x-t graph)	B1 B1 B1 B1 B1 B1
	(d)	A second, identical spring is attached in parallel to the first spring as shown in Fig. 8.3.  **Fig. 8.3**	

		(i)	State and explain how the extension of the spring system compares with that of the original single spring when the same 2.0 N mass is suspended from it.	
			....	
			....	
			....	[2]
			Solution: Effective spring constant **doubles** for springs in parallel Extension is **halved**	 **M1** **A1**
		(ii)	The mass is again displaced by 0.15 m and released to oscillate. State and explain how the period of oscillation of the new system compares with the period found in **(b)(iii)**.	
			....	
			....	
			....	
			....	
			....	[2]
			Solution: Higher *k* means **resultant force is higher**, **acceleration is higher** and **angular frequency is higher**. Hence, **period decreases**.	 **M1** **A1**

[Total: 20]

9	(a)	Two point charges A and B are placed in a vacuum 10.0 cm apart, as illustrated in Fig. 9.1. A point P lies on the line joining the charges, at a distance x from charge A. The variation of electric field strength E with distance x is shown in Fig. 9.2.	

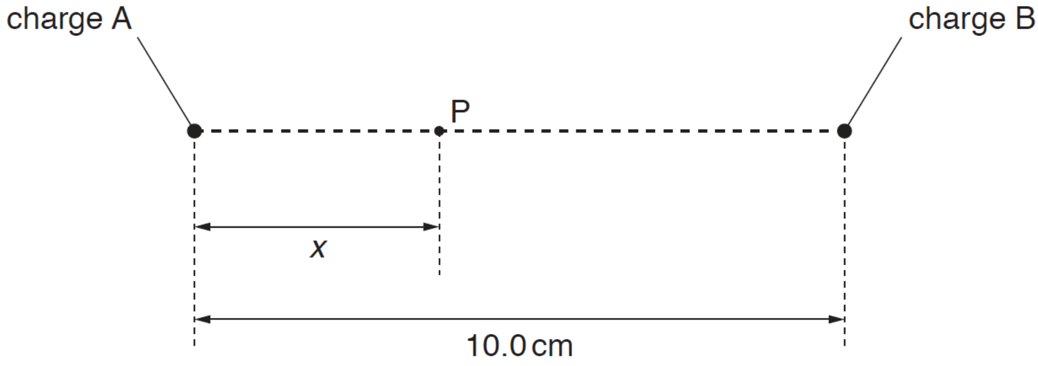


Fig. 9.1

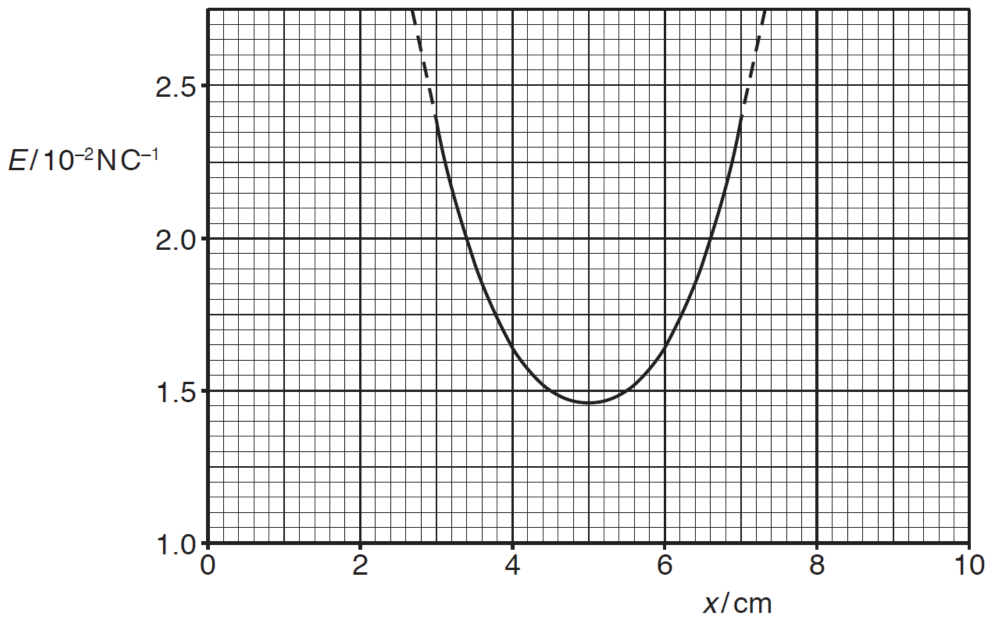


Fig. 9.2

State and explain whether the charges A and B:

		(i)	have the same, or opposite, signs.
			....
			....
			....[2]

Solution:

The electric field **does not change direction/ always positive / field strength does not become zero** along the line between the charges. M1

The charges have **opposite signs**. A1

		(ii)	State and explain whether the charges A and B have the same, or different, magnitudes.	
			……………………………………………………………………………………………… ……………………………………………………………………………………………… …………………………………………………………………………………………[2]	
			Solution: The electric field strength is **minimum at the midpoint** between the charges. (accept: graph is symmetric about the midpoint, not accepting parabola) This implies that both charges produce electric fields of **equal magnitude** at that point, so the charges must have the **same magnitude**.	M1 A1
	(b)	An electron is situated at point P. Without calculation, state and explain the variation in the magnitude of the acceleration of the electron as it moves from the position where x = 3.0 cm to the position where x = 7.0 cm.		
		……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… …………………………………………………………………………………………[4]		
		Solution: Acceleration is proportional to electric field strength, (use F = qE and F = ma → a ∝ E) From x = 3.0 cm to x = 5.0 cm: Electric field strength decreases → acceleration decreases. At x = 5.0 cm: Electric field strength is minimum → acceleration is minimum From x = 5.0 cm to x = 7.0 cm: Electric field strength increases → acceleration increases.	B1 B1 B1 B1	
	(c)	Determine the acceleration of the electron at x = 7.0 cm.		

[Turn over

acceleration = ... m s^{-2} [3]

Solution:

Read off the value of E from the graph at x = 7.0 cm
$E = 2.4 \times 10^{-2}$ N C^{-1} (accept 2.35) B1

Using Newton's Second Law:
$F = qE$ and $F = ma \Rightarrow a = \frac{Eq}{m}$ M1
$a = \frac{2.4 \times 10^{-2} \times 1.60 \times 10^{-19}}{9.11 \times 10^{-31}}$

$a = 4.21 \times 10^{9}$ m s^{-2} A1

(d) A particle of charge +q and mass m is travelling with a constant speed of 1.6×10^5 m s^{-1} in a vacuum. The particle enters a uniform magnetic field of flux density 9.7×10^{-2} T, as shown in Fig. 9.3.

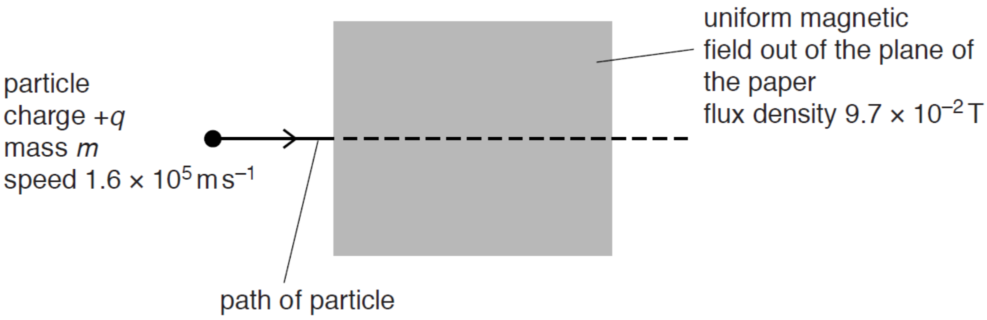


Fig. 9.3

The magnetic field direction is perpendicular to the initial velocity of the particle and perpendicular to, and out of, the plane of the paper.

A uniform electric field is applied in the same region as the magnetic field so that the particle passes undeviated through the fields.

(i) State and explain the direction of the electric field.

....

....

....[2]

Solution:

The **magnetic field exerts a downward force** on the positively charged particle (using Fleming's left-hand rule). To prevent deflection, the **electric field must exert an equal force in the opposite direction/ upwards.** M1

			Therefore, the electric field is directed **up the page** (same direction as electric force on a positive charge).	A1
		(ii)	The electric field is now removed so that the positively charged particle follows a curved path in the magnetic field. This path is an arc of a circle of radius 4.0 cm. Calculate, for the particle, the ratio $\frac{q}{m}$.	
			ratio = ...C kg^{-1}	[2]
			Solution Magnetic force provides the centripetal force. $\frac{mv^2}{r} = Bqv$ $\frac{q}{m} = \frac{v}{Br}$ $\frac{q}{m} = \frac{(1.6 \times 10^5)}{[(9.7 \times 10^{-2})(4.0 \times 10^{-2})]}$ $= 4.1 \times 10^7$ C kg^{-1}	 M1 A1
		(iii)	Determine the time taken for the particle to complete one full circle.	
			time taken = ... s	[2]
			Solution: $T = \frac{2\pi r}{v} = \frac{2\pi(0.040)}{1.6 \times 10^5}$ T = 1.57×10^{-6} s	 M1 A1

[Turn over

(e) With the electric field still switched off, a proton enters the same uniform magnetic field, but at an angle of 30° to the magnetic field lines as shown in Fig. 9.4.

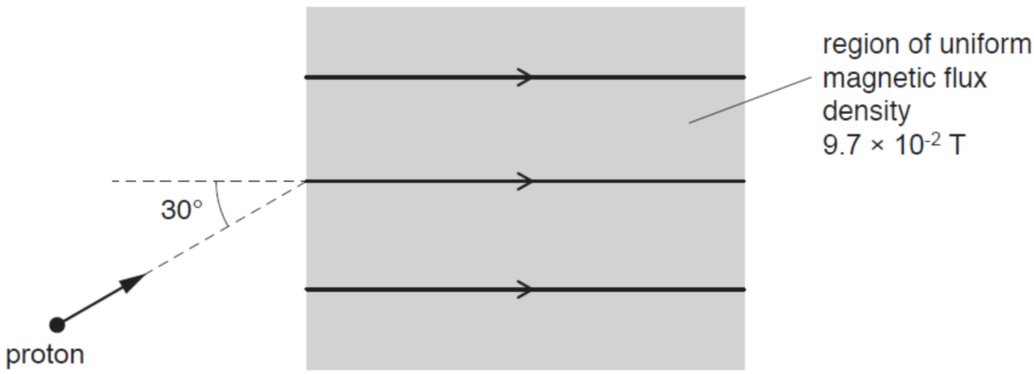


Fig. 9.4.

(i) Describe the resultant path of the proton in the magnetic field.

....

....[1]

Solution:

It follows a helical path. It is a helix. B1

(ii) Determine the speed of the proton if it experiences a magnetic force of 4.7×10^{-15} N.

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

Solution:

Magnetic force provides the centripetal force

$Bqv\sin\theta = 4.7 \times 10^{-15}$

$v = \frac{F}{Bq\sin\theta} = \frac{4.7 \times 10^{-15}}{9.7 \times 10^{-2}(1.6 \times 10^{-19})\sin 30}$ M1

$v = 6.0 \times 10^{5}$ m s^{-1} A1

END OF PAPER