Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
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	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/{}^{\circ}C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
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	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
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.

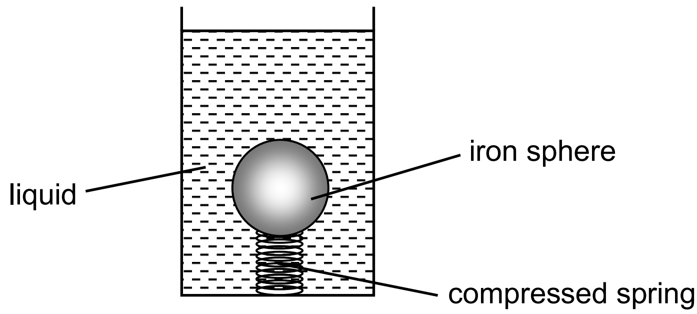


Fig. 1.1

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

[1]

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

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

(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.

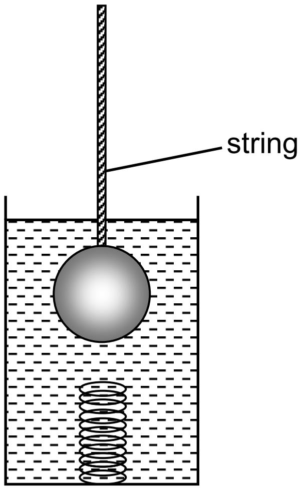


Fig. 1.2

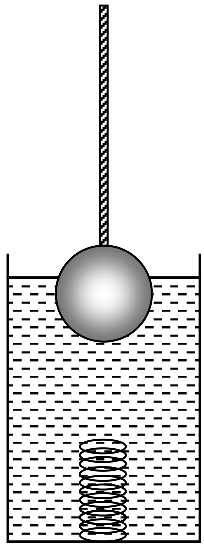


Fig. 1.3

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

…………………………………………………………………………………………...

…………………………………………………………………………………………...

…………………………………………………………………………………………...

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

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

volume = ……….…………..…………… m^3 [3]

[Total: 8]

[Turn over

2 A satellite S of mass m is in a stable circular orbit at an altitude of $2R$ 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.

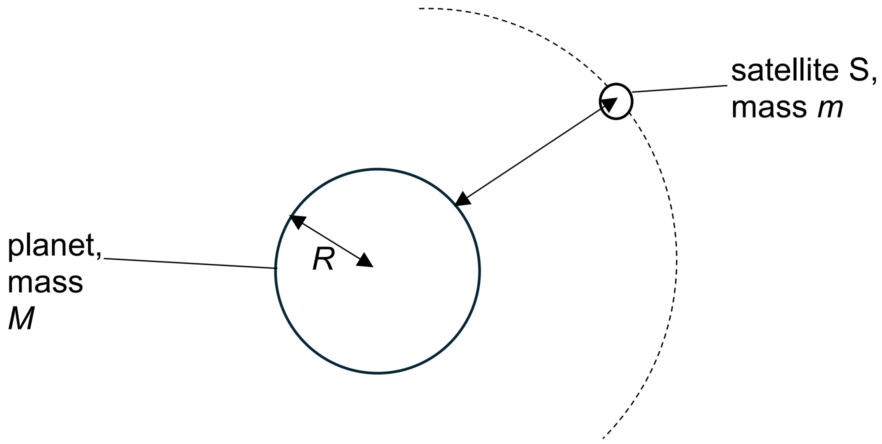


Fig. 2.1

(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]

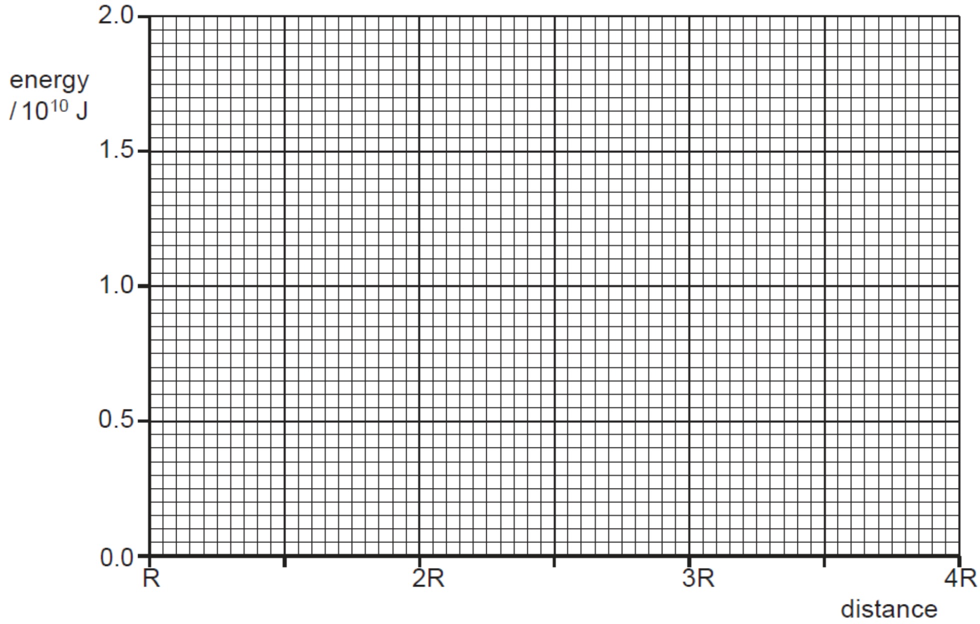
(b) The planet has mass 4.5×10^{24} kg and radius of 5.5×10^3 km. The satellite has a mass of 1500 kg.

Determine the total energy of satellite S in orbit.

total energy = ………………………………. J [2]

(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.



[2]

Fig 2.2

(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]

[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.

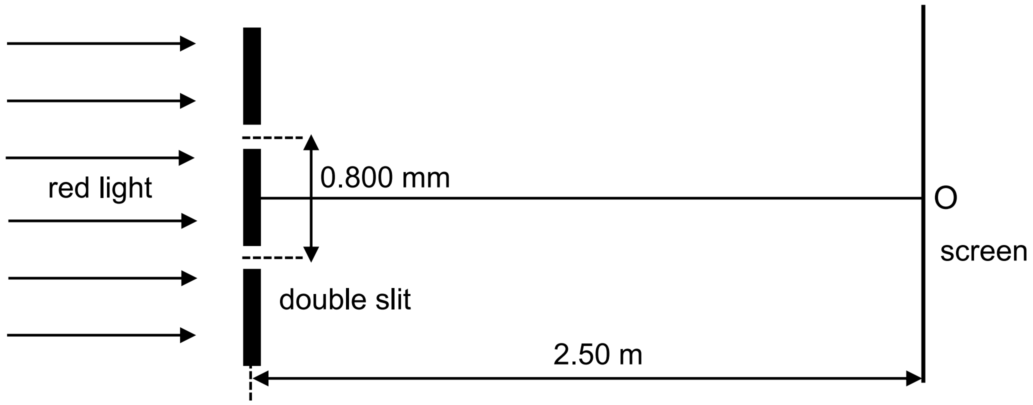


Fig. 3.1

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

....

....

....

.... [2]

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

....

....

....

.... [2]

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

separation = ... m [3]

(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]

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

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…………………………………………………………………………………………...

…………………………………………………………………………………………...

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

[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 internal energy.

....

....

....

.... [2]

(b) The coin does not undergo a change in volume after it lands on the ground.

Determine the gain in temperature of the coin given that the specific heat capacity of copper is 385 J kg^{-1} K^{-1}. Assume 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]

(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]

[Total: 6]

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

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

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

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

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

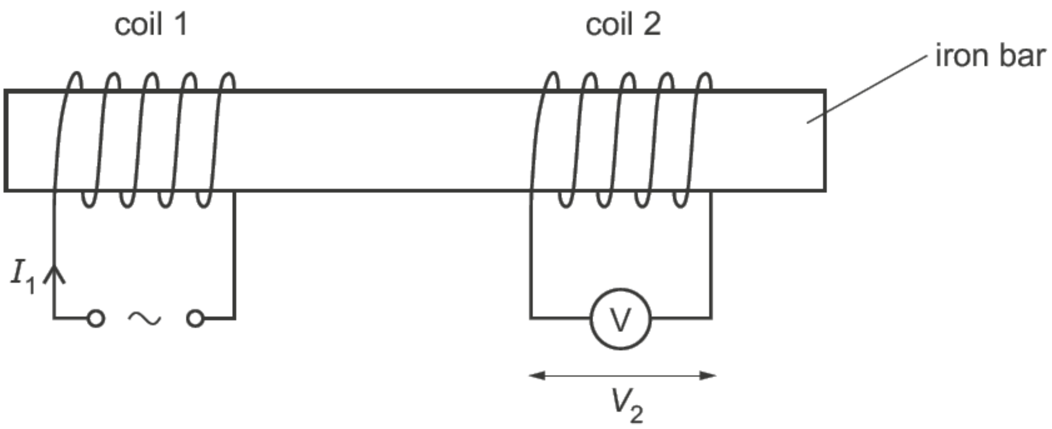

Fig. 5.1

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

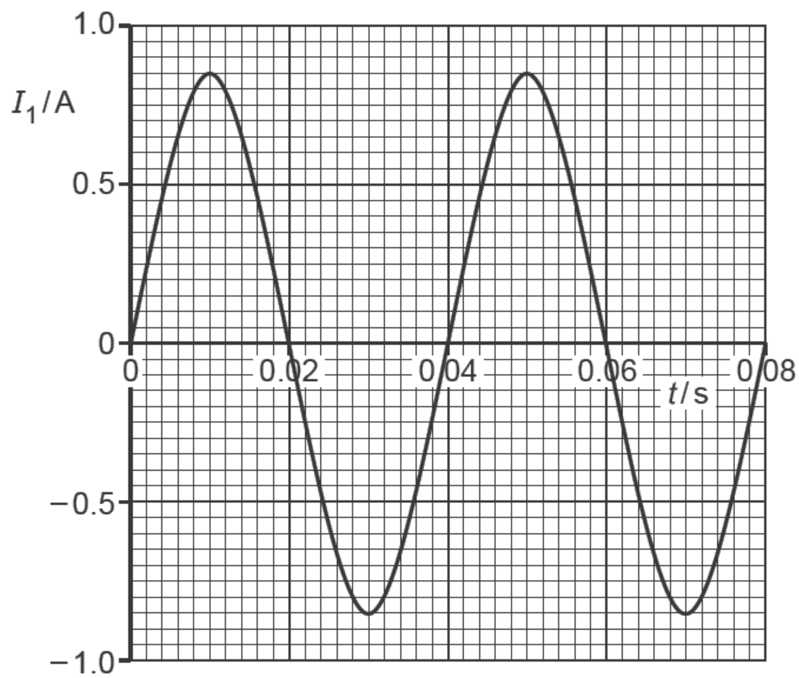

Fig. 5.2

(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]

(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.

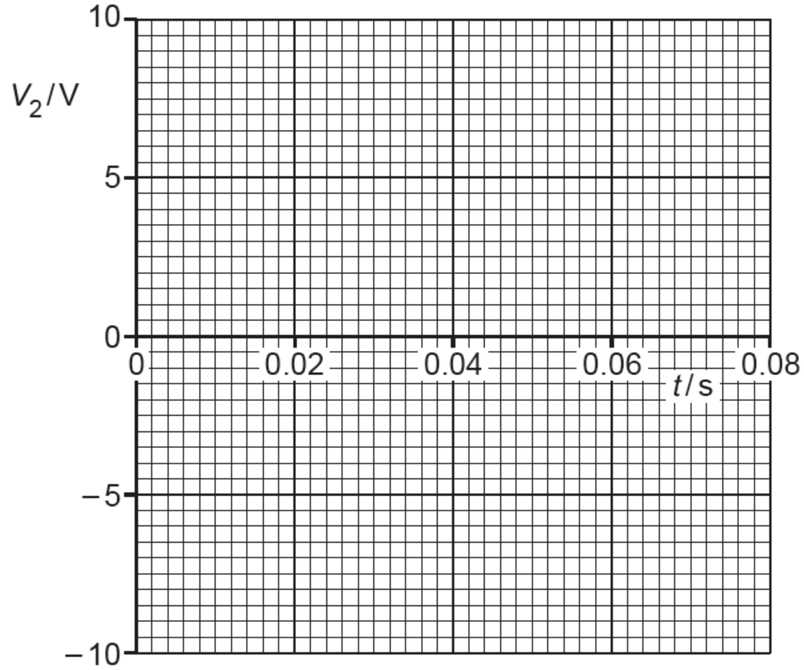

Fig. 5.3

[3]

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

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

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

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

……………………………………………………………………………………… [3]

[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.

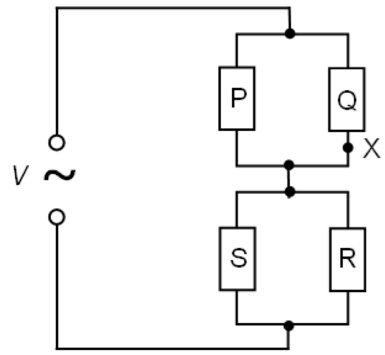

Fig. 6.1

(a) Calculate the maximum potential difference across resistor P.

potential difference = ... V [3]

(b) Determine the peak power dissipated across resistor P.

peak power = ... W [2]

(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.

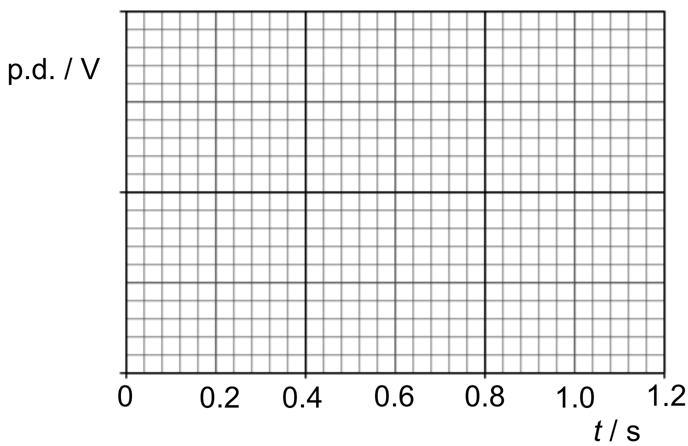

Fig. 6.2 [2]

[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.

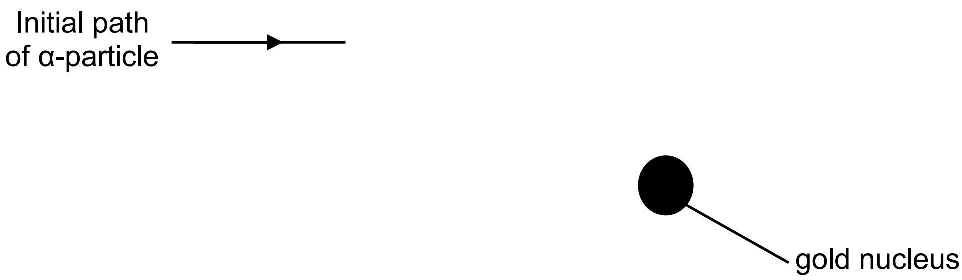

Fig. 7.1

[1]

(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]

(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.

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(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]

(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]

[Total: 10]

Section B

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

8 **(a)** Define *simple harmonic motion.*

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

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

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

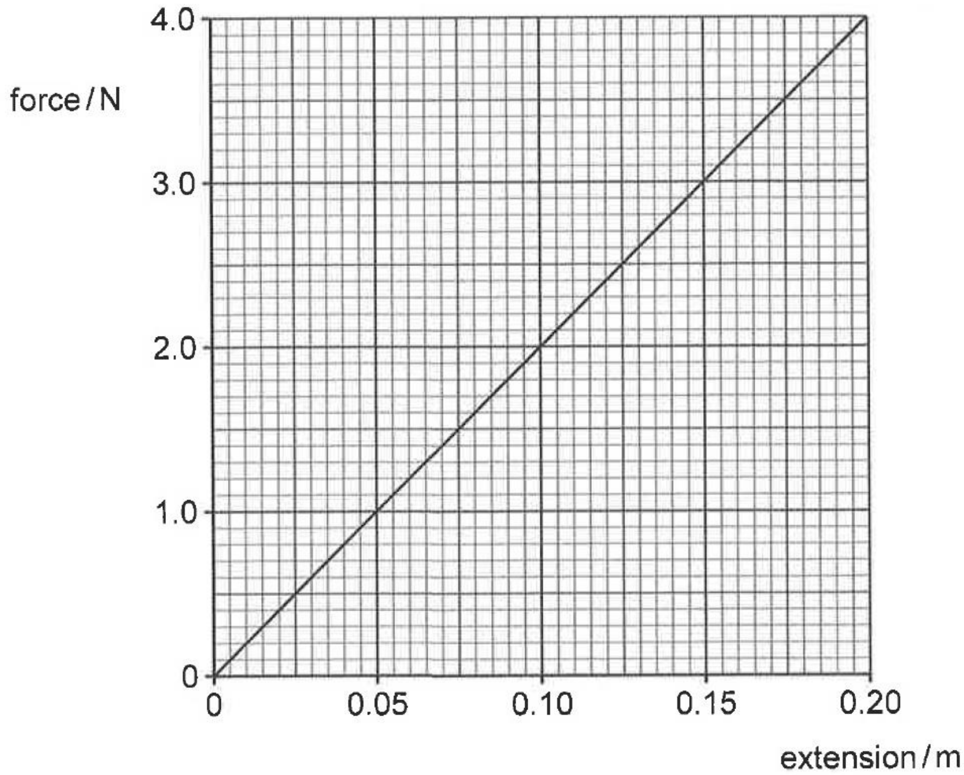

Fig 8.1

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]

(ii) Show that the maximum acceleration of the mass when it is oscillating in simple harmonic motion is 14.7 m s^{-2}.

[3]

(iii) Hence, determine the period of the oscillation.

period = …………………….. s [3]

(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 $t = 0$ when the mass is at its lowest position. Take upwards as positive.

Include an appropriate scale on the axes.

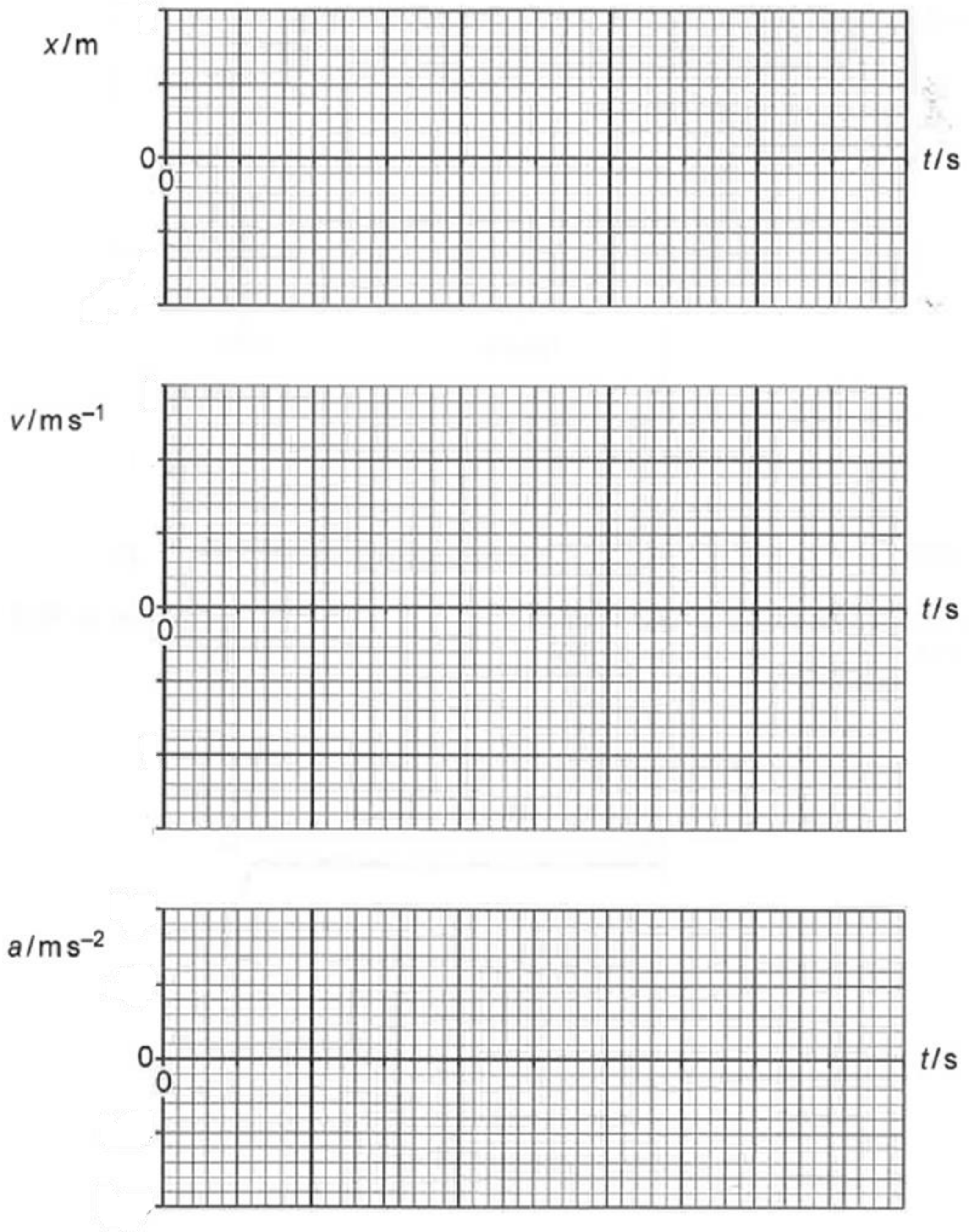

Fig. 8.2

[6]

(d) A second, identical spring is attached in parallel to the first spring as shown in Fig. 8.3.

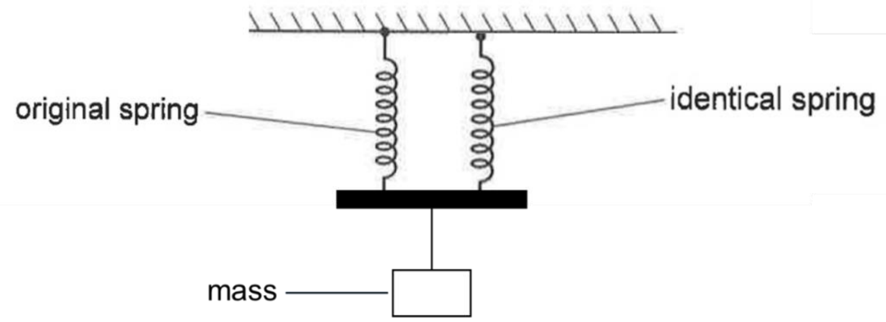

Fig. 8.3

(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]

(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)**.

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

[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.

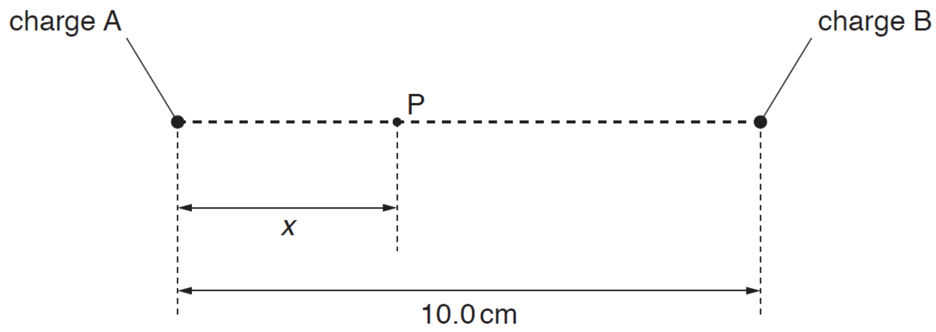

Fig. 9.1

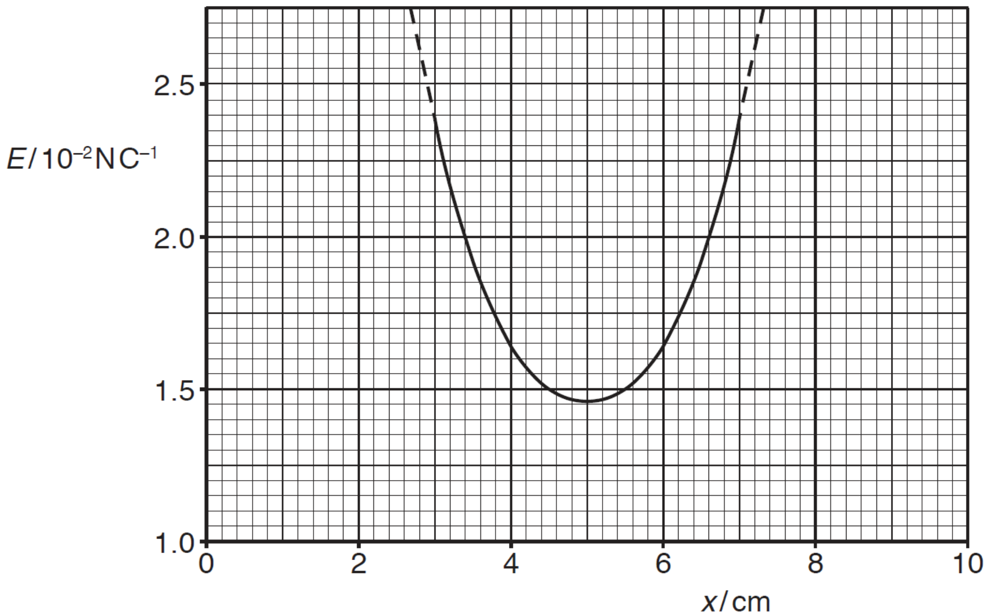

Fig. 9.2

State and explain whether the charges A and B:

(i) have the same, or opposite, signs.

....

....

.... [2]

(ii) State and explain whether the charges A and B have the same, or different, magnitudes.

....

....

.... [2]

[Turn over

(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]

(c) Determine the acceleration of the electron at x = 7.0 cm.

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

(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.

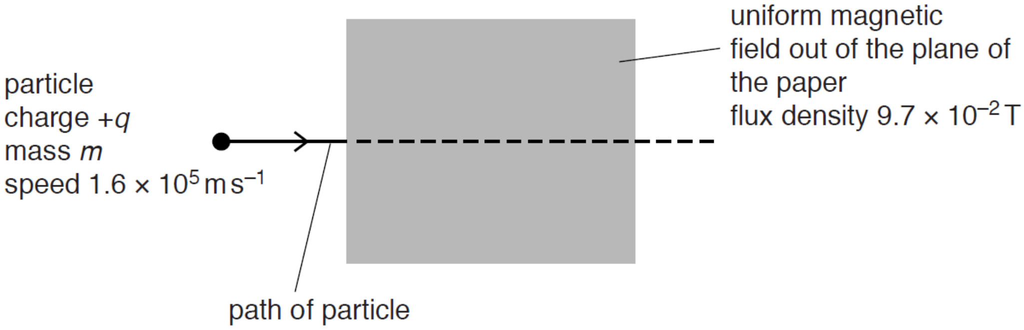

Fig. 9.3

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]

(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]

(iii) Determine the time taken for the particle to complete one full circle.

time taken = ………………………… s [2]

(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.

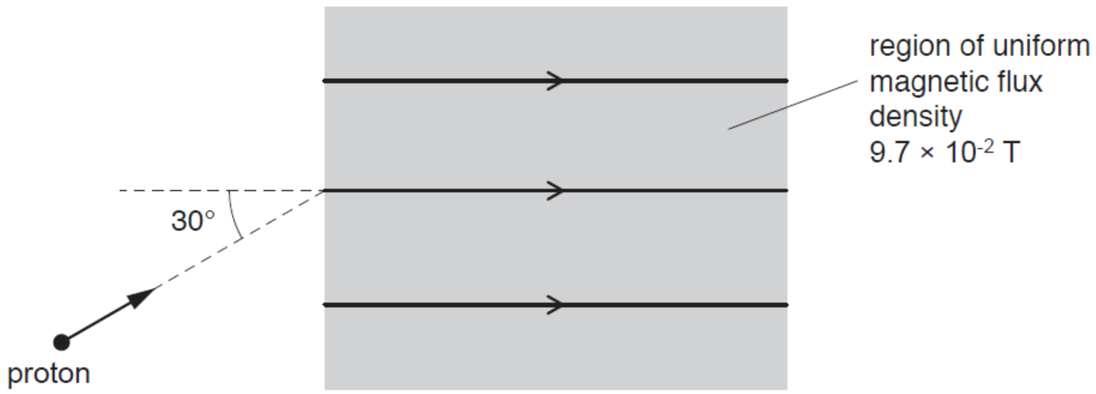

Fig. 9.4.

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

....

.... [1]

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

speed = ………………………….. m s^{-1} [2]

[Total: 20]

END OF PAPER