Name: ______________________________ (   )   Class: 24 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2024 JC2 Preliminary Examination

PHYSICS Higher 1 — 8867/02

Paper 2 Structured Questions — **Thursday 12 September 2024**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class in the spaces provided above.
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.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

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	
Paper 1 (30 marks)	
Paper 2 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
Deductions	
Total	

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

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$

Section A

Answer **all** the questions in this section.

1 **(a)** Length, mass and amount of substance are all SI base quantities.

(i) State **two** other SI base quantities.

1. ……………………………………………………………………………………………..

2. ……………………………………………………………………………………………..

[2]

(ii) State **one** derived quantity.

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

(b) The acceleration of free fall g may be determined from an oscillating pendulum using the equation

$$g = \frac{4\pi^2 l}{T^2}$$

where l is the length of the pendulum and T is the period of oscillation.

In an experiment, the measured values for an oscillating pendulum are

l = 1.50 m ± 2%
and T = 2.48 s ± 3%.

(i) Determine the percentage uncertainty in g.

percentage uncertainty = …………………………….. [1]

(ii) Calculate g together with its uncertainty.

g = ………………………….. ± ………………… m s^{-2} [3]

[Total 7]

2 A sky-diver jumps from a high-altitude balloon. The variation with time t of the vertical acceleration a of the sky-diver is shown in Fig. 2.1.

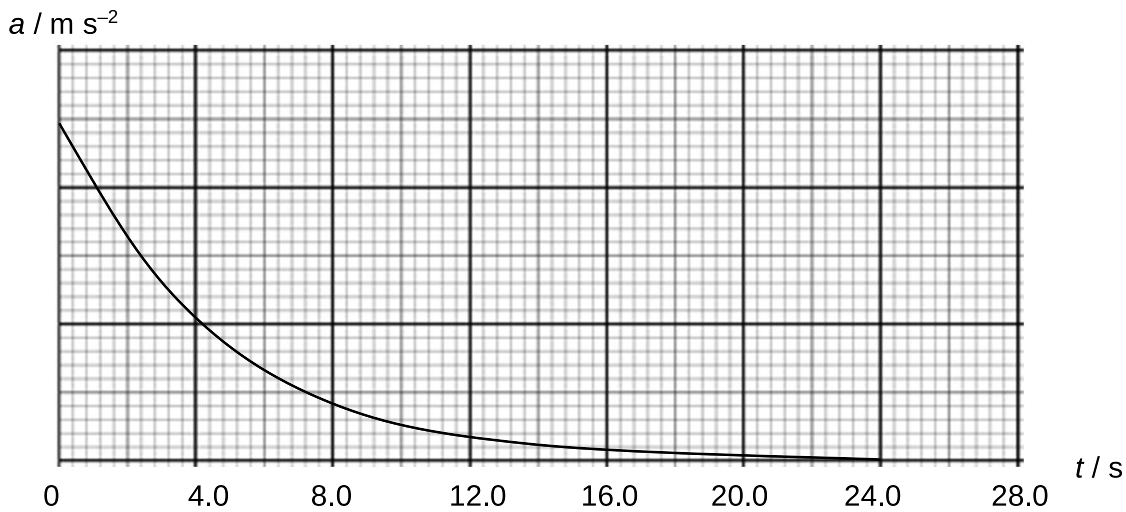

Fig. 2.1

(a) Explain why the acceleration of the sky-diver decreases with time.

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

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

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

(b) State and explain whether the acceleration at the start of the jump is greater than, equals to, or less than 9.81 m s^{-2}.

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

(c) With reference to Fig. 2.1, describe the motion of the sky-diver.

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

(d) Explain how the maximum velocity of the sky-diver can be determined from Fig. 2.1.

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(e) Sketch the displacement-time graph of the sky-diver on Fig. 2.2.

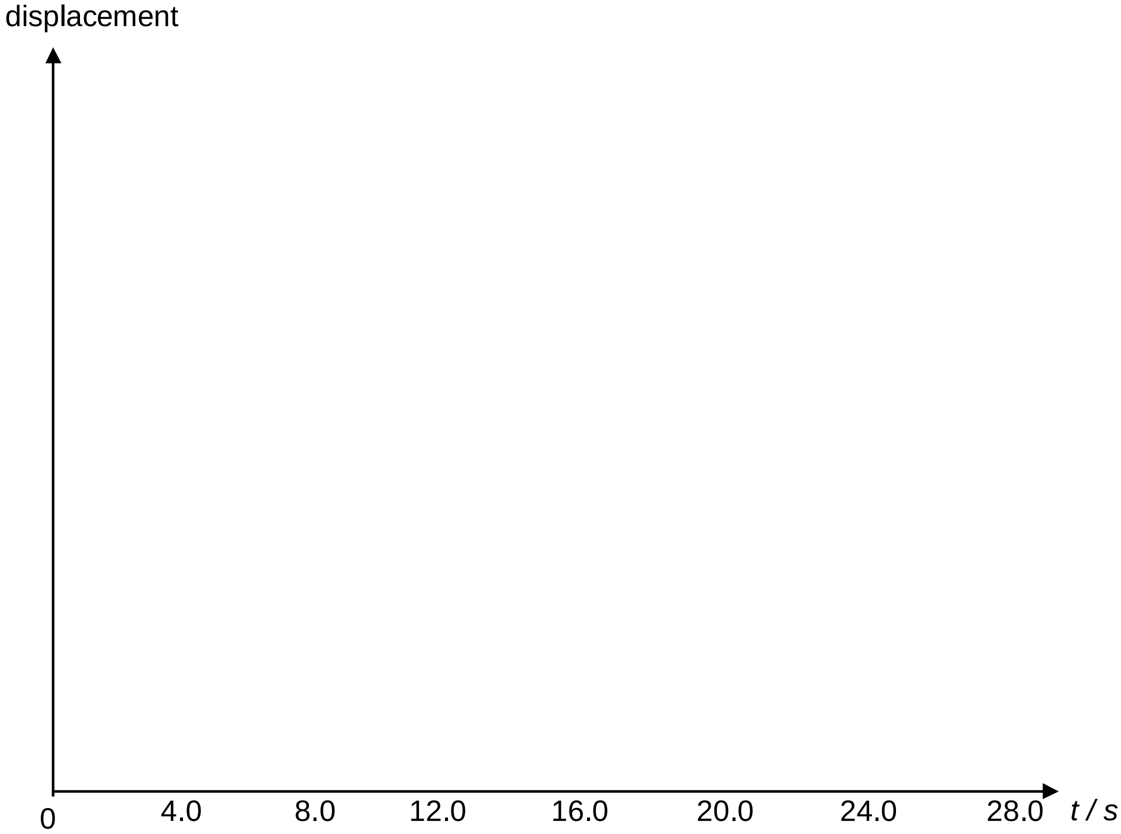

Fig. 2.2

[2]

[Total : 10]

3 A uniform beam AB is attached by a hinge to a wall at end A, as shown in Fig. 3.1.

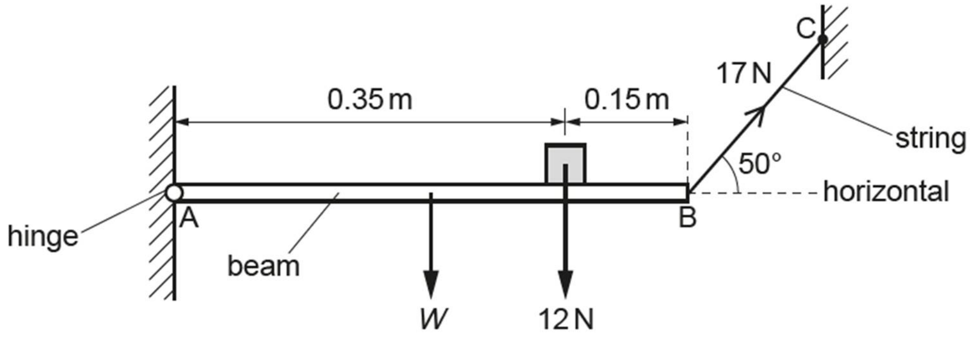

Fig. 3.1 (not to scale)

The beam has length 0.50 m and weight W. A block of weight 12 N rests on the beam at a distance of 0.15 m from end B.

The beam is held horizontal and in equilibrium by a string attached between end B and a fixed point C. The string has a tension of 17 N and is at an angle of 50° to the horizontal.

(a) State **two** conditions for an object to be in equilibrium.

1 ……………………………………………………………………………………………………

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

2 ……………………………………………………………………………………………………

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

(b) Show that the weight W of the beam is 9.2 N.

[2]

(c) A force F acts on the beam at A. Calculate the magnitude of F.

F = ……………………………N [3]

(d) The block is now moved closer to end A of the beam. Assume that the beam remains horizontal.

State and explain whether this change will increase, decrease or have no effect on the horizontal component of the force exerted on the beam by the hinge.

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[Total: 9]

4 This question is about the conduction properties of semiconductor and metal.

The variation with temperature θ of the resistance R of a sample of semiconducting material is shown in Fig. 4.1.

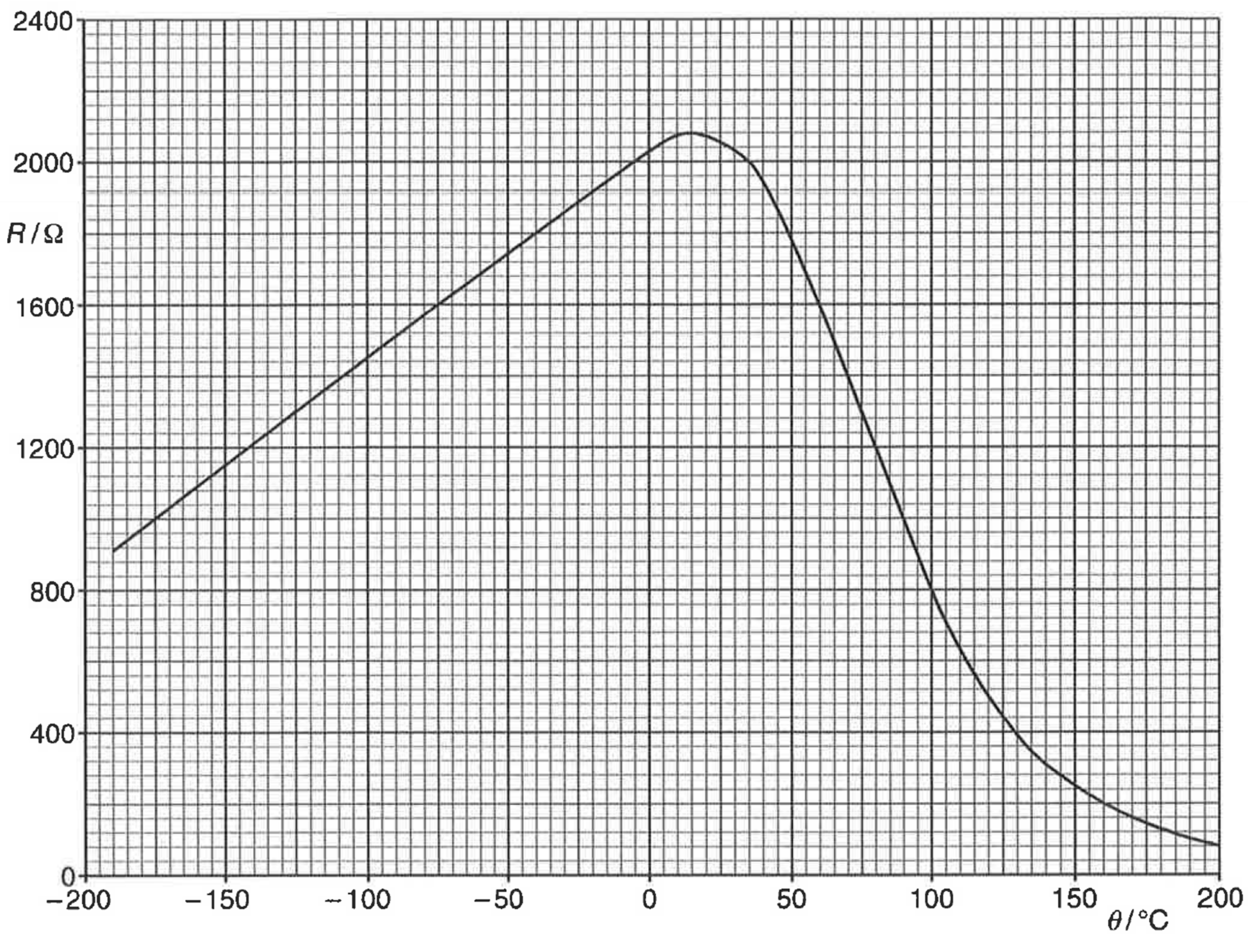

Fig. 4.1

(a) A student proposes that R may be inversely proportional to θ over the range of temperature from 50 °C to 150 °C. Show, without drawing a graph, that this proposal is **not** correct.

[2]

(b) A second student proposes that R decreases exponentially with temperature T for temperatures above about 100 °C, where temperature T is expressed in the unit kelvin (K).

The relationship between T and θ is

$$T = \theta + 273.15$$

Fig 4.2 shows some of the data for R, θ, T^{-1}, and $\ln(R / \Omega)$.

R/Ω	$\theta/°C$	$T^{-1}/10^{-3}K^{-1}$	$\ln(R/\Omega)$
500	120	2.54	6.21
400	130	2.48	5.99
310	140	2.42	5.74
250	150	2.36	5.52
	160		
158	170	2.26	5.06
120	180	2.21	4.79

Fig. 4.2

(i) Complete Fig. 4.2 for the temperature of 160 °C.

[1]

(ii) Fig. 4.3 is a graph of some of the data of Fig. 4.2.

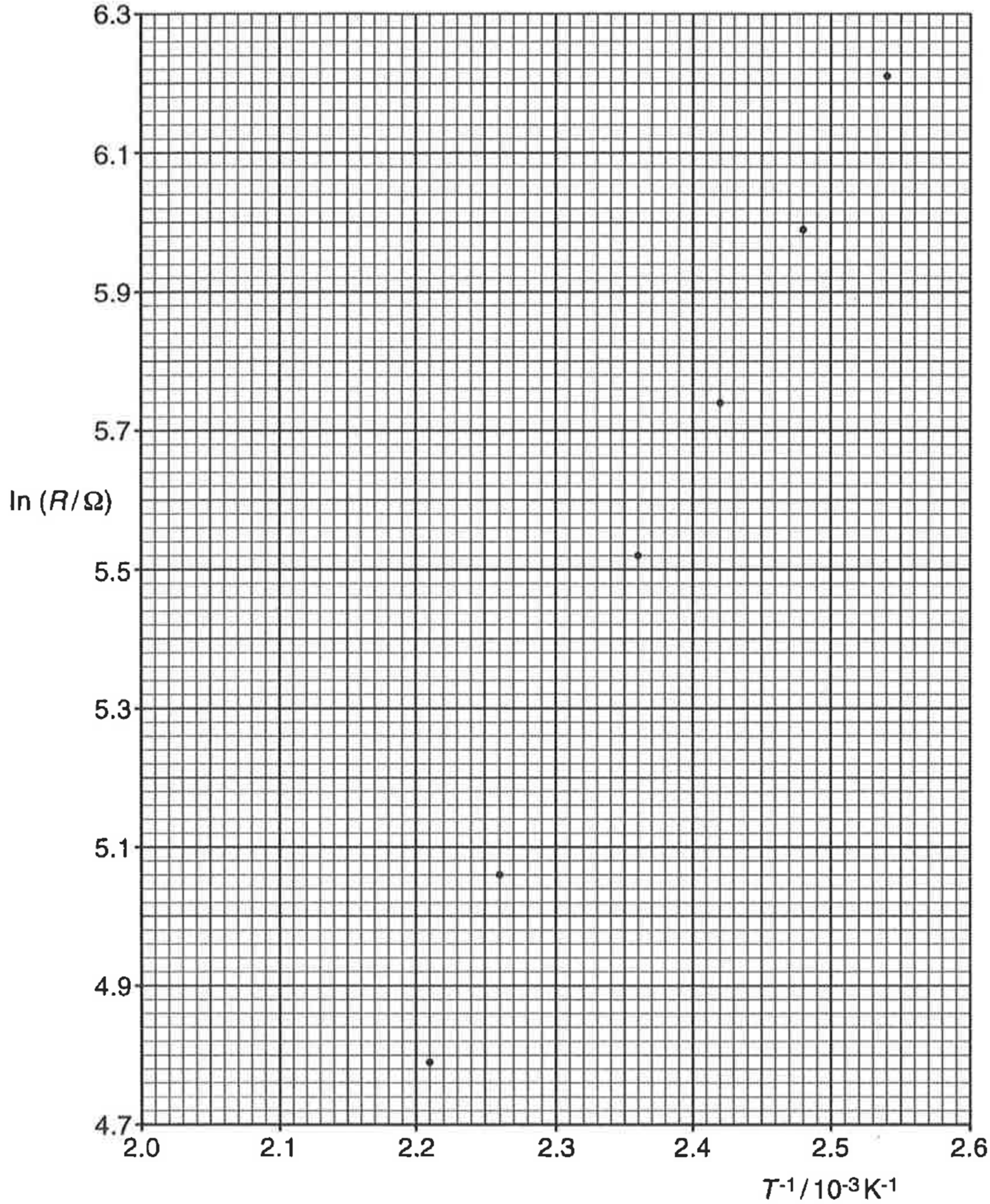

Fig. 4.3

Plot the point for the temperature of 160 °C on Fig. 4.3. [1]

(c) The proposal for the variation with T of R for temperature above about 100 °C is given by the expression

$$R = Ae^{E_g/2kT}$$

where A is a constant, E_g is the energy band gap for the semiconducting material and k is the Boltzmann constant.

(i) Explain why the graph of Fig. 4.3 supports this proposal.

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

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

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

(ii) The value of Boltzmann constant k is 1.38×10^{-23} J K^{-1}.

Use Fig. 4.3 to determine the energy band gap E_g in J.

E_g = …………………………….J [3]

(d) The resistance of resistors P and Q is 243 Ω and 90 Ω respectively. An NTC thermistor of resistance 120 Ω is connected in parallel with Q.

They are connected to a power supply of electromotive force 9.0 V and negligible internal resistance, as shown in Fig. 4.4.

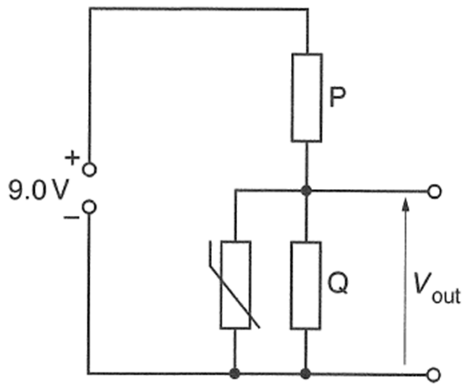

Fig. 4.4

Calculate the value of V_{out}, the potential difference across Q.

V_{out} = ……………………………V [3]

(e) Suggest why the resistance variation with temperature of a metal is different to that shown for semiconducting material.

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

(f) The variation with potential difference (p.d.) V of the current I in a lamp is shown in Fig. 4.5.

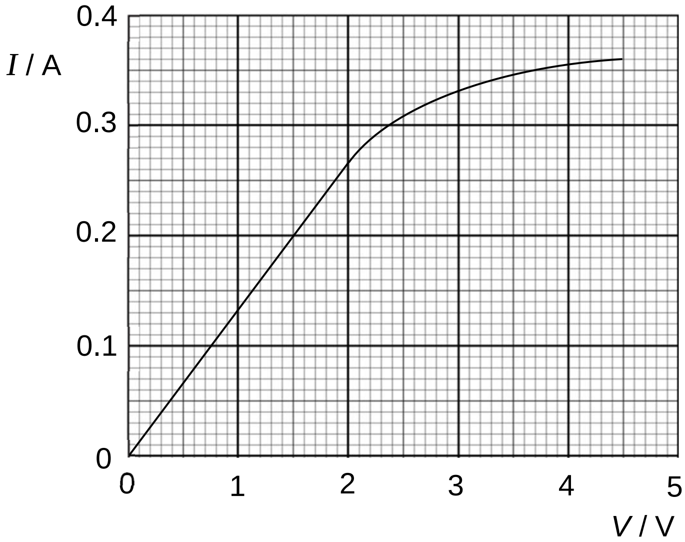

Fig. 4.5

Using Fig. 4.5, sketch a graph in Fig. 4.6 showing how the resistance of the lamp varies with the potential difference across it. Include appropriate values on the axes.

Fig. 4.6

[2]

[Total : 15]

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

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

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

(b) Electrons enter an electric field with uniform electric field strength of 4.0×10^4 N C^{-1}.

Calculate the magnitude of acceleration of the electrons.

a = ……………………………. m s^{-2} [2]

(c) Ions of the same isotope enter a magnetic field with a speed of 9.6×10^4 m s^{-1}. The ions are incident normally on a uniform magnetic field of flux density 640 mT. The ions follow semicircular paths A and B before reaching a detector, as shown in Fig. 5.1.

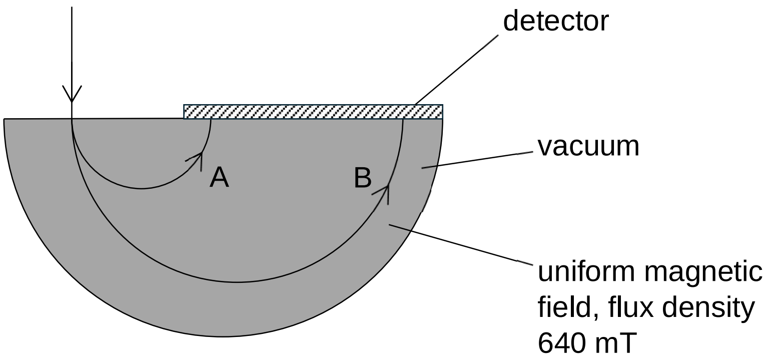

Fig. 5.1

Data for the diameters of the paths are shown in Fig. 5.2.

path	diameter / cm
A	4.1
B	12.3

Fig. 5.2

The ions in path B each have charge $+1.6 \times 10^{-19}$ C.

(i) Determine the mass, in u, of the ions in path B. Explain your working.

mass = ………………………….. u [3]

(ii) Suggest and explain quantitatively a reason for the difference in the radii of the paths A and B of the ions.

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

[Total: 9]

6 **(a)** State what is meant by nuclear fusion.

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

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

(b) A nucleus Z undergoes nuclear fission to form strontium-93 ($^{93}_{38}\text{Sr}$) and xenon-139 ($^{139}_{54}\text{Xe}$) according to

$$^{1}_{0}\text{n} + \text{Z} \rightarrow {}^{93}_{38}\text{Sr} + {}^{139}_{54}\text{Xe} + 2{}^{1}_{0}\text{n}$$

Fig. 6.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

Nucleus	binding energy / J
$^{93}_{38}\text{Sr}$	1.25×10^{-10}
$^{139}_{54}\text{Xe}$	1.81×10^{-10}

Fig. 6.1

Energy released in this reaction is 2.94×10^{-11} J

Determine the binding energy per nucleon, in MeV, of Z.

binding energy per nucleon = ……………………………MeV [4]

(c) Actinium-235 is unstable and undergoes alpha decay. The half-life of actinium-235 is 10 days.

(i) A sample contains N_0 nuclei of actinium-235 and no other nuclei at time $t = 0$.

On Fig. 6.2, sketch the variation with t of the number of nuclei of actinium-235 in the sample up to 30 days.

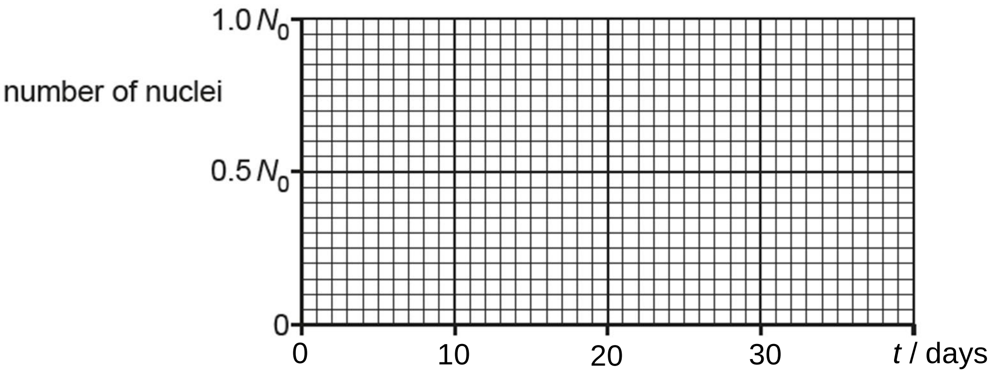

Fig. 6.2

[3]

(ii) Explain why alpha emitters such as actinium-225 are suitable in cancer treatment.

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.... [1]

[Total: 10]

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Section B

Answer **one** question in this section.

7 **(a)** Fig. 7.1 illustrates a model helicopter that is hovering in a stationary position.

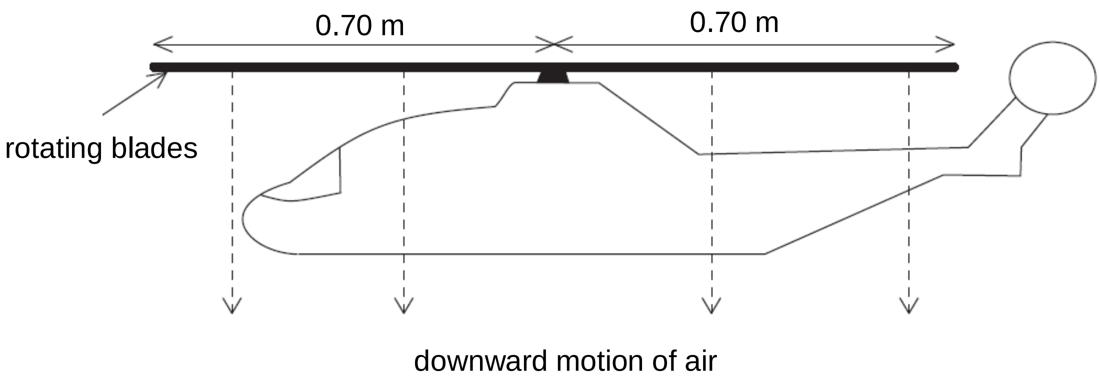

Fig. 7.1

(i) The rotating blades of the helicopter force a column of air to move downwards. Using Newton's Laws, explain how this may enable the helicopter to remain stationary vertically.

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

(ii) The length of each blade of the helicopter is 0.70 m. It is assumed that all the air beneath the blades is pushed vertically downwards with the same speed of 4.0 m s^{-1}. No other air is disturbed. The density of the air is 1.2 kg m^{-3}.

For the air moved downwards by the rotating blades,

1. show that the mass per unit time is 7.4 kg s^{-1}

[3]

2. calculate the rate of change of momentum.

rate of change of momentum = …………………. kg m s^{-2} [2]

(iii) Hence or otherwise, calculate the total mass of the helicopter and its load.

total mass =…………………. kg [2]

(b) A car of mass 950 kg is travelling at constant speed of 60 km h^{-1} along a horizontal straight road.

(i) Explain why a higher power is required when travelling at a constant higher speed.

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

(ii) For the car to maintain the constant speed of 60 km h^{-1} along the horizontal straight road, an effective power of 22 kW is required.

Determine the total resistive force on the car at this speed.

Show your working clearly.

total resistive force = …………………………... N [3]

(iii) The car, travelling at the speed limit of 60 km h^{-1}, collides with a truck that is travelling at the same speed but in opposite directions as shown in Fig. 7.2. The truck has twice the mass of the car.

Fig. 7.2

The vehicles collide head-on and become stuck together.

1. Determine the speed of the combined wreck immediately after the collision.

speed = ……………………. km h^{-1} [2]

2. Both the car and truck drivers are wearing seat belts. Explain which driver experience a greater force by the seat belt. Assume that the masses of both drivers are approximately equal.

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…………………………………………………………………………….…………[3]

[Total: 20]

8 **(a)** A steel sphere of mass 0.29 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 8.1.

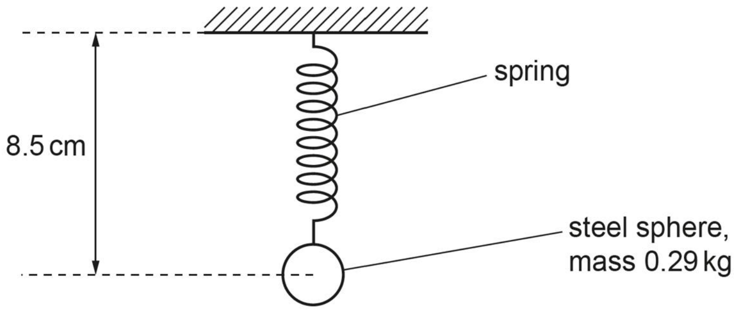

Fig. 8.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 8.2.

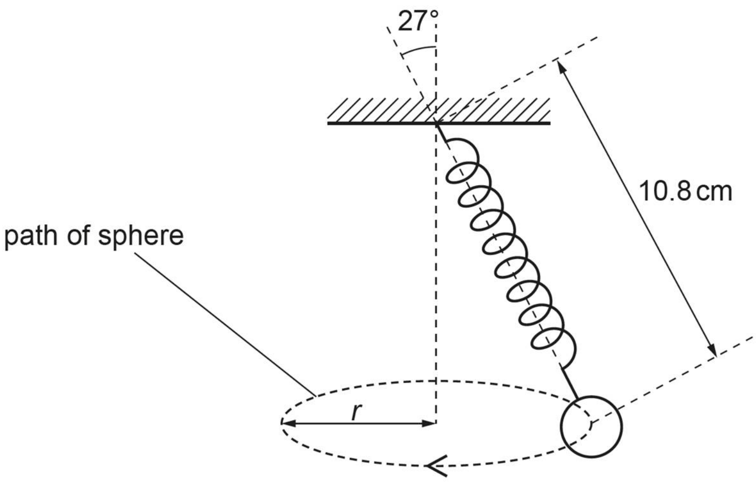

Fig. 8.2

The distance from the centre of the sphere to the top of the spring is now 10.8 cm.

(i) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 8.2 is greater than in Fig. 8.1

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....[3]

(ii) The angle between the linear axis of the spring and vertical is 27°.

1. Show that the radius r of the circle is 4.9 cm.

[1]

2. Show that the tension in the spring is 3.2 N.

[2]

3. The spring obeys Hooke's law.

Calculate the spring constant, in N cm^{-1} of the spring.

spring constant = ………………………… N cm^{-1} [2]

(iii) **1.** Use the information in **a(ii)** to determine the centripetal acceleration of the sphere.

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

2. Calculate the period of the circular motion of the sphere.

period = ………………………… s [2]

(b) A binary star consists of two stars A and B of equal mass M that orbit one another, as shown in Fig. 8.3.

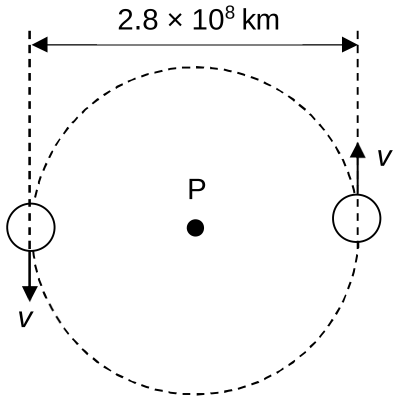

Fig. 8.3

The stars move with constant speed v in a circular orbit about their common centre of mass, P. The separation of the centres of the stars is 2.8×10^8 km.

(i) Explain why the path taken by the stars is circular.

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....

....[1]

(ii) By considering the forces acting on the stars, explain why the centripetal force acting on both stars has the same magnitude.

....

....

....

....[2]

(iii) Explain how the centripetal force acting on the stars cause acceleration, but there is no change to the kinetic energy of the stars.

....

....

....[1]

(iv) The period of the orbit of the starts about point P is 4.0 years.

Calculate the speed v of the stars.

v = ………………………… m s^{-1} [2]

(v) Use your answer in **b(iv)** to determine the mass M of each star.

Explain your working.

M = ………………………… kg [2]

[Total: 20]

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