Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 1

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	

CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER				

PHYSICS **8867/02**

Paper 2 Structured Questions

22 August 2024
2 hours

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

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 an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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 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 Examiners' use only	
Section A	
1	/ 6
2	/ 9
3	/ 7
4	/ 6
5	/ 8
6	/ 8
7	/ 16
Total	/ 60
Section B	
8 / 9	/ 20
Grand Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
elementary charge	e	=	1.60×10^{-19} C
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
the Avogadro constant	N_A	=	6.02×10^{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}	=	$u^{2} + 2as$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

For Examiner's Use

Section A

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

1 **(a)** Distinguish between *precision* and *accuracy*.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) A simple pendulum consists of a mass attached to a light inextensible string of length L. The pendulum is secured to a fixed point and made to undergo oscillations when displaced by a small angle.

The acceleration of free fall g can be found by the following equation:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where T is the period of oscillation.

The following data is given:
L = 50.0 ± 0.2 cm
T = 1.42 ± 0.01 s

(i) Determine g with its associated uncertainty. Give your answer to an appropriate number of significant figures.

g = …………………… ± …………………… m s^{-2} [3]

[Turn over

For Examiner's Use

(ii) When finding period T using a stopwatch, it is a good practice to time a large number of oscillations such that the total time taken is more than 20 seconds.

Explain why this should be done.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [1]

[Total: 6]

For Examiner's Use

2 A stone is projected vertically at a velocity of u from the edge of a building. The stone reaches a maximum height of 27 m above the top of the building and falls down to the ground below. Take the upward direction as positive.

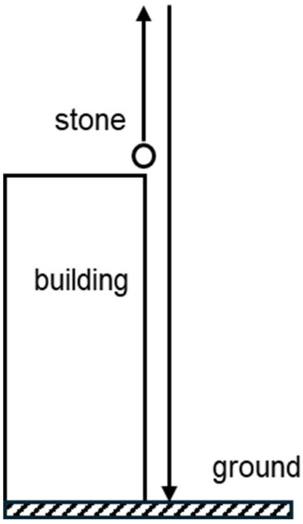

Fig. 2.1

(a) (i) Assume that air resistance is negligible.

1. Show that u is 23 m s^{-1}.

[2]

[Turn over

For Examiner's Use

2. The stone hits the ground after 6.0 s.

On Fig. 2.2, sketch the variation with time *t* of the velocity *v* from the time the stone is projected at *t* = 0 s until *t* = 6.0 s. Label the axes with appropriate values.

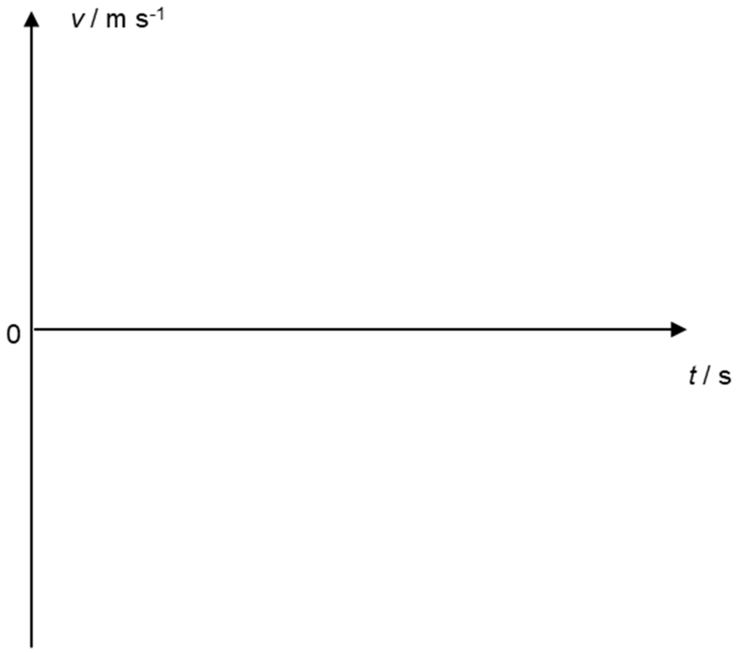

Fig. 2.2

[2]

(ii) In reality, air resistance is not negligible.

On Fig. 2.2, sketch the variation with time *t* of the velocity *v* of the stone till 6.0 s. Label the graph *R*. [2]

.

For Examiner's Use

(b) An elastic net is now placed on top of the ground to catch the stone, so that it does not hit the ground. To simplify the analysis, Fig. 2.3 shows two identical springs and a rigid container which are used to model the elastic net. Assume the masses of the springs and rigid container to be negligible. The stone hits the rigid container when the springs are at length x_0 and subsequently, the springs stretch by a maximum extension of x_s.

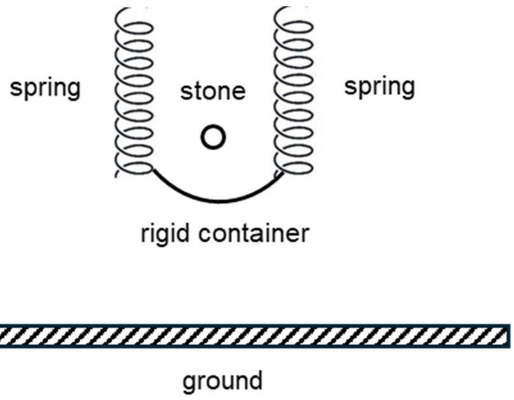

Fig. 2.3

On Fig. 2.4, sketch graphs of the following quantities to show the variation with extension *x* of the spring.

(i) The kinetic energy of the stone and container. Label this graph *K*.

(ii) The gravitational potential energy (GPE) of the stone and container. Take GPE to be zero at the lowest point of the motion. Label this graph *G*.

(iii) The elastic potential energy of the spring. Label this graph *E*.

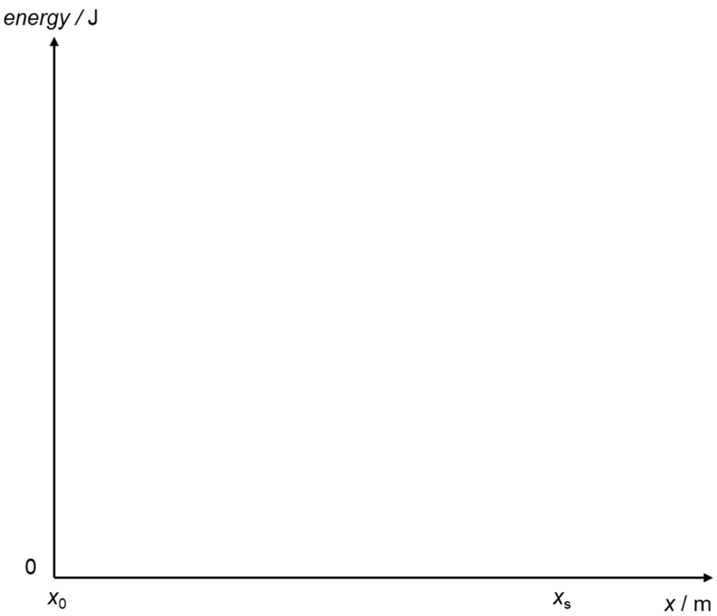

Fig. 2.4

[3]

[Total: 9]

[Turn over

3 A uniform, rectangular canopy is 1.30 m wide. It is kept horizontal and in equilibrium by two steel cables. Fig. 3.1 shows the canopy fixed to the wall by a hinge.

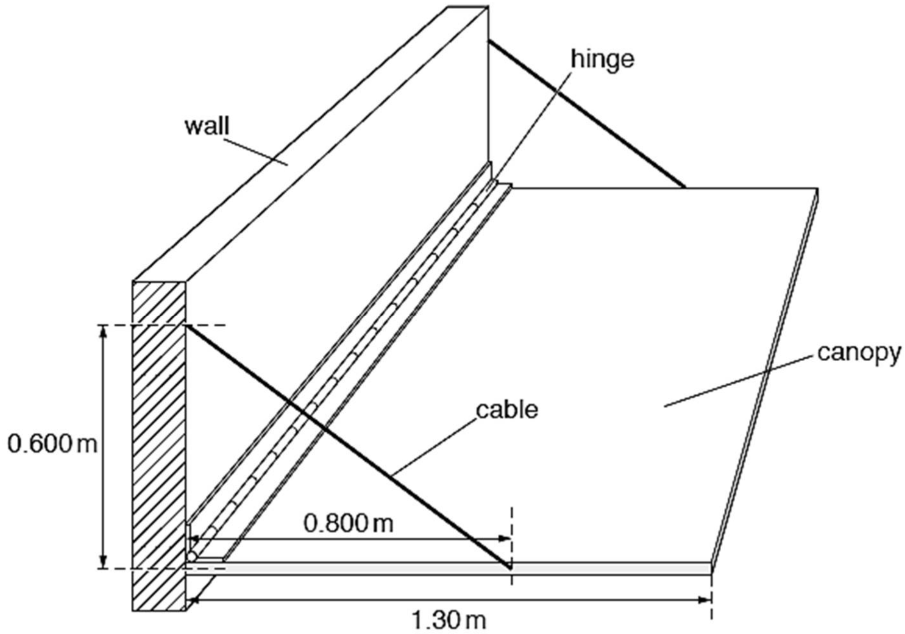

Fig. 3.1 (not to scale)

One end of each cable is attached to the canopy at a distance of 0.800 m from the wall. The other ends are attached to the wall at a distance of 0.600 m above the canopy.

The tension in each cable is 47.5 N.

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

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

…………………………………………………………………………………………..

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

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

(b) Determine the mass of the canopy.

mass = …………..……… kg [3]

For Examiner's Use

(c) Suggest and explain the direction of the force the hinge must exert on the canopy.

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

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

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

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

[Total: 7]

[Turn over

For Examiner's Use

4 **(a)** State the *principle of conservation of momentum*.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

(b) A 75.0 kg ice skater, moving at 10.0 m s^{-1}, crashes into a stationary skater of mass 55.0 kg. After the collision, the two skaters move together with a common velocity *v*.

(i) Show that *v* is 5.77 m s^{-1}.

[1]

(ii) The average force a skater can experience without sustaining an injury is 4500 N. The impact time of the collision between the skaters is 0.100 s.

Determine if the skaters would sustain an injury from the collision.

[3]

[Total: 6]

For Examiner's Use

5 **(a)** Define the *volt.*

…………………………………………………………………………………………………

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

(b) A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 5.1.

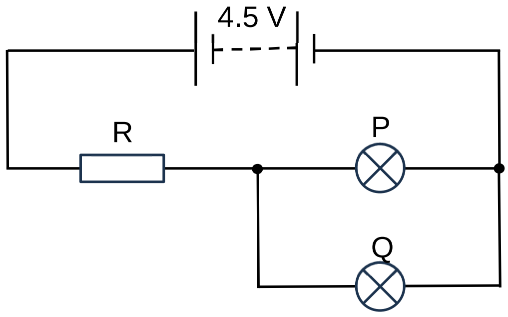

Fig. 5.1

The current in lamp P is 0.15 A. The I–V characteristics of the filament lamps are shown in Fig. 5.2.

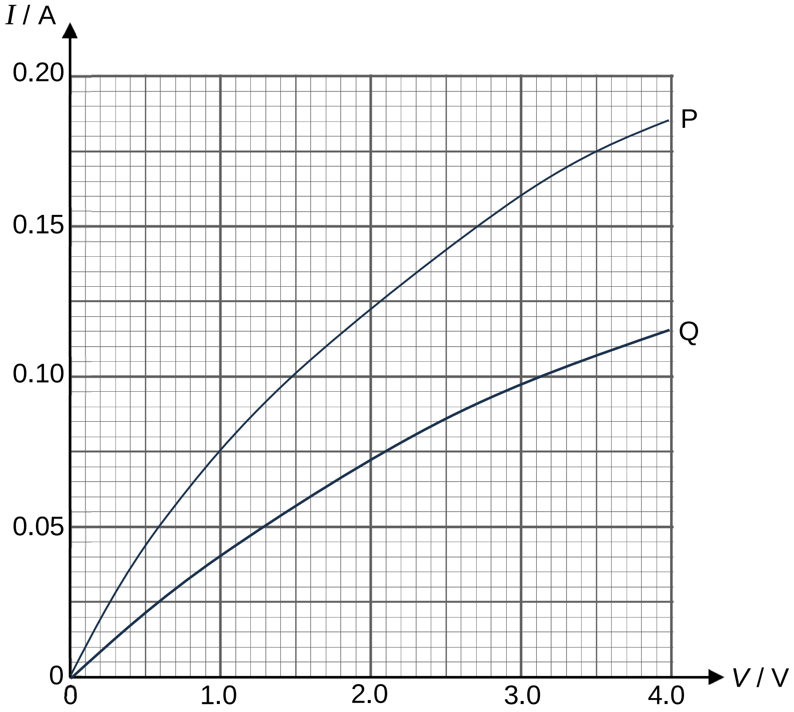

Fig. 5.2

[Turn over

For Examiner's Use

(i) Use Fig. 5.2 to determine the current in the battery. Explain your working.

current = …………..……… A [2]

(ii) Calculate the resistance of resistor R.

resistance = …………..……… Ω [2]

(iii) The filament wires of the two lamps are made from material with the same resistivity at their operating temperature in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}.$$

ratio = …………..……… [3]

[Total: 8]

For Examiner's Use

6 **(a)** Define *magnetic flux density*.

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

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

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

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

(b) In an experiment to determine the charge to mass ratio $\frac{e}{m}$ for an electron, a beam of electrons, travelling horizontally in a vacuum with uniform speed v, enters a region R where uniform electric and magnetic fields can be applied. The electric field strength has a magnitude E and acts into the plane of the paper as shown in Fig. 6.1.

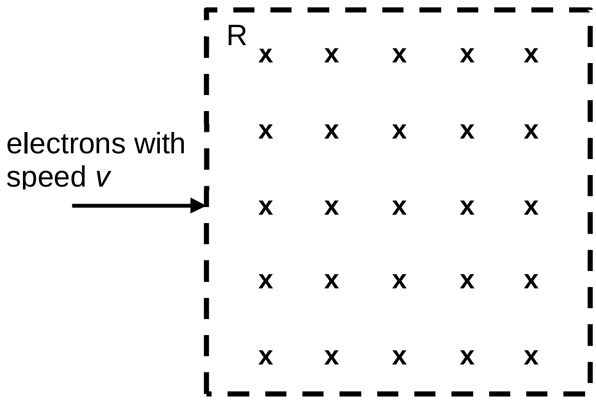

Fig. 6.1

The strength of the fields, when applied in combination, can be adjusted such that the beam remains undeflected when passing through R.

(i) On Fig. 6.1, draw how the magnetic field should be applied in region R so that the electron beam can pass through undeflected. [1]

For Examiner's Use

(ii) Electrons with speed of 3.3×10^{7} m s^{-1} are produced using an electron gun. The magnetic flux density of the magnetic field is 3.0×10^{-3} T.

Determine the electric field strength E required to produce an undeflected beam.

E = ………….……… N C^{-1} [2]

(iii) When the electric field is switched off, the electrons move in an arc of radius 6.0×10^{-2} m.

Deduce a value for the charge to mass ratio $\dfrac{e}{m}$ of an electron.

$\dfrac{e}{m}$ = ………….……… C kg^{-1} [3]

[Total: 8]

For Examiner's Use

7 Solar cells are used for the generation of electrical energy. When light is incident on the surface of such a cell, an e.m.f is generated between the terminals of the cell. Connecting a resistor between the terminals will result in a current and electrical power dissipation in the resistor.

The variation with output potential difference V of the current I from a solar cell can be investigated using the circuit in Fig. 7.1.

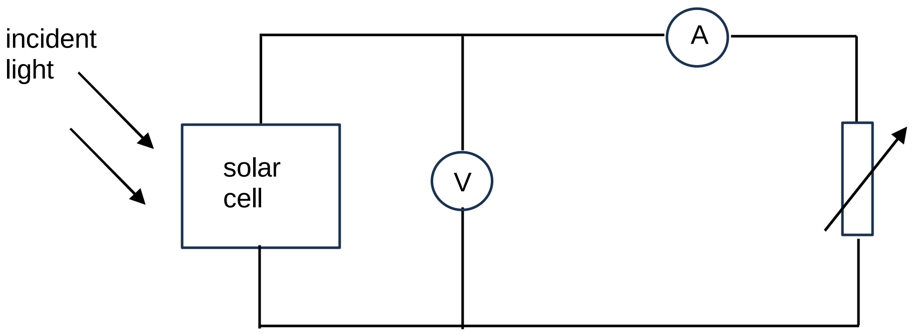

Fig. 7.1

The ammeter and voltmeter are assumed to be ideal. Light of constant intensity is incident on the solar cell.

[Turn over

For Examiner's Use

The I-V characteristic of the solar cell when it is illuminated by the constant intensity light is shown in Fig. 7.2.

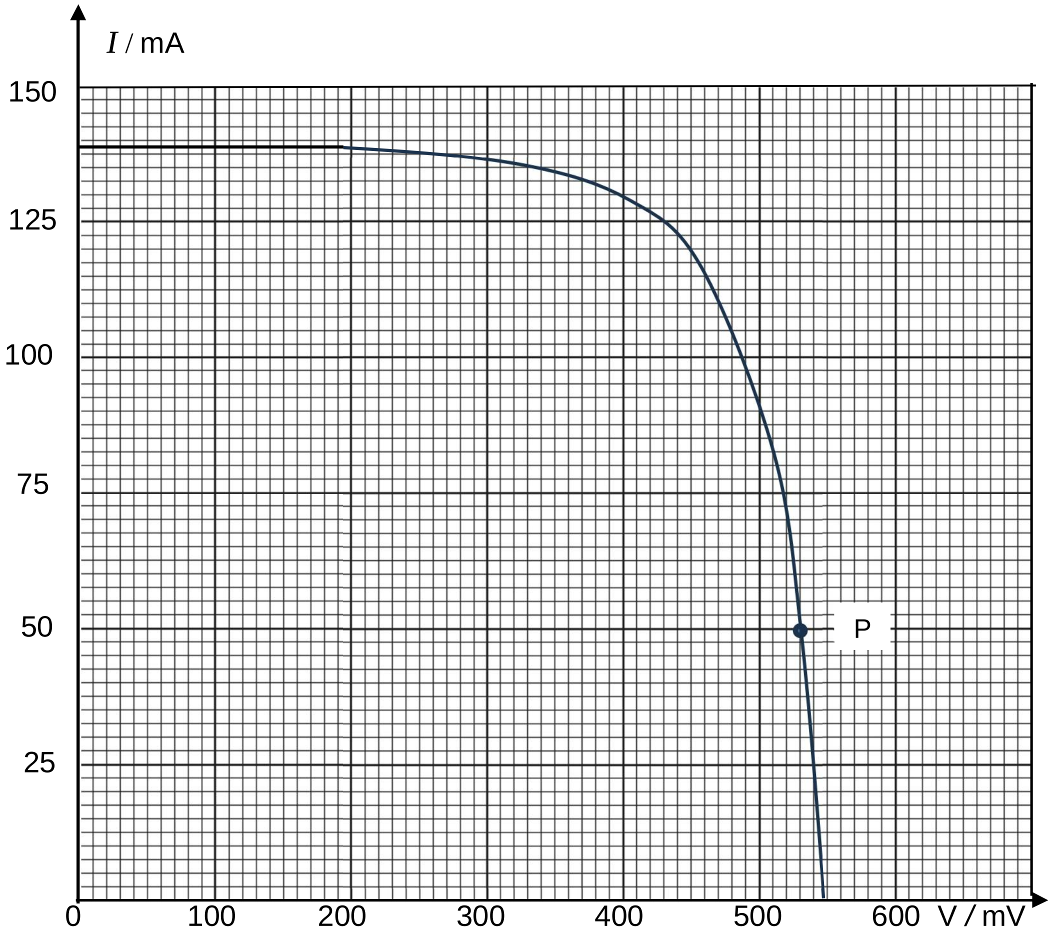

Fig. 7.2

(a) **(i)** Determine the current from the solar cell for an output potential difference of 300 mV.

current = …………..……… A [1]

(ii) Explain how the graph shows that the e.m.f. of the solar cell is 550 mV.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

For Examiner's Use

(iii) Use your answers in **(a)(i)** and **(a)(ii)** to determine the internal resistance of the cell at an output potential difference of 300 mV.

internal resistance = …………..……… Ω [2]

(iv) Hence, determine the efficiency of the solar cell in dissipating power in the load resistor.

efficiency = ………..……… % [2]

(b) **(i)** On Fig. 7.2, shade an area that represents the power dissipation in the load resistor for point P. [2]

(ii) By reference to your answer in **(b)(i)**, state whether the power dissipated in the load resistor increases, stays the same or decreases when the potential difference, *V* across it

1. decreases from 530 mV to 490 mV,

………………………………………………………………………………………

2. decreases from 440 mV to 250 mV.

……………………………………………………………………………………… [2]

(ii) Hence, or otherwise, mark with the letter Q the approximate point on Fig. 7.2 at which the power dissipation is a maximum. [1]

[Turn over

For Examiner's Use

(c) The solar cell is now connected to a fixed load resistor of resistance 4.2 Ω, with the same intensity of light incident on the solar cell as before.

(i) The graph in Fig. 7.2 is now reproduced exactly in Fig. 7.3.

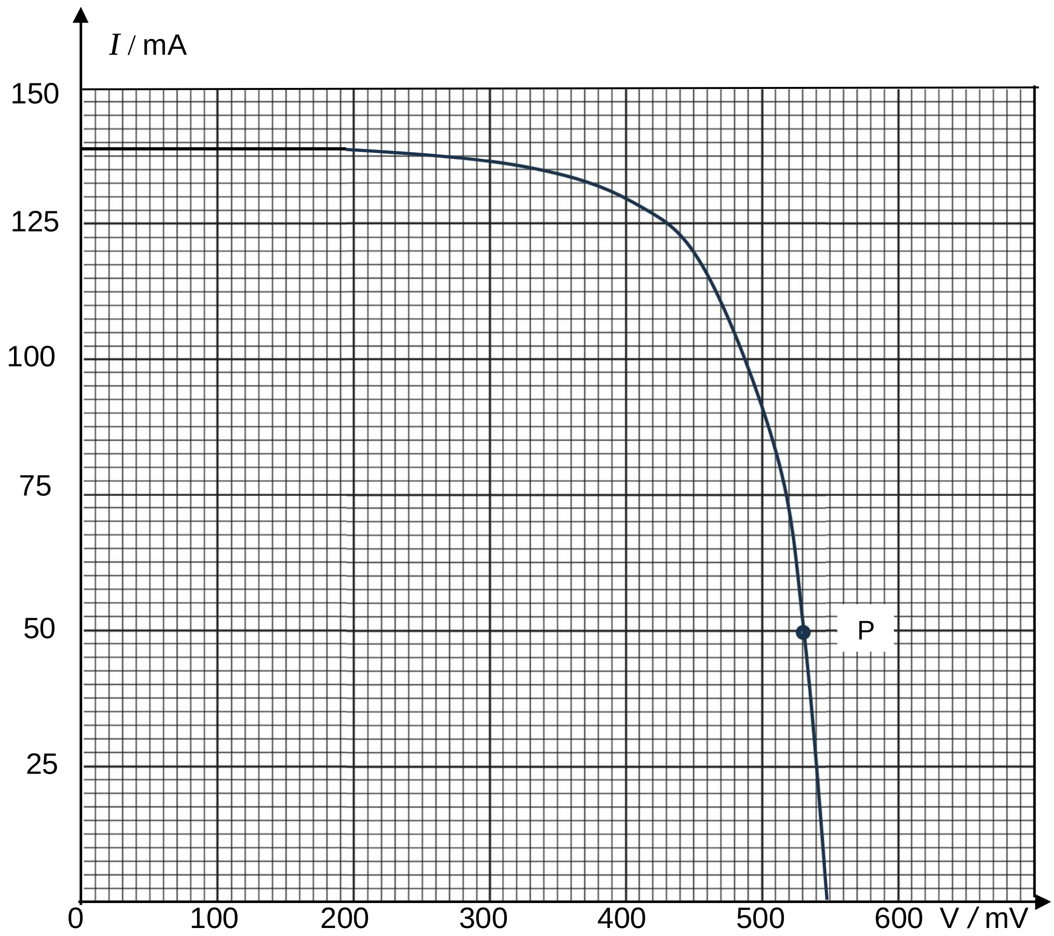

Fig. 7.3

On Fig. 7.3, draw a line to show the variation with current I of the potential difference V across the resistor. [2]

(ii) Determine the power dissipated in the load resistor.

power = …………………… W [2]

[Total: 16]

For Examiner's Use

Section B

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

8 **(a)** State *Newton's Law of Gravitation*.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) A satellite of mass m orbits planet Mars of mass M in a circular path of radius r.

Show that the kinetic energy of the satellite is

$$\frac{GMm}{2r}.$$

[2]

(c) It was discovered that for every revolution of the satellite around Mars, Mars has rotated about its axis three times.

Data are given for the satellite and Mars in Table 8.1.

Table 8.1

duration of one day on Mars	24.6 hours
mass of Mars, M	6.39×10^{23} kg
mass of satellite, m	470 kg

(i) State why the satellite can be considered as a point mass.

……………………………………………………………………………………………

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

[Turn over

For Examiner's Use

(ii) Show that the radius r of the circular path is 4.24×10^{7} m.

[3]

(iii) Hence, calculate the kinetic energy of the satellite orbiting around Mars.

kinetic energy = …………..……… J [1]

(d) An object moves in a circular path at constant speed.

Explain why the object is considered to be accelerating.

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

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

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

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

For Examiner's Use

(e) A carriage of mass m enters a circular loop-the-loop at point A with speed v_A, reaches the top of the loop at B with speed v_B and exits the loop with the same speed v_A as shown in Fig. 8.1.

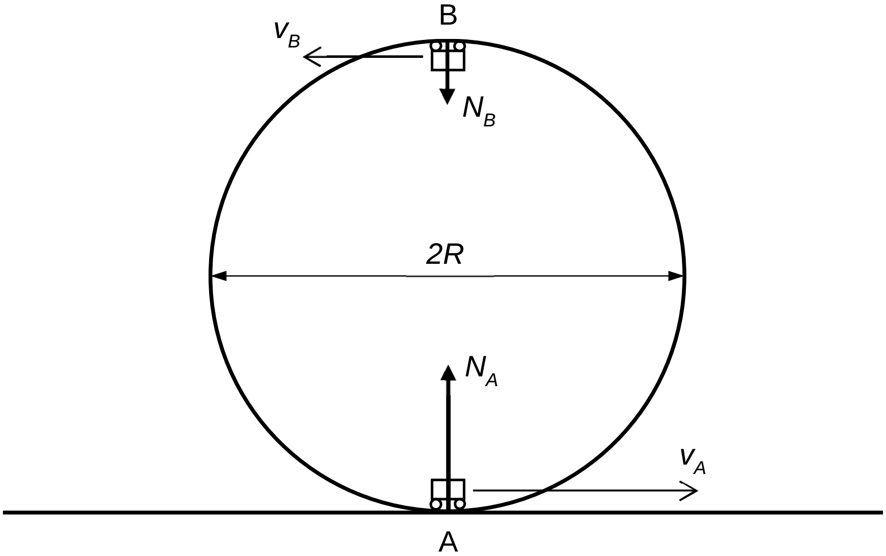

Fig. 8.1

The radius of the loop is R. The magnitudes of the normal contact forces acting on the carriage at A and B are N_A and N_B respectively.

(i) Derive an expression for the loss in kinetic energy of the carriage in going from A to B in terms of m, g and R, where g is the acceleration of free fall.

loss in kinetic energy = …………..……… [2]

[Turn over

For Examiner's Use

(ii) By considering the forces acting on the carriage at A and at B, and using your answer in **(e)(i)**, show that

$$N_A - N_B = 6\,mg.$$

[3]

(iii) Using your answer in **(e)(ii)**, state and explain the minimum possible value of N_A.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iv) Hence, given that R is 20.0 m, determine the minimum velocity to enter the loop at A for the carriage to complete one full revolution along the loop.

minimum velocity = …………………… m s^{-1} [2]

[Total: 20]

For Examiner's Use

9 **(a)** Radioactive decay is *random* and *spontaneous*.

Explain what is mean by random and spontaneous.

random: ……………………………………………………………………………………..

……………………………………………………………………………………………..

spontaneous: …………………………………………………………………………….

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

(b) A stationary polonium nucleus $^{210}_{84}\text{Po}$ decays to a lead (Pb) nucleus by emitting an alpha-particle. The nuclear equation for this emission is

$$^{210}_{84}\text{Po} \rightarrow \, ^{206}_{82}\text{Pb} + \, ^{4}_{2}\text{He}.$$

Table 9.1 shows the data of the nuclei in this reaction.

Table 9.1

nucleus	mass / *u*
$^{210}_{84}\text{Po}$	209.98264
$^{206}_{82}\text{Pb}$	205.97440
$^{4}_{2}\text{He}$	4.00260

(i) Show that the energy released in this reaction is 8.4×10^{-13} J.

[3]

[Turn over

For Examiner's Use

(ii) Determine the following ratios after the nuclear reaction has occurred.

1. $\dfrac{\text{magnitude of the momentum of alpha-particle}}{\text{magnitude of the momentum of lead nucleus}}$,

ratio = ……………..……… [1]

2. $\dfrac{\text{kinetic energy of alpha-particle}}{\text{kinetic energy of lead nucleus}}$.

ratio = ……………..……… [2]

(iii) Hence, or otherwise, calculate the kinetic energy of the alpha-particle.

kinetic energy = …………..………… J [2]

(iv) Suggest why the sum of the kinetic energies of the alpha-particle and the lead nucleus after the decay is less than the energy released in the decay.

……………………………………………………………………………………………

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

For Examiner's Use

(v) The half-life of polonium is 138 days.

Estimate the time taken for the activity of a source of polonium to decrease to 15% of its initial activity.

time taken = ………….……… days [2]

(c) Another nucleus, platinum-199 ($^{199}_{78}\mathrm{Pt}$), decays to gold (Au) by emitting a beta particle.

(i) Write a nuclear equation to represent this emission.

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

(ii) The nucleus of gold-199 is not stable and will decay further to mercury-199 which is a stable nucleus.

A sample of radioactive isotopes consists of only platinum-199 nuclei initially. The half-life of platinum-199 is 30.8 months and the half-life of gold-199 is 3.13 days.

After 30.8 months, suggest which nuclei would be of the smallest percentage. Explain your answer.

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………. [2]

[Turn over

For Examiner's Use

(d) Discuss the effects of ionising radiation on living cells.

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

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

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

[Total: 20]

End of Paper