Name: ________________________________ Class: ______________

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2024

PHYSICS **8867/02**

Higher 1

27 August 2024

Paper 2 Structured Questions **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 or graphs.
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	
Section A	
1	/ 5
2	/ 7
3	/ 12
4	/ 8
5	/ 13
6	/ 15
Section B	
7	/ 20
8	/ 20
Total	/ 80

This document consists of **25** printed pages and **3** blank pages.

[Turn over

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	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$

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

1 **(a)** All bodies radiate energy. The power P radiated by a body is given by

$$P = kAT^4$$

where T is the thermodynamic temperature of the body,
A is the surface area of the body
and k is a constant.

Determine the SI base units of k.

SI base units .... [2]

(b) The maximum useful output power P of a car travelling on a horizontal road is given by

$$P = v^3 b$$

where v is the maximum speed of the car and b is a constant.

For the car,

$P = 84\ \text{kW} \pm 5\%$
and $b = 0.56 \pm 7\%$ in SI units.

Determine the absolute uncertainty in the value of v.

absolute uncertainty = ... m s^{-1} [3]

2 A golf ball is chipped at an angle of θ above the horizontal and strikes the level ground 1.5 s later, reaching a horizontal distance of 15 m.

Air resistance negligible. Take g to be 10 m s^{-2}.

(a) Calculate the vertical component of the initial velocity.

vertical component of initial velocity = …………………............. m s^{-1} [2]

(b) Using your answer to **(a)**, or otherwise, draw on Fig. 2.1 the variations with time t of the horizontal displacement s_h, the horizontal component of the velocity v_h and the vertical component of the velocity v_v of the ball until it strikes the ground.

Add a suitable scale to each vertical axis.

Take the upward direction as positive.

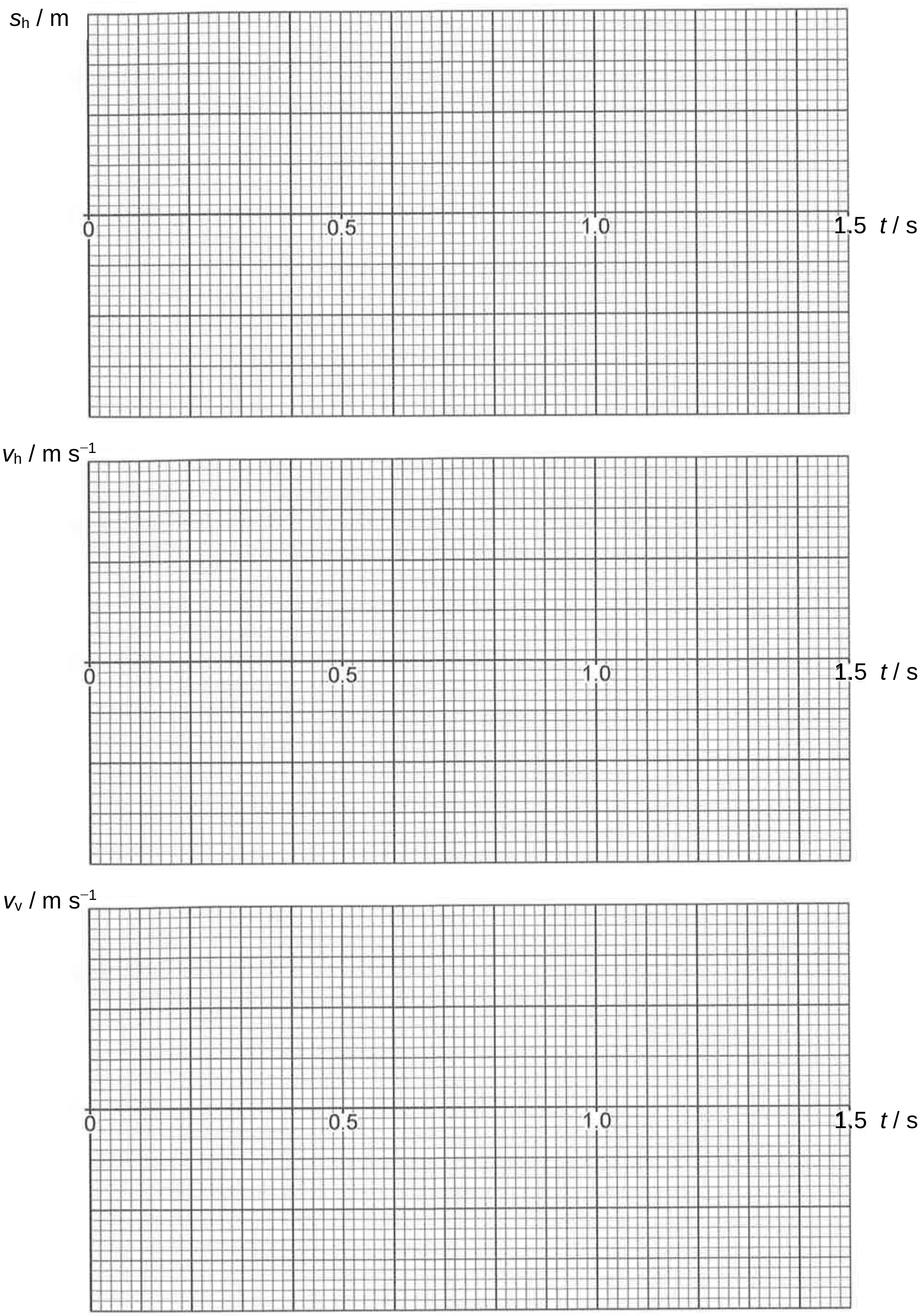

Fig. 2.1

[5]

3 (a) State Newton's second law of motion.

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

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

(b) Define *impulse*.

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

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

(c) Fig. 3.1 shows a model of a system being designed to move concrete building blocks from an upper to a lower level.

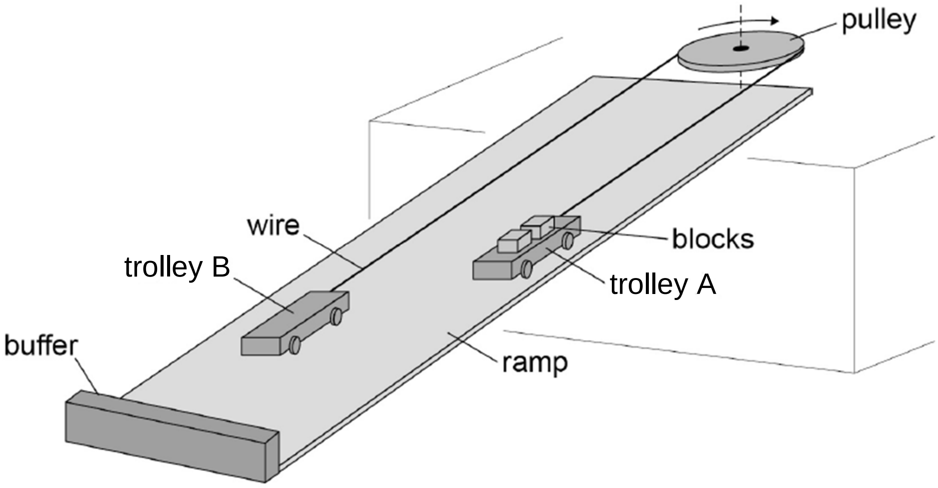

Fig. 3.1

The model consists of two identical trolleys of mass M on a ramp which is at 35° to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the smooth ramp.

Two concrete blocks each of mass m are loaded onto trolley A at the top of the ramp. The trolley is released and accelerates to the bottom of the ramp where it is stopped by a flexible buffer. The blocks are unloaded from trolley A and two blocks are loaded onto trolley B that is now at the top of the ramp. The trolleys are released and the process is repeated.

Assume that no friction acts at the axle of the pulley and air resistance is negligible.

Fig. 3.2 shows the side view of trolley A loaded with two concrete blocks when it is moving down the ramp.

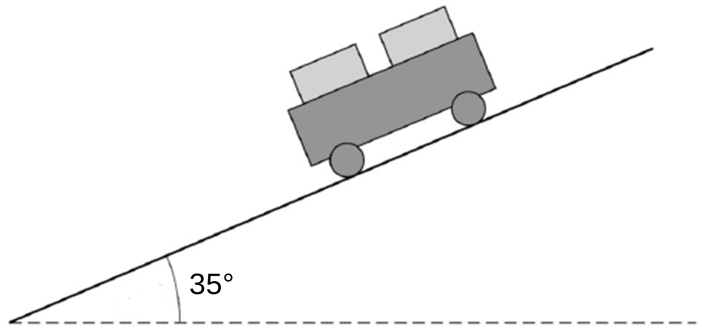

Fig. 3.2

(i) The tension in the wire when the trolleys are moving is T.

Draw arrows on Fig. 3.2 to represent the magnitudes and directions of any forces and components of forces that act on the loaded trolley A parallel to the ramp as it travels down the ramp.

Label the arrows. [2]

(ii) Show that the acceleration a of trolley A along the ramp is given by

$$a = \frac{mg \sin 35°}{M + m}.$$

[3]

(iii) In practice, for safety reasons there is a friction brake in the pulley that provides a resistive force to reduce the acceleration to 25% of the maximum possible acceleration.

The distance travelled for each journey down the ramp is 9.0 m.

The following data apply to the arrangement.

Mass of a trolley M = 95 kg
Mass of a concrete block m = 30 kg

Calculate the time taken for a loaded trolley to travel down the ramp with this reduced acceleration.

time = ... s [3]

(iv) Discuss how the flexible buffer ensures minimal damage to each trolley when it is stopped by the buffer.

....

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....

....

.... [2]

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4 Fig. 4.1 shows a 60.0 kg painter on a uniform scaffold of mass 25.0 kg and length 6.0 m, supported from above by ropes. A 4.0 kg pail of paint is placed 1.0 m away from one of the supports.

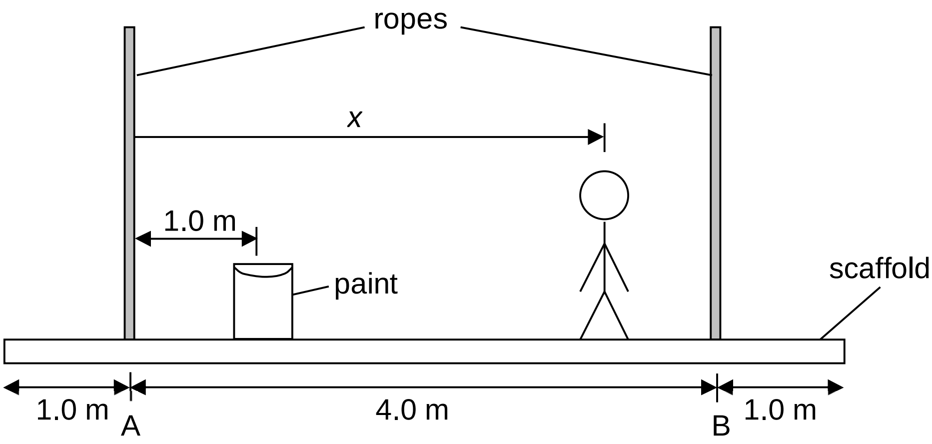

Fig. 4.1

(a) On Fig. 4.2, draw and label the forces acting on the scaffold.

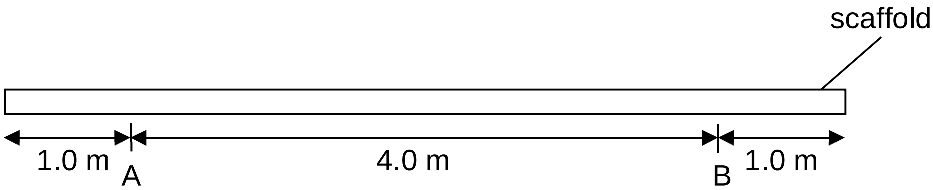

Fig. 4.2

[2]

(b) Given that the painter is standing at x = 3.6 m, determine

(i) the tension in the rope attached to point B,

tension = ... N [2]

(ii) the tension in the rope attached to point A.

tension = ... N [2]

(c) Describe and explain what would happen to the tension in both ropes as the painter walks slowly towards point A on the scaffold.

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....

....

.... [2]

5 **(a)** Explain why an object moving with uniform speed in a circle must experience a resultant force towards the centre of the circle.

....

....

....

.... [2]

(b) Fig. 5.1 shows a pendulum bob of mass m, attached to the end of a light rigid rod of length L, moving in a vertical circle at a constant speed v.

The rod starts from position A and sweeps through an angle θ in moving to position B.

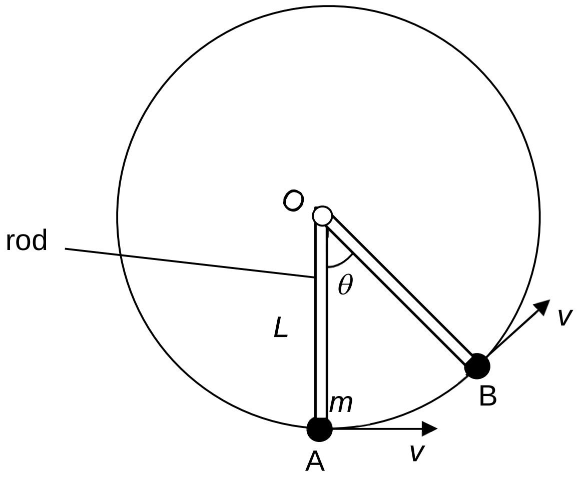

Fig. 5.1

(i) Show that the tension T in the rod at position B is

$$T = mg\cos\theta + \frac{mv^2}{L}.$$

[2]

(ii) As the bob moves in the vertical circle, the force in the rod can change from being in tension to being compressed at certain points in the circle.

For a rod of length L = 0.80 m and a bob of mass m = 50 g moving at $v = 2.0$ m s^{-1}, determine the angle θ beyond which the rod is under compression.

θ = ... ° [2]

(iii) 1. Fig. 5.2 shows the bob at the top of the vertical circle.

Draw on Fig. 5.2, the forces acting on the bob at that instant. Label your forces clearly. [1]

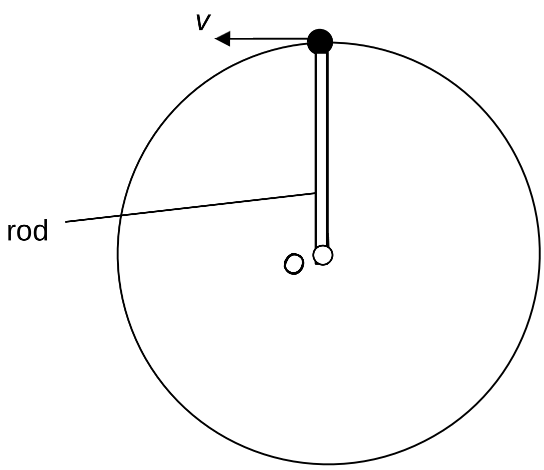

Fig. 5.2

2. Determine the magnitude of the force acting in the rod at that point, using data provided in **(ii)**.

force = ... N [2]

(iv) On the axes of Fig. 5.3, sketch the variation with θ of T (for $0° \le \theta \le 180°$). Label the maximum and minimum T in terms of m, v, L and g.

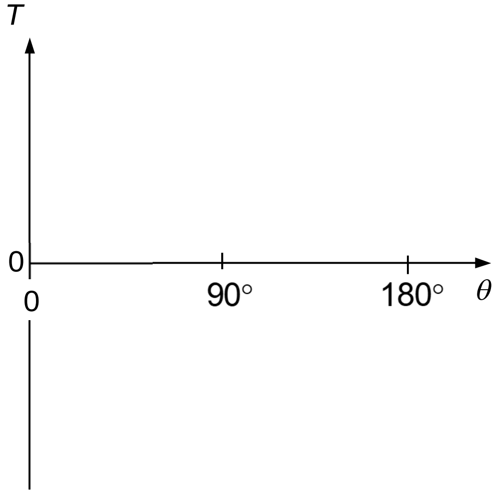

Fig. 5.3

[2]

(v) Using energy considerations, discuss how the mass can move at a constant speed in a vertical circle.

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....

.... [2]

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6 While participating in a Tour de France cycle race, a cyclist needs to eat between three and five times the average normal daily energy requirement. This question asks you to consider why.

In one Tour de France race, records show that on one day a cyclist rode a distance of 161 km in a time of 4 hours, 48 minutes and 20 seconds.

(a) Calculate his average speed on this day.

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

(b) During one 15 km section of the race on this day, the cyclist climbed approximately 1300 m.

For this cyclist, the time taken since the start of the section was measured at 7 different places over the 15 km section.

The graphs in Fig. 6.1 on page 17 showing the cyclist's performance are plotted with straight lines between the points representing the measurements.

Fig. 6.1a shows the altitude above sea level at the places where times were measured. Fig. 6.1b shows the time taken to reach each of the 7 places where measurements are taken.

Sketch on Fig. 6.1c a graph to show the variation in the average speed of the cyclist between the places where measurements were taken on the 15 km section. [4]

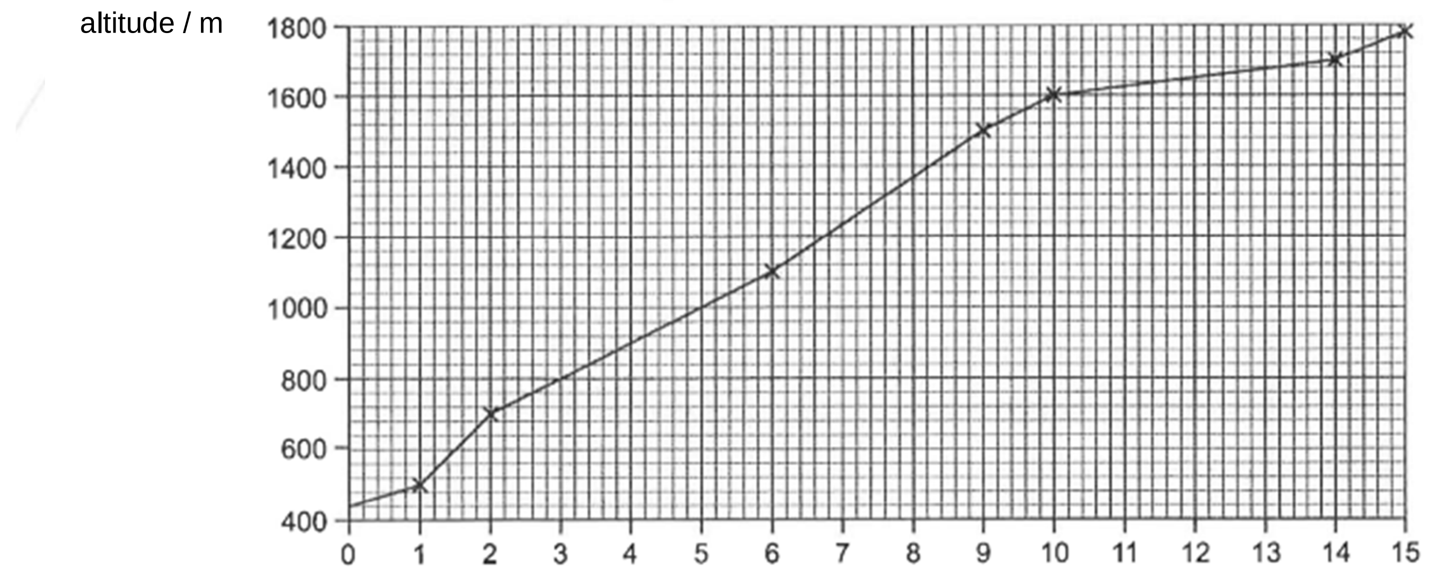

Fig. 6.1a

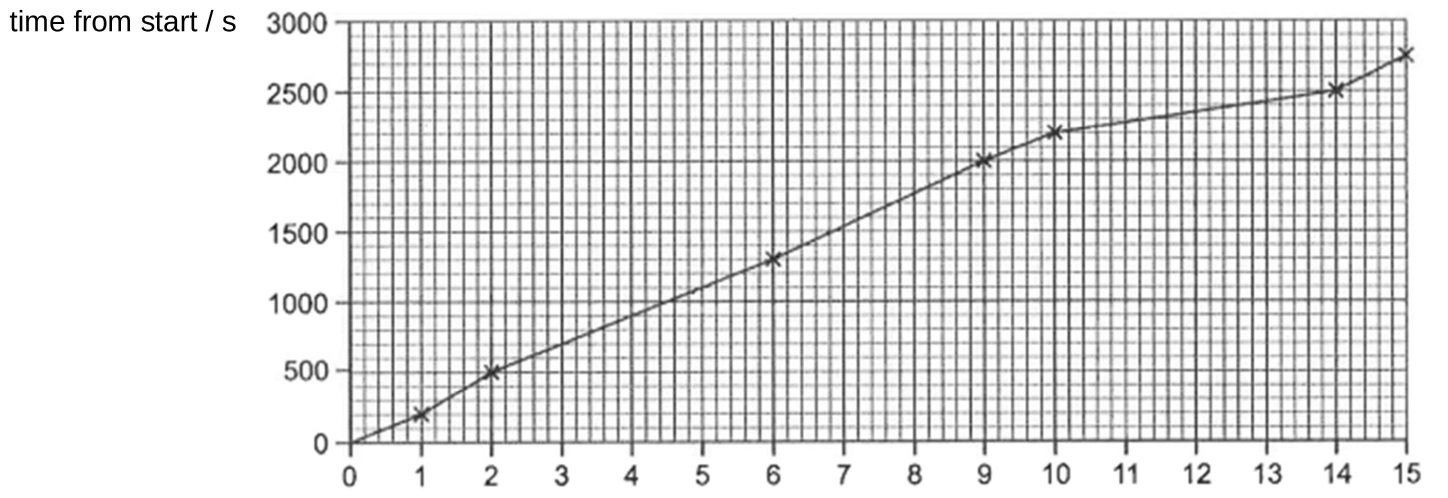

Fig. 6.1b

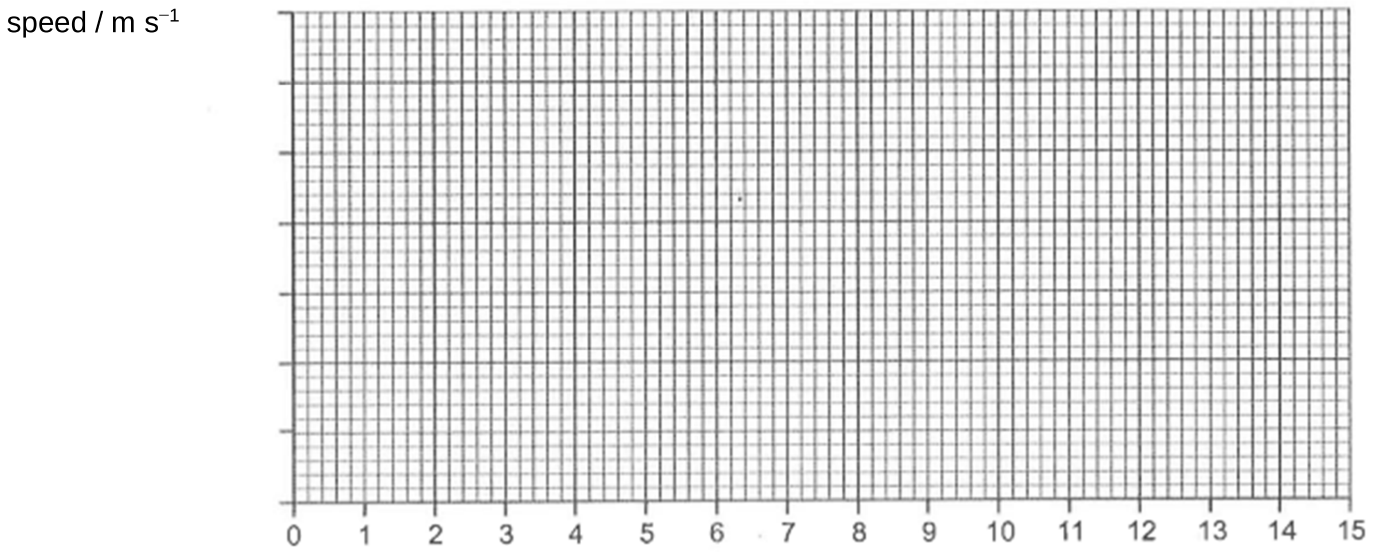

Fig. 6.1c

(c) In order to determine the power output of a competitor in the Tour de France, an estimate needs to be made of the work done against air resistance and friction. Assume that, during the stage from the 6th km mark to the 9th km mark, these resistive forces had a value of 24 N. The cyclist and his bike had a mass (body mass) of 78 kg.

Calculate, for these 3 km,

(i) the work done by the cyclist against these resistive forces,

work done = ……………….............. J [1]

(ii) the power per unit body mass supplied by the cyclist in work done against these resistive forces,

power per unit body mass = ……………….............. W kg^{-1} [3]

(iii) the total power per unit body mass supplied by the cyclist over the stage from the 6th km mark to the 9th km mark.

total power per unit body mass = ……………….............. W kg^{-1} [3]

(d) A typical male office worker, of average mass 70 kg, needs around 12 000 kJ every 24 hours to maintain his mass.

(i) Calculate the total power per unit body mass of the office worker.

total power per unit body mass = ……………….............. W kg^{-1} [1]

(ii) Compare your answer in **(d)(i)** with the energy needed by a cyclist in the Tour de France and comment on the difference.

....

.... [1]

Section B

Answer **one** question from this section.

7 **(a)** The variation with potential difference V of current I in a resistor X is shown in Fig. 7.1.

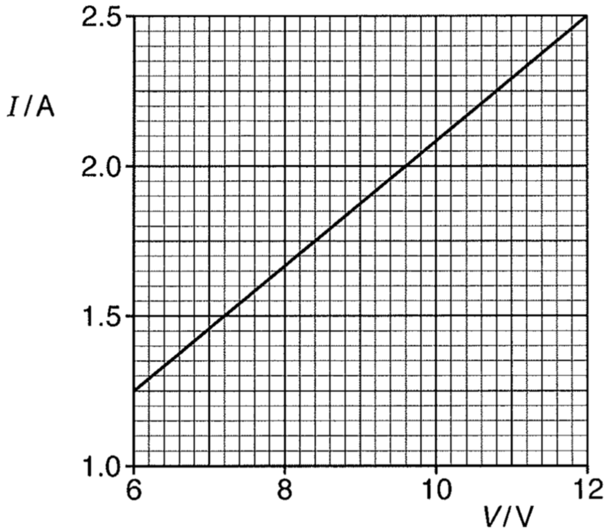

Fig. 7.1

(i) Use data from Fig. 7.1 to show that I is proportional to V.

[2]

(ii) The resistor X is connected in the circuit shown in Fig. 7.2.

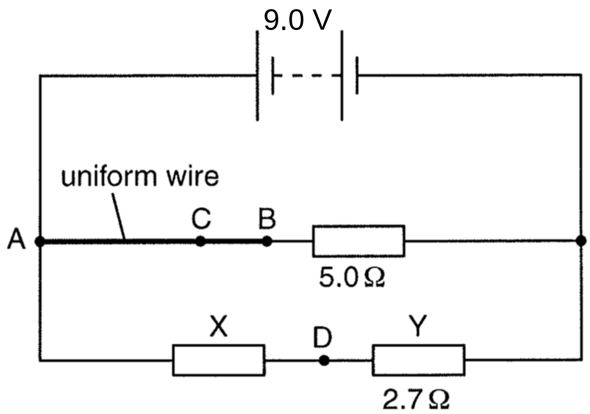

Fig. 7.2

A power supply of e.m.f. 9.0 V and negligible internal resistance is connected across a uniform resistance wire AB and a resistor of resistance 5.0 Ω.
The wire AB has length 1.0 m and resistance 4.0 Ω.
Resistor X and a resistor Y of resistance 2.7 Ω is connected in series across the power supply.

1. Determine the resistance of the resistor X.

resistance = ……………….............. Ω [1]

2. Calculate the current in the wire AB.

current = ……………….............. A [1]

3. Calculate the current in the resistor X.

current = ……………….............. A [1]

4. On Fig. 7.2, point C is at a distance 70 cm from point A on the wire AB. Point D is between resistor X and Y.

Calculate the potential difference between the points C and D.

potential difference = ……………….............. V [3]

5. If the internal resistance of the power supply is not negligible, state and explain the change (if any) to answer in **(ii)4**.

....

.... [1]

(b) Fig. 7.3 shows an electron with a horizontal velocity of 1.5×10^7 m s^{-1} entering the region between two horizontal plates which are 40 mm apart and 80 mm long. The upper plate is at a potential of +40 V and the lower plate is at a potential of –40 V.

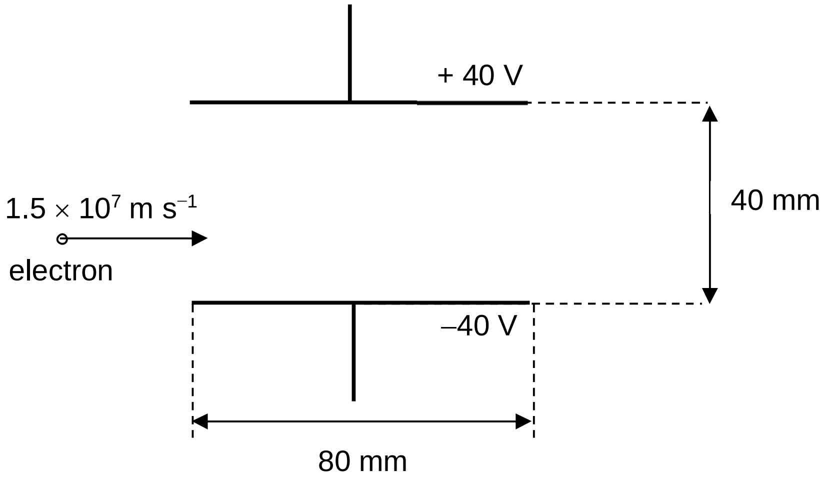

Fig. 7.3

(i) Determine the magnitude of the electric field strength in the region between the plates.

field strength = …………………............. V m^{-1} [1]

(ii) Determine the magnitude of the acceleration of the electron in the region between the plates.

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

(iii) Show that the vertical component of the velocity of the electron as it emerges from the plates is 1.9×10^6 m s^{-1}.

[2]

(iv) Determine the angle θ through which the electron has been deflected as a result of passing between the plates.

angle θ = ……………….............. ° [1]

(v) After passing through the plates, the electron enters the region of magnetic field B of flux density 1.62×10^{-4} T at an angle θ, as found in **(iv)**, and goes into helical motion of radius R, as shown in Fig. 7.4.

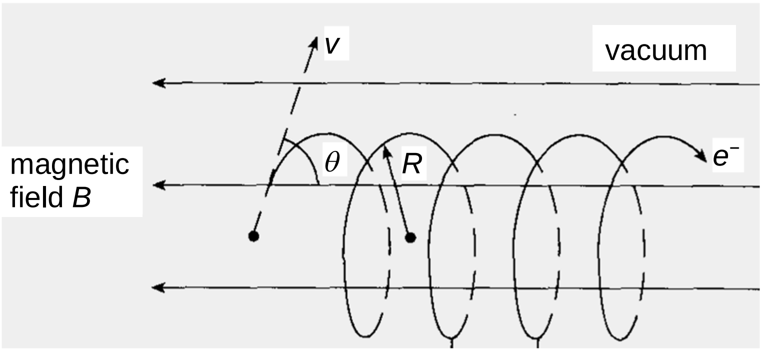

Fig. 7.4

1. Calculate the radius R of the helical path.

R = ……………….............. m [3]

2. Calculate the time taken for the electron to complete one revolution of the helical motion.

time = ……………….............. s [2]

8 **(a)** A stationary nucleus of polonium-210 decays to lead-206 by emitting an α-particle.

Data for the α-decay are given in Fig. 8.1.

nucleus	mass of nucleus / u
polonium-210	209.98313
lead-206	205.97470
α-particle	4.00263

Fig. 8.1

(i) Calculate, to two places of decimals, the energy released during the decay.

energy = ... MeV [3]

(ii) 98% of the energy from the decay is released as kinetic energy of the α-particle.

Calculate the speed of the α-particle immediately after the decay.

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

(iii) Explain why not all of the energy from the decay is released as kinetic energy of the α-particle.

....

....

.... [2]

(b) A nucleus of uranium-235 absorbs a neutron and becomes unstable. It then undergoes a fission reaction. One possible reaction is

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{54}Xe + {}^{90}_{38}Sr + \text{neutrons.}$$

(i) Determine the number of neutrons produced in this fission reaction.

number = ... [1]

(ii) State what is meant by the *binding energy* of a nucleus.

....

.... [1]

(iii) Data for the binding energies per nucleon for this fission reaction are given in Fig. 8.2.

isotope	binding energy per nucleon / MeV
uranium-235	7.59
xenon-142	8.37
strontium-90	8.72

Fig. 8.2

Calculate the energy released from the fission of one nucleus of uranium-235.

energy = ... MeV [2]

(iv) The isotope xenon-142 is unstable.

Suggest a reason why xenon-142 is unstable.

....

.... [1]

(v) Xenon-142 decays into the isotope caesium-142.

A sample initially contains only nuclei of xenon-142. After a time equal to 6.0 s, the ratio

$$\frac{\text{number of decayed nuclei of xenon-142}}{\text{number of undecayed nuclei of xenon-142}}$$

is equal to 31.

1. Define *half-life*.

………………..……………………………………………………………………..

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

2. Calculate the half-life of xenon-142.

half-life = ... s [3]

(c) Measurements for a radioactive source using the indicated absorber between the source and detector are shown in Fig. 8.3.

absorber	counts per minute
none	1004
sheet of paper	597
2 mm of aluminium	23
15 cm of lead	27

Fig. 8.3

Explain these observations.

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....

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....

....

....

....

.... [4]

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