Class	Index Number	Name

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2024
Preliminary Examination

PHYSICS, Higher 1 **8867/02**

Paper 2 Structured Questions **28 August 2024**
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group 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 a HB pencil for any diagrams or graphs.
Do not use staplers, 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

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

For Examiner's Use	
Section A	
1	**/ 8**
2	**/ 4**
3	**/ 6**
4	**/ 12**
5	**/ 16**
6	**/ 14**
Section B	
7	**/ 20**
8	**/ 20**
Total	**/ 80**

This question paper consists of **22** printed pages including this page.

DATA AND FORMULAE

Data

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

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 the spaces provided.

1 **(a)** A circuit is set up to measure the resistance *R* of a metal wire. The potential difference (p.d.) *V* across the wire and the current *I* in the wire are to be measured. Readings for p.d. *V* and the corresponding current *I* are obtained. These are shown in Fig. 1.1.

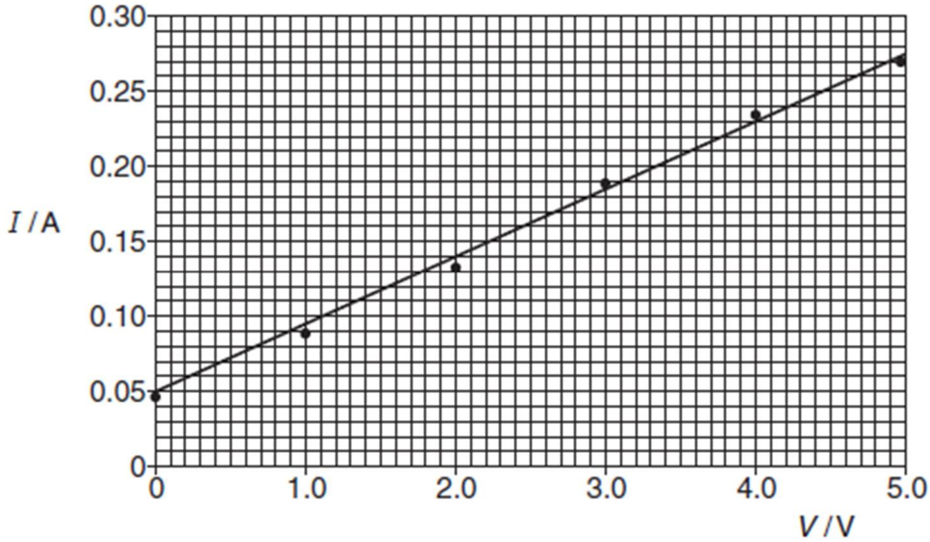


Fig. 1.1

(i) Explain how Fig. 1.1 indicates that the readings are subjected to

1. a systematic uncertainty,

……..

……[1]

2. random uncertainties.

……..

……[1]

(ii) Use data from Fig. 1.1 to determine *R*. Explain your working.

R = ……………………………..Ω [3]

(b) In another experiment, a value of resistance *R* of a wire is determined from the following data:

Current I = 0.64 ± 0.01 A and p.d. V = 6.8 ± 0.1 V.

Calculate the value of *R*, together with its uncertainty. Give your answer to an appropriate number of significant figures.

R = ………………… ± ……….………..Ω [3]

2 Fig 2.1 shows how the gravitational force *F* acting on a 1 kg mass varies with distance from the centre of the Earth. The radius of the Earth is 6300 km.

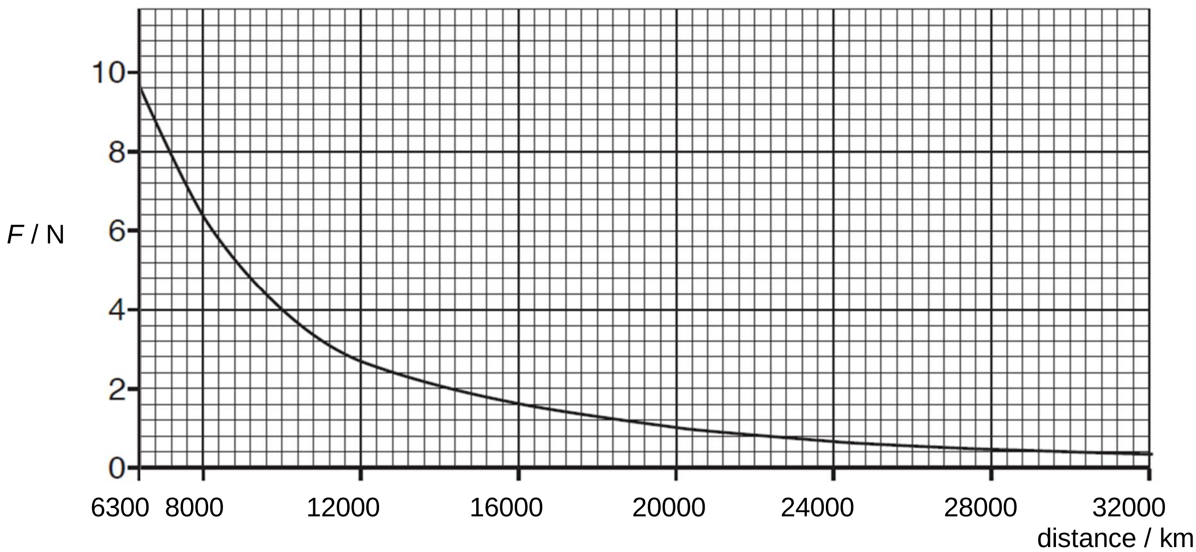


Fig. 2.1

(a) State Newton's law of gravitation.

……...

……...

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

(b) Use Fig. 2.1 to calculate the mean mass of the Earth.

mass = …............................... kg [3]

3 Fig. 3.1 shows two parallel metal plates A and B, each of length 10 cm, at a distance of 4.0 cm apart in a vacuum environment. A proton with speed 6.5×10^{5} m s^{-1} and charge 1.6 x 10^{-19} C is emitted from a proton source.

The proton travels along a straight path exactly down the middle of the region between the parallel plates when there is no electric field applied between the plates. It then hits a screen where it shows up as a bright spot.

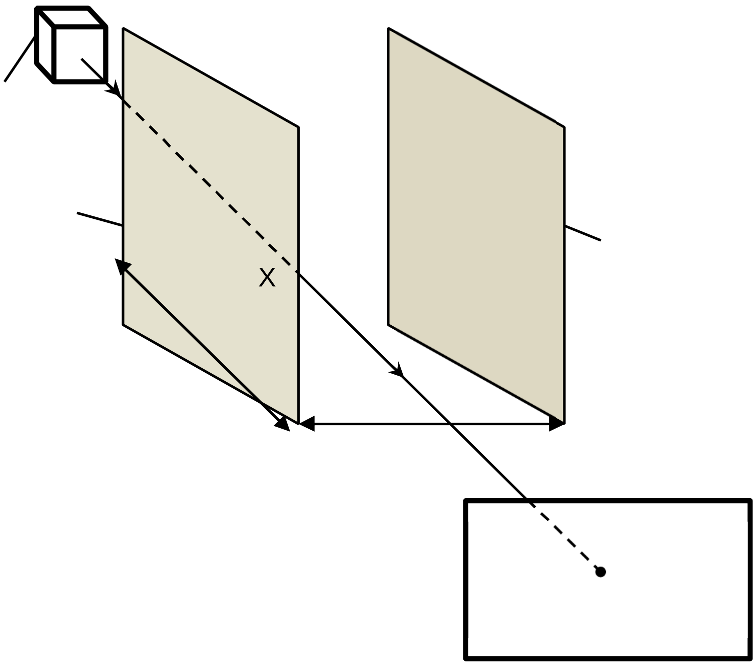


Fig. 3.1 (not to scale)

proton
source
proton path
10 cm
4.0 cm
screen
plate A
(higher potential)
plate B

(lower potential)

A uniform electric field is now applied in the region between the plates, where plate A is set at a higher potential. The electric field strength is 1.25 kN C^{-1} between the plates.

(a) Determine the time taken for a proton to travel through the plates.

time = …………………………….. s [1]

(b) Show that the acceleration on a proton due to the electric field is 1.2 x 10^{11} m s^{-2}. Draw on Fig. 3.1, when the proton just enters the electric field region at point X, the direction of this acceleration.

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

(c) Determine the speed at which the proton emerges from the region of uniform electric field.

speed = ……………………………. m s^{-1} [2]

(d) On Fig. 3.1, indicate with a cross (×) where the deflected proton is likely to hit the screen. [1]

4 **(a)** Two charged particles X and Y travelling in the same direction, each with velocity v, enter a uniform magnetic field of flux density B pointing into the plane of the paper in a vacuum.

Particles X and Y have the same mass m but different charges q_X and q_Y respectively.

The paths of particles X and Y in the magnetic field are shown in Fig. 4.1. The radius of the semi-circular path of particle Y is double that of particle X.

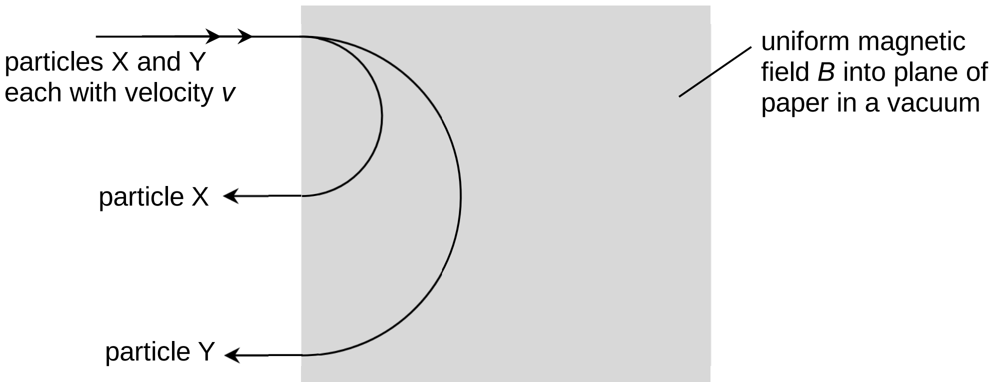


Fig. 4.1

(i) Explain why the paths of the charged particles are circular in the magnetic field.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(ii) State if the charge of the particles is positive or negative.

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

(iii) Calculate the ratio .

= ………………………….. [3]

(b) Particle X with velocity v now enters another uniform magnetic field region having the same flux density B as before but with air molecules throughout. It moves in a path in the magnetic field as shown in Fig. 4.2.

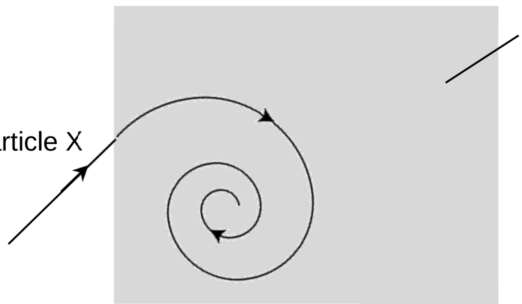


Fig. 4.2

(i) Explain, using any relevant equations, the path of particle X shown in Fig. 4.2.

……

……

……

……[2]

(ii) **1.** Show that the expression for the time T taken for one revolution of the path is T = .

[2]

2. The tau particle is an elementary particle that has the same charge as an electron but has a mass that is 3000 times that of an electron. The average time that this tau particle can survive before it decays is known to be 2.9×10^{-13} s.

Using the expression in **(b)(ii)1**, hence explain if particle X in Fig. 4.2 could be a tau particle if B = 1.0 T.

………………………………………………………………………………………………

………………………………………………………………………………………………

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

5 **(a)** The results of the alpha-particle scattering experiment provide evidence for the structure of the atom.

Result 1: The vast majority of the alpha-particles pass straight through the metal foil or are deviated by small angles.

Result 2: A vey small minority of the alpha-particles is scattered through angles greater than 90º.

State what may be inferred (deduced) from:

(i) Result 1:

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(ii) Result 2:

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(b) **(i)** State what is meant by nuclear fusion.

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(ii) On Fig. 5.1, sketch the variation of binding energy per nucleon with nucleon number A for values of A between 1 and 250.

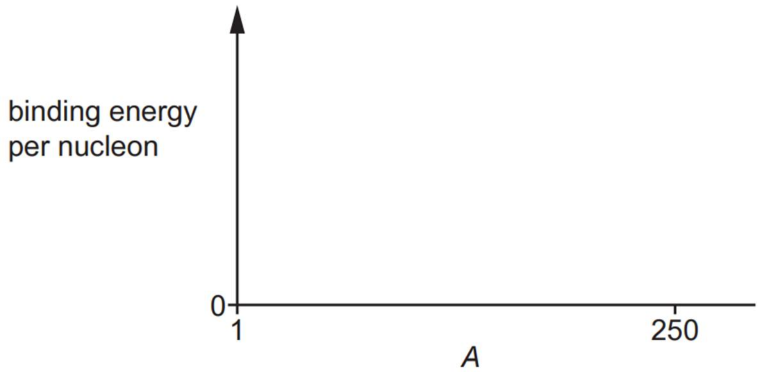


Fig. 5.1

[1]

(iii) On your line in Fig. 5.1, label:

1. a point **X** that could represent a nucleus with highest stability, and the corresponding nucleon number on the *A*-axis. [1]

2. a point **Y** that could represent a nucleus that undergoes nuclear fusion. [1]

(iv) A nucleus Z undergoes nuclear fission to form strontium-93 (3893Sr) and xenon-139 (54139Xe) according to

$$01n + \mathrm{Z} \rightarrow 3893Sr + 54139Xe + 201n.$$

Table 5.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

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

Table. 5.1

The fission of 1.00 mol of Z releases 1.77×10^{13} J of energy.

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

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

(c) Yittrium-90 decays into zirconium-90, a stable isotope. A sample initially consists of pure yittrium-90.

Calculate the time, in days, when the ratio of the number of yittrium-90 nuclei to the number of zirconium-90 nuclei would be 2.0.

The half-life of yittrium-90 is 2.7 days.

time = …………………… days [3]

(d) A sample of a radioactive isotope emits a beam of beta particles. 9.8×10^{10} beta particles is found to pass a fixed point in the beam in a time of 2.0 minutes.

Calculate the current, in pA, produced by the beam of beta particles.

current = …………………… pA [2]

6 A serious hazard for fire-fighters is the explosion of containers of 'liquefied gas' (butane) that have been heated in a fire. When the butane suddenly burns in an explosion, the fire spreads very rapidly in the form of a spherical fireball of increasing radius that is at very high temperature.

In order to study such fireballs, a series of experiments is carried out. Some butane of volume 12.5×10^{-3} m^3 is put in a sealed container and is then heated until it explodes. The variation with time *t* of the radius *R* of the fireball is determined. The results are shown in Fig. 6.1.

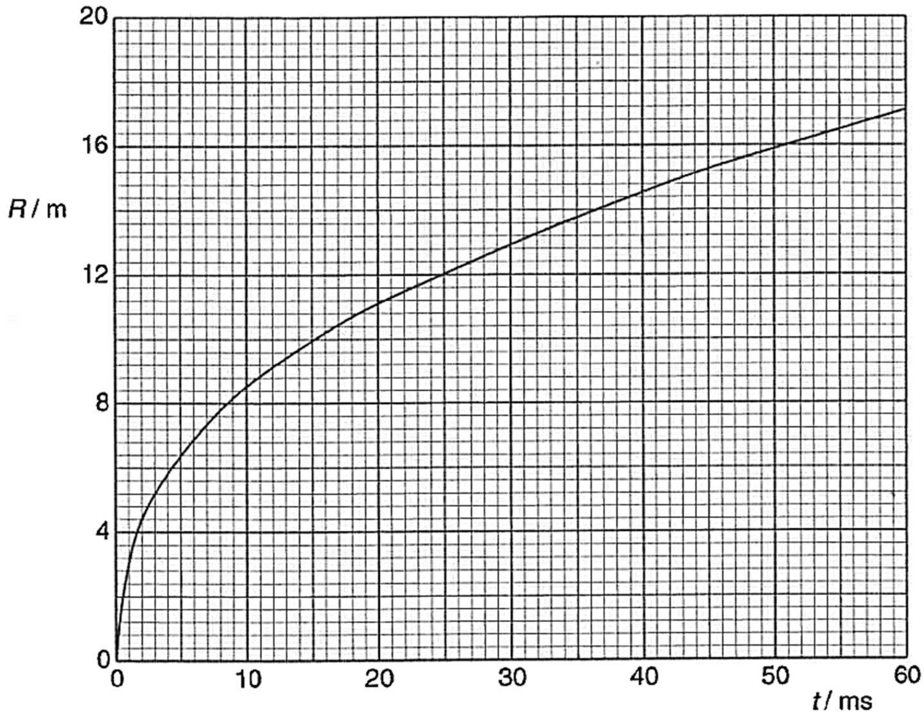


Fig. 6.1

(a) Use Fig. 6.1 to

(i) describe, without any calculation, the variation with time of the **rate** at which the radius of the fireball increases,

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

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

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

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

(ii) suggest why, in a room of length 12 m and width 12 m, such an explosion would be very hazardous.

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

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

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

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

(b) It is thought that, for a fixed volume of butane, the radius R of the fireball varies with time t according to the expression

$$R^n = k\,t^m,$$

where n and m are integers and k is a constant.

Some corresponding values of lg t and lg R for the data in Fig. 6.1 are plotted on the graph of Fig. 6.2.

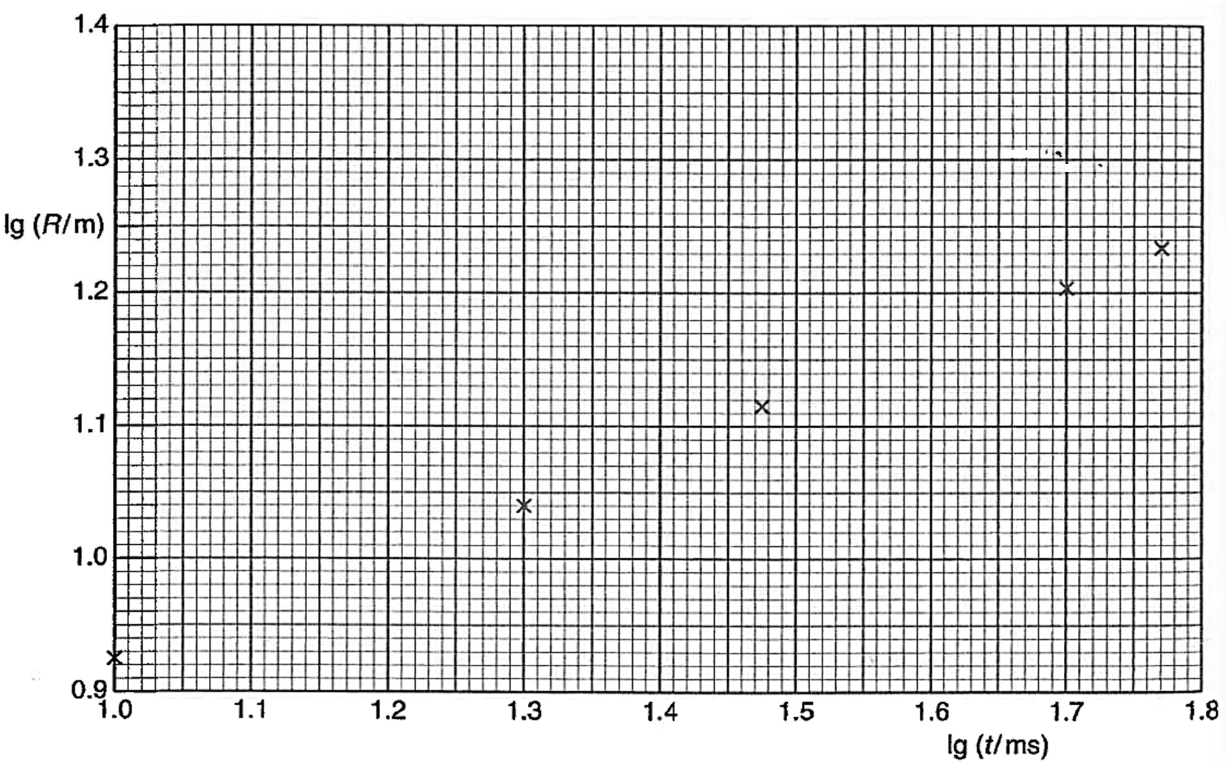


Fig. 6.2

(i) On Fig. 6.2,

1. plot the point corresponding to time t = 40 ms,

2. draw the best-fit line for all the plotted points. [2]

(ii) Determine the gradient of the line drawn in **(i) part 2**.

gradient = ……………………………. [2]

(iii) Hence, *suggest* values for the integers n and m. Explain your working.

n = ……………………………….

m = ……………………………. [3]

(c) The experiment is repeated using similar containers but with different volumes of butane. The results are shown in Fig. 6.3.

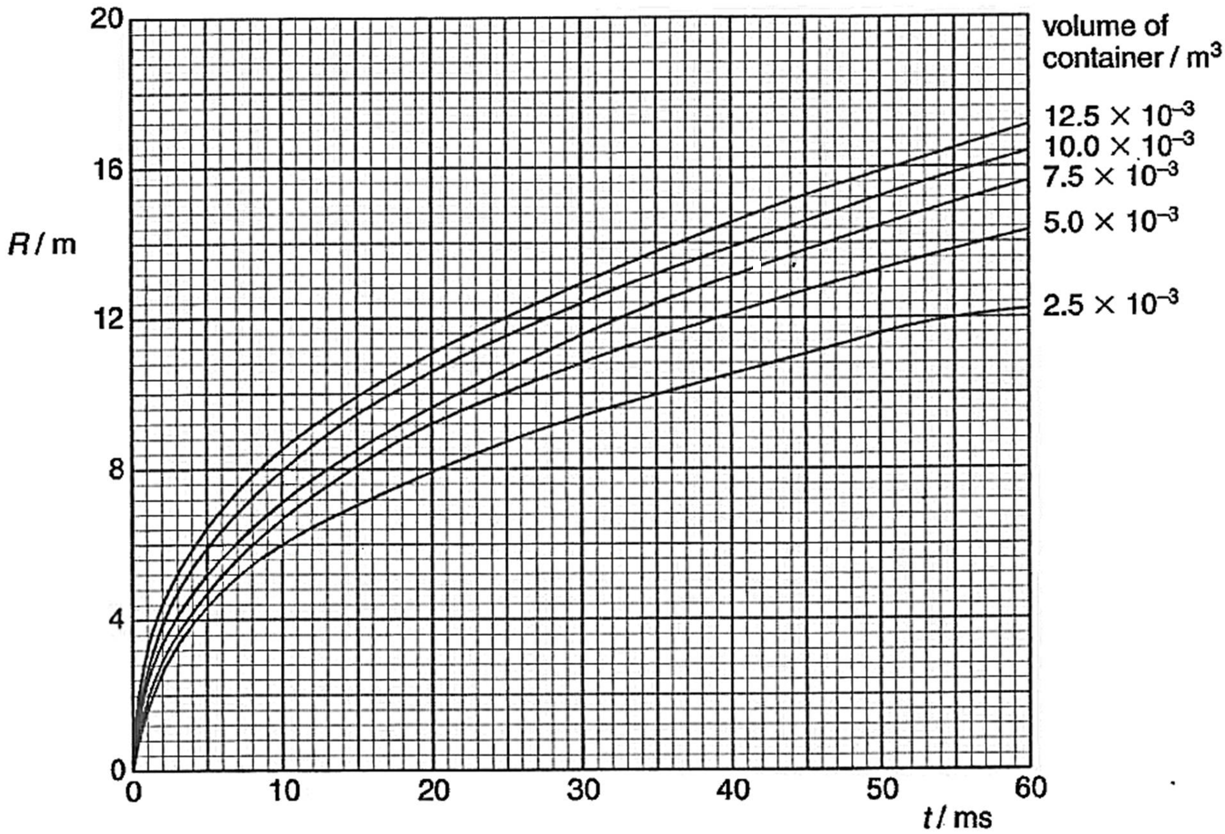


Fig. 6.3

Without drawing a further graph, show that, at time t = 40 ms, the radius R of the fireball is related to the volume V of butane by the expression

$$R^5 = cV,$$

where c is a constant.

[3]

Section B

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

7 **(a)** A rigid uniform beam of weight W is connected to a fixed support by a hinge, as shown in Fig. 7.1.

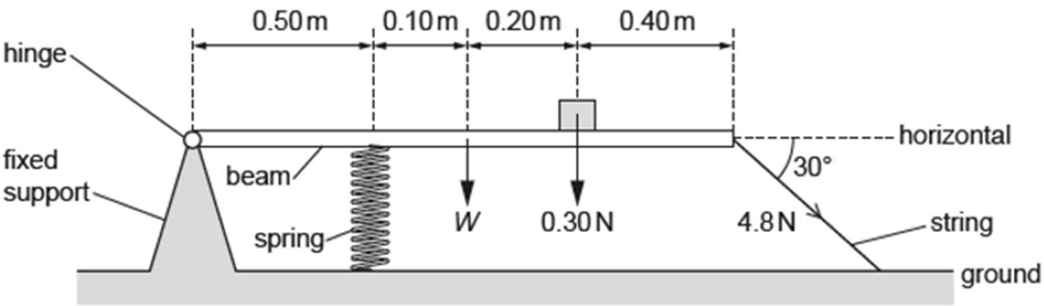


Fig. 7.1 (not to scale)

A compressed spring exerts a total force of 8.2 N vertically upwards on the horizontal beam. A block of weight 0.30 N rests on the beam. The right-hand end of the beam is connected to the ground by a string at an angle of 30° to the horizontal. The tension in the string is 4.8 N. The distances along the beam are shown in Fig. 7.1.

The beam is in equilibrium. Assume that the hinge is frictionless.

(i) Show that the vertical component of the tension in the string is 2.4 N.

[1]

(ii) By taking moments about the hinge, determine the weight W of the beam.

W = ……………………… N [3]

(iii) Calculate the horizontal component of the force exerted on the beam by the hinge.

force = ……………………… N [1]

(iv) The spring obeys Hooke's Law and has an elastic potential energy of 0.32 J. Calculate the compression of the spring.

compression = ……………………… m [2]

(v) The string is cut so that the spring extends upwards. This causes the beam to rotate and launch the block into the air. The block reaches its maximum height and then falls back to the ground. Fig. 7.2 shows part of the path of the block in the air shortly before it hits the horizontal ground.

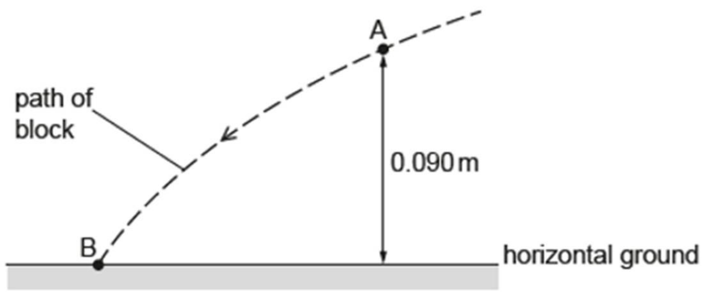


Fig. 7.2 (not to scale)

The block is at a height of 0.090 m above the ground when it passes through point A. The block has a kinetic energy of 0.044 J when it hits the ground at point B. Air resistance is negligible.

1. Calculate the decrease in the gravitational potential energy (GPE) of the block for its movement from A to B.

decrease in GPE = ………………………… J [1]

2. Hence or otherwise, determine the speed of the block at point A.

speed = ……………………… m s^{-1} [3]

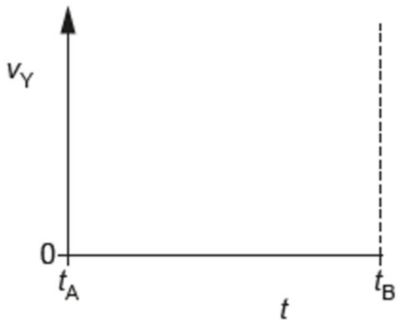
(vi) By reference to the force on the block, explain why the horizontal component of the velocity of the block remains constant as it moves from A to B.

…….
.

…….
.

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

(vii) The block passes through point A at time t_A and arrives at point B at time t_B. On Fig. 7.3, sketch a graph to show the variation of the magnitude of the vertical component v_Y of the velocity of the block with time t from $t = t_A$ to $t = t_B$. Numerical values of v_Y are not required.



[2]

Fig. 7.3

(b) A trolley A moves along a horizontal surface at a constant velocity towards another trolley B which is moving at a lower constant speed in the same direction. Fig. 7.4 shows the trolleys at time $t = 0$.

Fig. 7.4

Table 7.1 shows data for the trolleys.

trolley	mass / kg	initial speed / m s^{-1}
A	0.25	0.48
B	0.75	0.12

Table 7.1

The two trolleys collide elastically and then separate. Resistive forces are negligible.

Fig. 7.5 shows the variation with time *t* of the velocity *v* for trolley B.

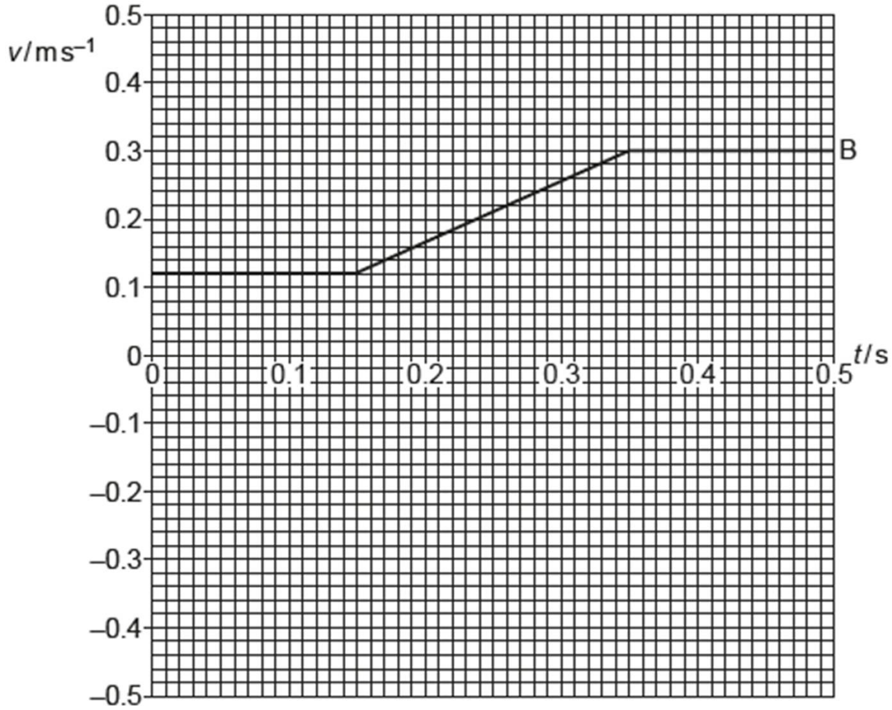


Fig. 7.5

(i) Use Table 7.1 and Fig. 7.5 to determine:

1. the acceleration of trolley B during the collision

acceleration = ………………….. m s^{-2} [1]

2. the magnitude of the final velocity of trolley A.

magnitude = ………………….. m s^{-1} [2]

(ii) On Fig. 7.5, sketch the variation of the velocity of trolley A with time *t* from *t* = 0 to *t* = 0.50 s.

[3]

8 **(a)** Define electrical resistance.

…….

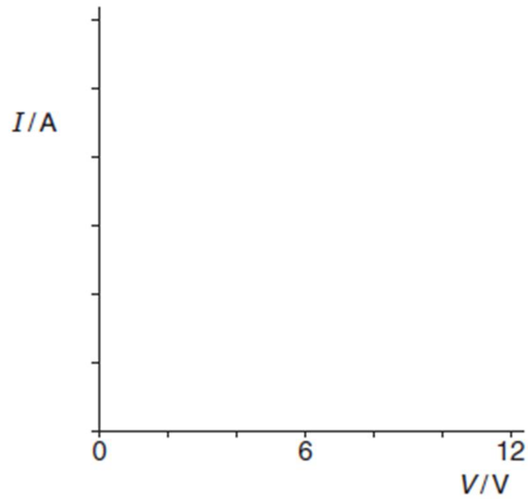
………..[1]

(b) A filament lamp is rated as 12 V, 36 W.

(i) Calculate the resistance of the lamp at its working temperature.

R = ………….……..………..Ω [2]

(ii) On the axes of Fig. 8.1, sketch a graph to show the current-voltage (*I*-*V*) characteristic of the filament lamp. Mark an appropriate scale for current on the *y*-axis.



[2]

Fig. 8.1

(iii) The filament lamp is constructed of wire of diameter 0.54 mm and the material of the wire has resistivity 4.9 x 10^{-7} Ωm. Using your answer from **(i),** calculate the length of the wire required.

length = ……………..…..………..m [2]

(c) Fig. 8.2 shows the variation with applied potential difference *V* of the current *I* in an electrical component C.

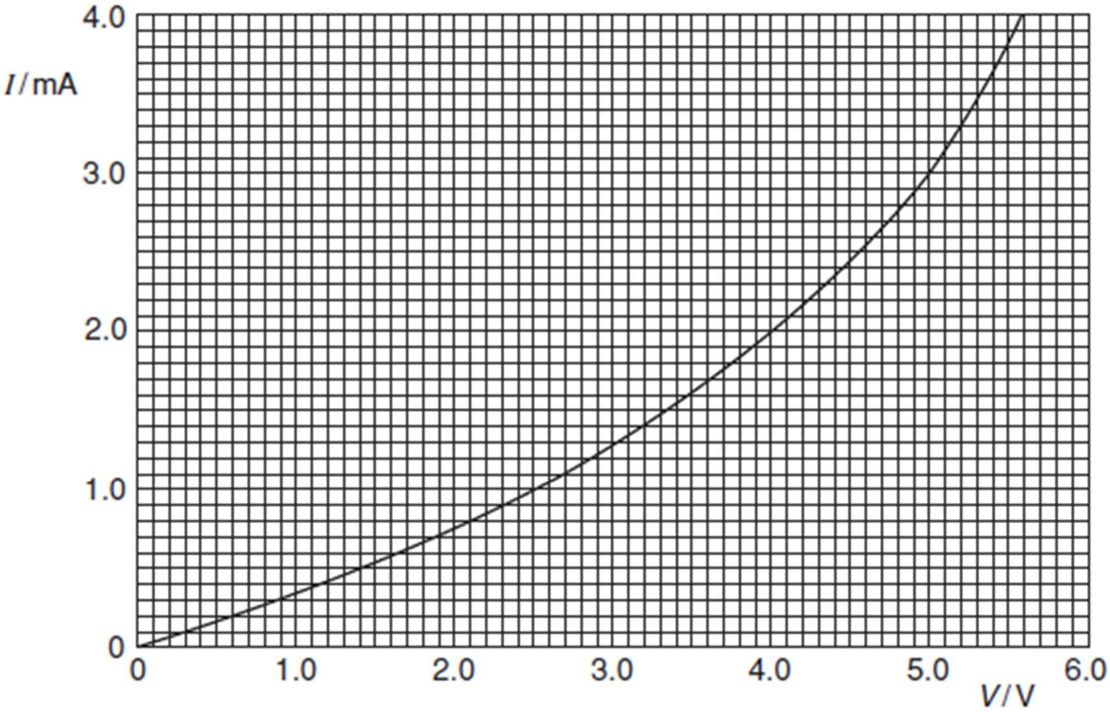


Fig. 8.2

(i) State, with a reason, whether the resistance of component C increases or decreases with increasing potential difference.

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

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

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

(ii) Determine the resistance of component C at a potential difference of 4.0 V.

R = ……………………………Ω [2]

(iii) Component C is connected in parallel with a resistor R of resistance 1500 Ω and a battery of e.m.f. E and internal resistance r, as shown in Fig. 8.3.

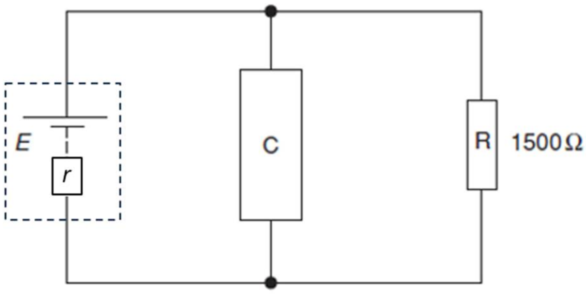


Fig. 8.3

1. On Fig. 8.2, draw a line to show the variation with potential difference V of the current I in resistor R. [2]

2. Hence, or otherwise, use Fig. 8.2 to determine the current in the battery for a terminal potential difference across the battery of 2.0 V.

current = ………………………….. A [2]

3. Calculate the internal resistance r if the e.m.f. of the battery is 2.02 V.

r = ……………………….. Ω [2]

(iv) The resistor R of resistance 1500 Ω and the component C are now connected in series across another supply of e.m.f. 7.0 V and negligible internal resistance. Using information from Fig. 8.2, state and explain which component, R or C, will dissipate thermal energy at a greater rate.

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

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

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

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

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

End of paper