Class

Candidate Name: ____________________

Adm No

H

millennia institute

2023 Preliminary Examinations
Pre-University 3

H2 PHYSICS
9749/02

Paper 2 Structured Questions

14 September

2 hours

Candidates answer on the Question Paper

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

Write your full name, class and Adm number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of this booklet.
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.
Answer **all** questions.

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

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For Examiner's Use		
1		/ 6
2		/ 7
3		/ 7
4		/ 8
5		/ 9
6		/ 9
7		/ 14
8		/ 20
Presentation		
Total		/ 80

This document consists of **25** printed pages and 1 blank page.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** The final velocity *v,* initial velocity *u,* acceleration *a* and displacement *s* of a body moving in a straight line at uniform acceleration is related by the equation

$$v^2 = u^2 + 2as$$

Show that this equation is homogenous. [2]

(b) A student measures the three dimensions of a solid cube:

width = 1.99 cm ± 1%,
length = 1.95 cm ± 1%,
height = 2.02 cm ± 1%.

The manufacturer of the cube quotes the density of the material used for the cube as (1.24 ± 0.05) g cm^{-3}.

Determine the mass of the cube. Express the mass of the cube together with its uncertainty.

mass = (±) g [4]

[Total: 6]

2 A skateboarder starts from rest at point A as shown in Fig. 2.1.

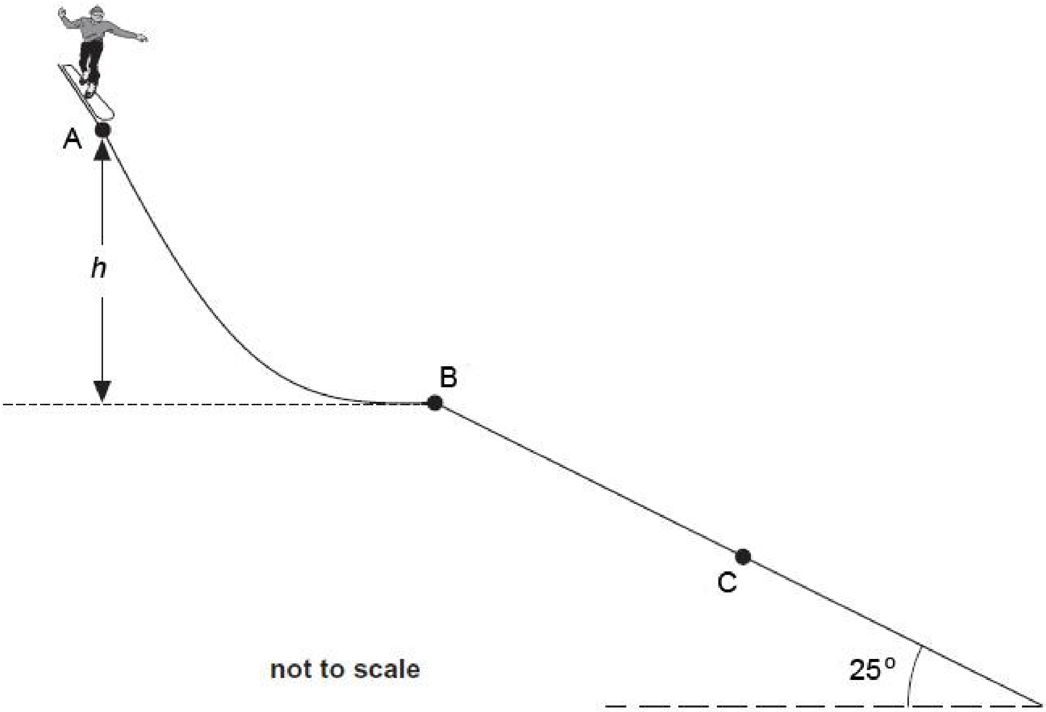


Fig. 2.1

The skateboarder reaches a speed of 17 m s^{-1} at point B.

Consider the skateboarder to be a point mass of 65 kg and ignore the effects of friction and air resistance.

(a) Calculate the height difference, *h*, between point A and point B.

h = ……………………… m [1]

(b) The skateboarder takes off at point B, travelling horizontally with a velocity of 17 m s^{-1}.
He lands at point C after being in the air for 1.6 s.

(i) Calculate v_v, the vertical component of his velocity, just before landing at point C.

v_v = …………………… m s^{-1} [2]

(ii) On Fig. 2.2, sketch the variation with time of the vertical component of the velocity v_v of the skateboarder from point B to point C.

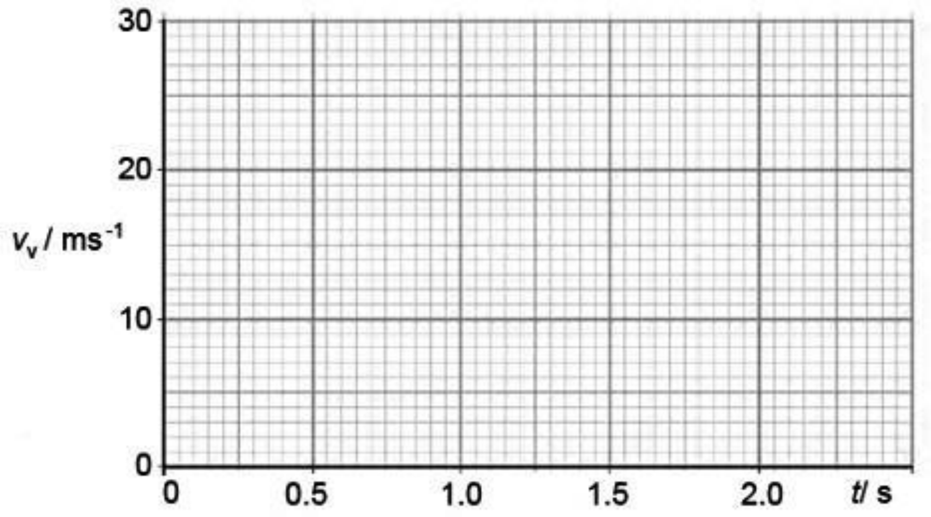


Fig. 2.2

[1]

(iii) Show that the magnitude of the resultant velocity just before landing at point C is 23 m s^{-1}.

[1]

(c) Explain why it is safer for the skateboarder to land on a downward slope than on a horizontal surface.

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

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

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

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

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

....

....

[Total: 7]

3 **(a)** **(i)** State Archimedes' principle.

....

....

....[1]

(ii) Explain why an object submerged in a fluid experiences upthrust.

....

....

....

....[2]

(b) A mini submarine has a mass of 4800 kg and total volume 5.0 m^3. To dive into the sea, it takes on mass in the form of seawater into its ballast tank.

Fig. 3.1, Fig. 3.2 and Fig. 3.3 show a simplified cross sectional diagram of the mini submarine when it is at the surface of the sea, diving and submerged respectively.

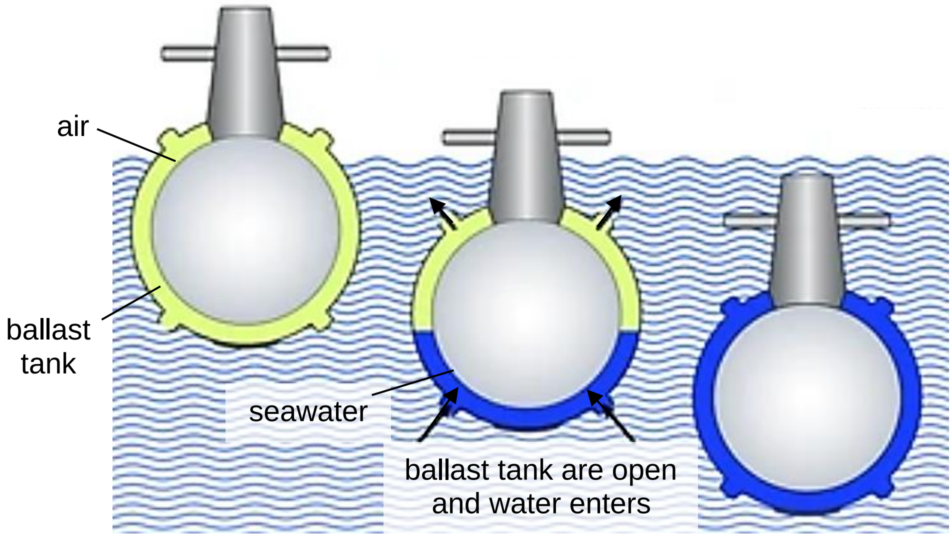


Fig. 3.1 **Fig.3.2** **Fig. 3.3**

Calculate the mass of seawater that the fully submerged mini submarine must take on if it is to descend at a constant speed, when the average resistive force acting on it is 1100 N. Assume the density of seawater is 1030 kg m^{-3}.

mass of seawater = ……………………………… kg [3]

(c) Calculate the pressure at a sea depth of 200 m.
Assume the atmospheric pressure is 1.01×10^5 Pa.

pressure = ……………………………… Pa [1]

[Total: 7]

4 A cyclist made a left turn on a rough level road surface at a constant speed *v*, as shown in Fig. 4.1. The total mass of the bicycle and rider is *m* and their combined centre of gravity is at G.

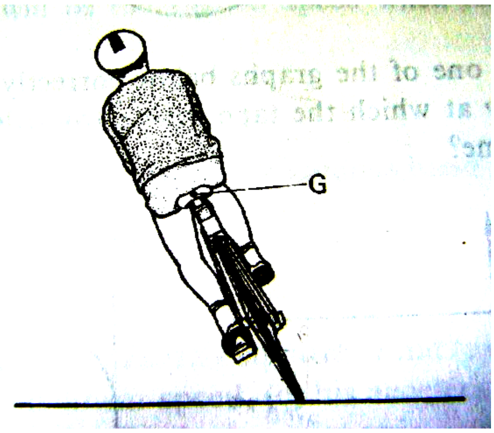


Fig. 4.1

(a) In Fig. 4.1, draw and label all the forces acting on the system of the cyclist and his bicycle. Ignore forces parallel to the direction of motion. [2]

(b) If the rider is negotiating a turn with a radius of curvature of 55 m, the total mass of the rider and bicycle is 80 kg, and the friction provided by the road surface is 70 N, calculate the speed with which he is turning.

speed = ………………….. m s^{-1} [1]

(c) The rider now makes the same left turn on a rough surface banked at 20° to the horizontal as shown in Fig. 4.2.

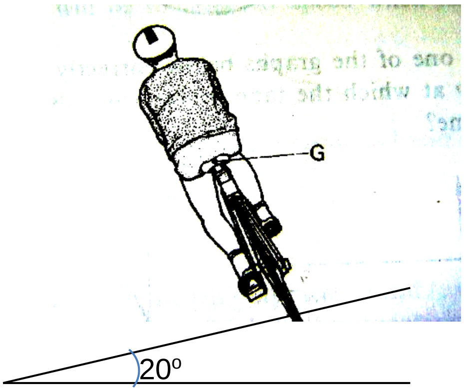


Fig. 4.2

Assuming that the frictional forces remain as 70 N, and radius of curvature is still 55 m,

(i) explain how the banked surface assists the cyclist in travelling around the corner at a higher speed.

....

....

....

....[2]

(ii) Calculate the new maximum speed with which the rider may negotiate the turn.

maximum speed = ………………….. m s^{-1} [3]

[Total: 8]

5 A space rocket on Earth is fired for a few minutes to provide it with the necessary kinetic energy for it to travel directly to the Moon. Along the line joining the centres of the Earth and Moon, there is a point P where the rocket does not experience any gravitational force. P is 3.46×10^5 km from the centre of the Earth and 3.80×10^4 km from the centre of the Moon as shown in Fig. 5.1.

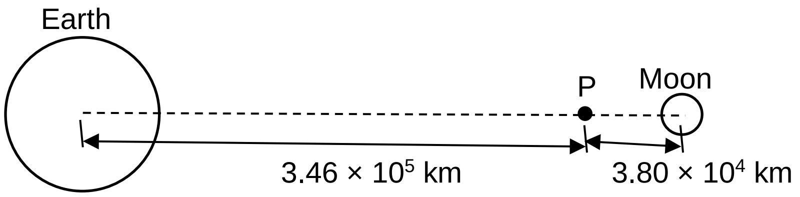


Fig. 5.1

(a) Explain why the rocket does not experience any gravitational force at P.

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

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

…………………………………………………………………………………………………

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

(b) Suggest two reasons why a return rocket from the Moon would need much less fuel than that required for the outward journey from the Earth.

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

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

…………………………………………………………………………………………………

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

(c) Given that the mass of the Earth is 5.97×10^{24} kg, calculate the mass of the Moon.

mass = ... kg [2]

(d) A meteorite of mass 7.5 kg moves towards P under the gravitational attraction of the Earth and Moon. It is initially at rest at a large distance away from P.

(i) Define gravitational potential at a point.

…………………………………………………………………………………………………

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

(ii) Calculate the kinetic energy of the meteorite when it reaches P.

kinetic energy = ………………………….. J [3]

[Total: 9]

6 **(a)** A circuit is setup as shown below in Fig 6.1. A cell *E* with internal resistance *r* is connected to a network of resistors.

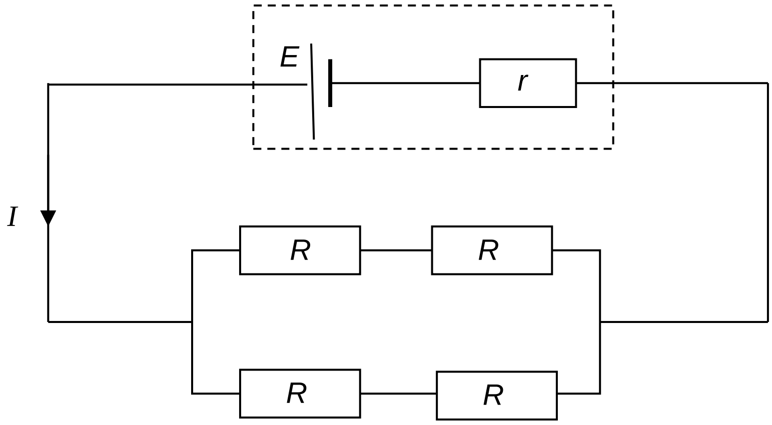


Fig 6.1

(i) Express the current I in the circuit, in terms of *R*, *r* and *E.*

[2]

(ii) Show that the fraction of power dissipated in the external resistors by the battery is $\frac{R}{R+r}$.

[1]

(iii) Suggest a reason for having 4 resistors connected in a network as shown in Fig 6.1 instead of just using a single resistor of resistance *R*.

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

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

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

(b) A circuit is set up as shown in Fig 6.2 below. The potentiometer wire XY has a resistance of 1.5 Ω and is 1.00 m long. The movable contact J can be connected to any point along wire XY.

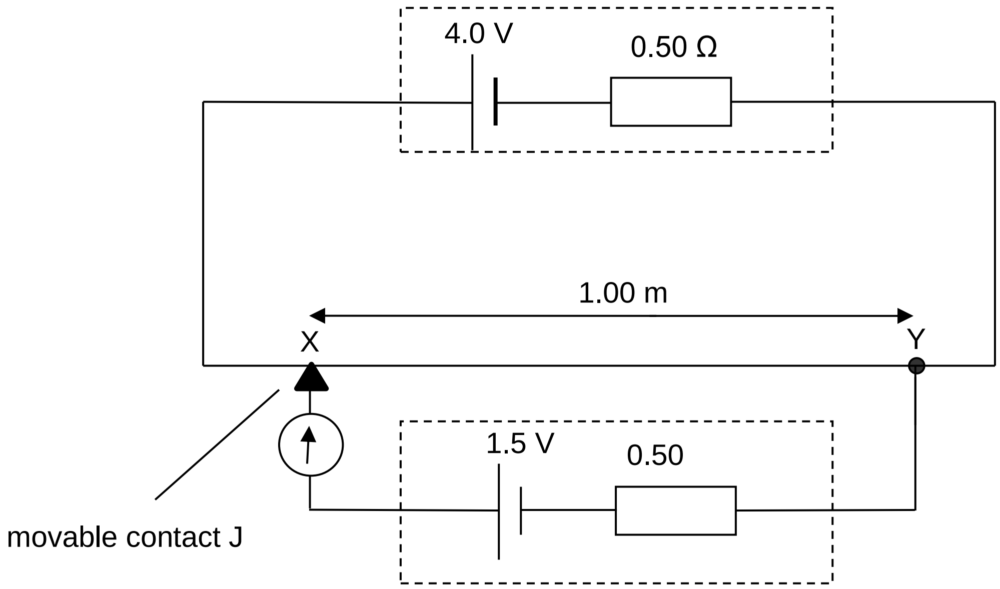


Fig 6.2

(i) Determine the distance of the contact J from Y, such that there is no deflection in the galvanometer.

distance JY = ………………………. m [2]

(ii) Now, a 4.7 Ω resistor is connected across points A and B.

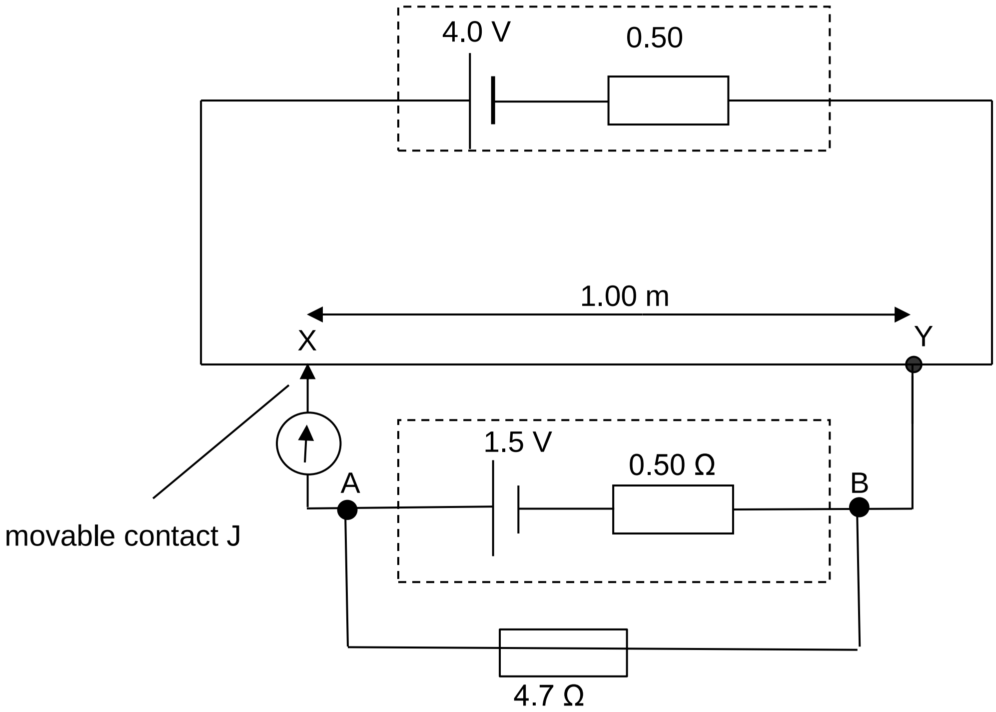


Fig 6.3

Determine the new distance of the contact J from Y, such that there is no deflection in the galvanometer.

new distance = ………………………... m [3]

[Total: 9 marks]

7 **(a)** For a particular gas, the emission and absorption spectra are obtained for the visible light spectrum.

State one similarity and one difference between the discrete lines of the absorption and emission spectra of this gas.

Similarity: ……………………………………………………………………………………….........

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

Difference: ……………………………………………………………………………………….........

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

(b) Fig. 7.1 gives information on three lines observed in the emission spectrum of hydrogen atoms.

wavelength / nm	**energy of photon / eV**
486	2.56
656	
1880	0.66

Fig. 7.1

(i) Complete Fig. 7.1 and show your working clearly in the space below. [2]

(ii) Fig. 7.2 is a partially completed diagram to show energy levels of a hydrogen atom.

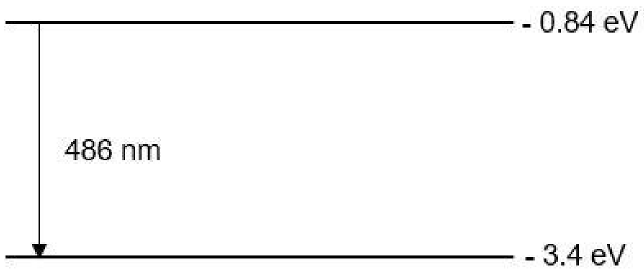


Fig. 7.2

On Fig. 7.2, draw an additional labelled energy level between the two given energy levels to account for the emission of the photons in Fig. 7.1 [1]

(c) Three of the energy levels of a lithium atom are shown in Fig. 7.3.

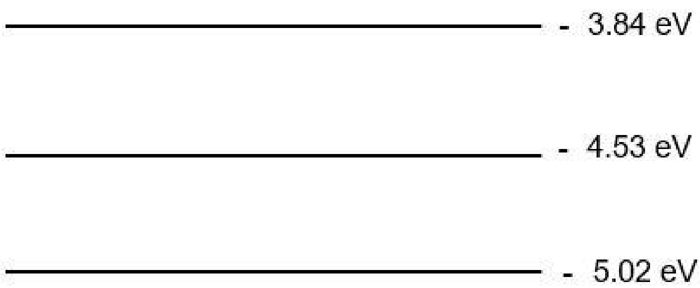


Fig. 7.3

One way to study the energy levels of an atom is to bombard the atom with electrons and measure the kinetic energies of the bombarding electrons before and after the collision. If a lithium atom which is originally in the – 5.02 eV level is bombarded with an electron of kinetic energy 0.92 eV, the scattered electron can have only two possible kinetic energies.

States these two kinetic energy values, and state what happens to the lithium atom in each case.

1st possible kinetic energy value: ………………………. eV [1]

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

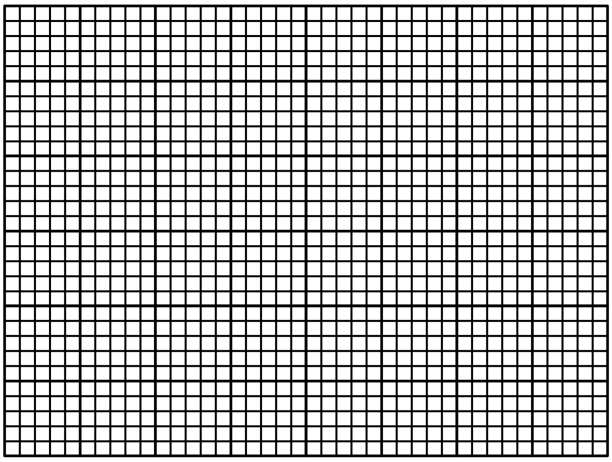
……………………………………………………………………………………………………[1]

2nd possible kinetic energy value: ………………………. eV [1]

....

....[1]

(d) X-ray photons are produced in an X-ray tube when electrons are accelerated through a potential difference V_o towards a metal target. An X-ray spectrum is shown in Fig. 7.4.



0
2.0
4.0
6.0
Wavelength / 10^{-11} m
Relative
Intensity
8.0

Fig. 7.4

(i) Explain how the characteristic X-ray photons are produced.

[2]

(ii) Determine the minimum potential difference V_o applied across the X-ray tube.

V_o = kV [2]

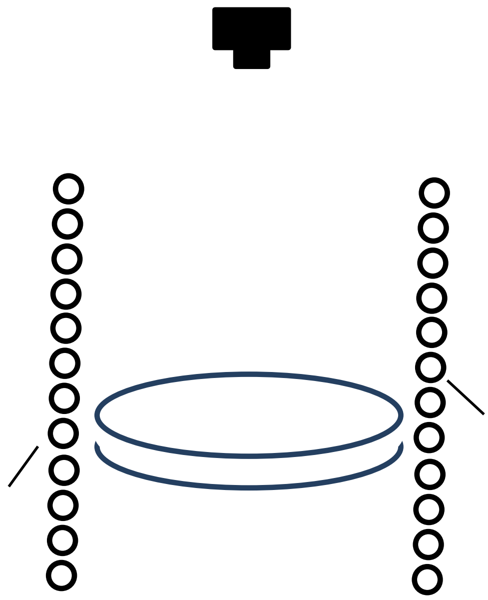
(iii) The potential difference in **(d)(ii)** to accelerate the electrons is increased.

On Fig. 7.4, sketch the new spectrum obtained. [1]

[Total: 14]

8 Read the passage below and answer the questions that follow.

Fig. 8.1 shows a bubble chamber which consists of a sealed chamber filled with a liquefied gas. The coils around the chamber provide a magnetic field. The pressure inside the chamber can be reduced quickly by an adjustable piston. The liquid is originally at a temperature just below its boiling point. When the pressure is reduced, the boiling point of the liquid becomes lower, so that it is less than the original temperature of the liquid, leaving the liquid superheated.



magnetic coils

charged particles

magnetic field

piston

magnetic coils

camera

liquid

Fig. 8.1

As beams of charged particles pass through the liquid, they deposit energy by ionising the liquid atoms. This causes the liquid to boil and tiny gas bubbles are formed along the paths of the charged particles.

Some charged particles may also collide with an atomic nucleus of the liquid and form products which are charged too. These charged products will move on and ionise the liquid, causing more trails of bubbles to form.

The chamber is illuminated so that the tracks of the charged particles can be photographed. By analyzing the tracks, the charged particles can be identified and any complex events involving the particles can be studied.

In the presence of a magnetic field, the tracks of the charged particles will be curved. The degree of curvature depends on the mass, speed, and charge of each particle.

Neutral particles can be detected indirectly by applying various conservation laws to the events recorded in the bubble chamber or by observing their decay into pairs of oppositely charged particles.

Fig. 8.2 is a picture taken by the camera from a bubble chamber that is filled with liquid hydrogen. The lines show the path of the particles entering the chamber from one of the sides.

A parallel beam of K^- particles, each with an energy of 8.2 GeV and a charge of $-e$ enters from the bottom of Fig. 8.2.

The radius of any circular path made by a moving charged particle in the bubble chamber is proportional to the momentum and inversely proportional to the charge of the particle.

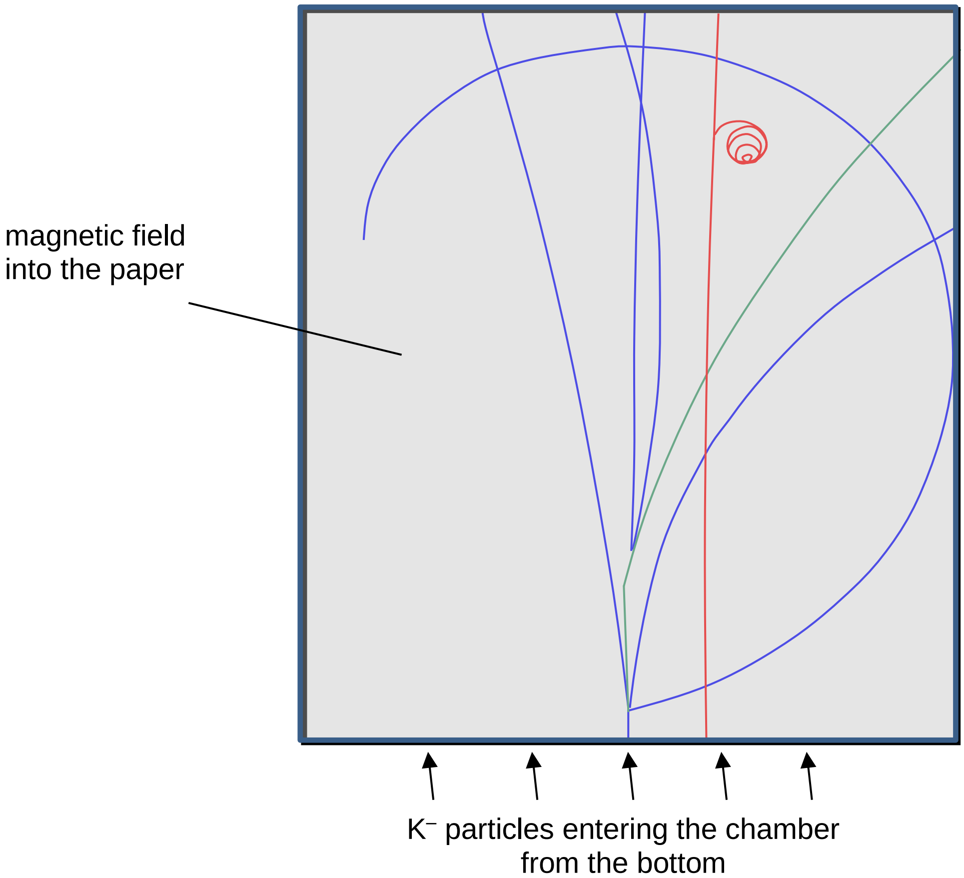


Fig. 8.2

(a) State and explain the number of positively charged particles as shown in Fig. 8.2.

....

....

.... [2]

[Turn over

(b) Fig. 8.3 shows the enlarged picture of the little curly track at the top right quadrant of Fig. 8.2.

It has been proposed that this track is produced by an electron which is knocked out of the hydrogen atom by a passing K^- particle.

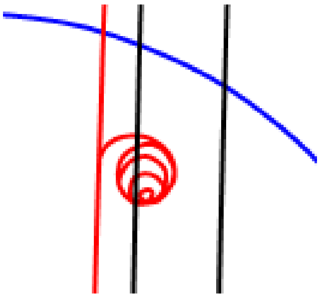


Fig. 8.3

(i) By comparing the curly path in Fig. 8.3 with paths made by other particles in Fig. 8.2, explain whether this proposal is possible.

....

....

....

.... [2]

(ii) Suggest why is this path a spiral.

....

....

....

.... [2]

(c) Fig. 8.4 shows a K^- particle colliding with the positively charged nucleus of a hydrogen atom at point A. The collision produced four charged particles as illustrated by the four outgoing tracks, numbered 1 to 4.

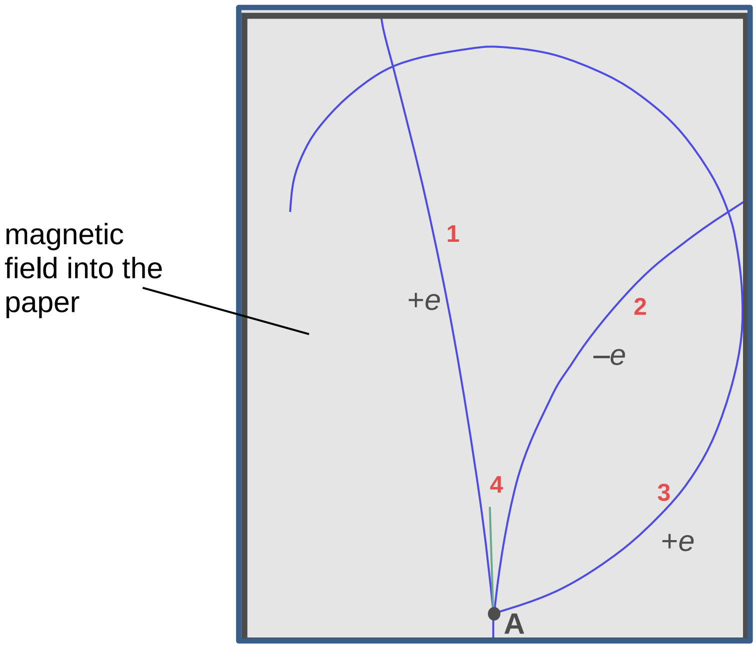


Fig. 8.4

The charges of three of the four outgoing particles after the collision are indicated beside their tracks.

(i) Deduce the charge of the fourth outgoing particle. Justify your answer.

....

....

....

.... [2]

(ii) State which of the outgoing particles 1 to 4 has the lowest momentum.

....

.... [1]

(d) There is a fifth outgoing particle from the collision at point A which is neutral and does not produce any visible track. This particle eventually decays into two smaller particles at point B as shown in Fig. 8.5.

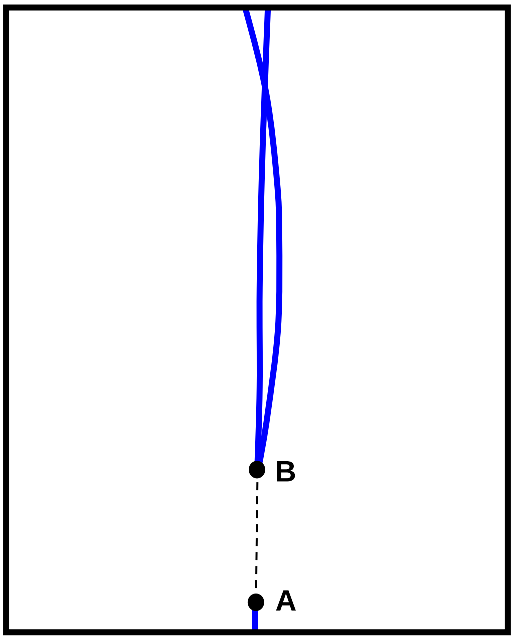


Fig. 8.5

(i) Explain why it leaves no track.

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

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

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

(ii) Deduce the charge of the two particles that are formed from the decay of the fifth particle. Explain your answer.

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

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

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

(e) The bubble chamber is used to study the collision between a K^- particle and a stationary proton p. The total energy E and momentum in three dimensions p_x, p_y, p_z of each particle produced in a collision is governed by the formula

$$E^2 = (p_x{}^2 + p_y{}^2 + p_z{}^2)c^2 + m^2c^4$$

where m is the mass of the particle and c is the speed of light.

In a particular collision, three additional particles Ω^-, Ω^+ and K^0 are formed and the data collected are shown in Fig. 8.6 below.

Before collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	438.05	-13.24	0.81	1317.12
p	0.00	0.00	0.00	150.13
sum				

After collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	79.03	1.48	11.95	252.50
Ω^-	7.98	-0.60	2.07	33.38
Ω^+	2.02	-6.52	-1.21	30.51
p	80.46	6.85	-3.76	285.22
K^0	189.10	-8.69	-13.07	574.78
sum				

Fig. 8.6

(i) Complete Fig. 8.6 to show

1. the sum of the momentum in all the dimensions for the particles before and after the collision, [1]

2. the sum of the energy for the particles before and after the collision. [1]

(ii) The sum of the total energies E before and after the collision are not equal, implying that more particles are formed but have gone undetected.

Assuming that there is only one undetected particle, determine

1. the components of its momentum p_x, p_y, p_z and its total energy E,

p_x = ...N s

p_y = ...N s

p_z = ...N s

E = ... J [4]

2. its mass m.

m = ... kg [2]

[Total: 20]

END OF PAPER

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