Name: ________________________ (   )   Class: 21 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2021 JC2 Preliminary Examination

PHYSICS Higher 2 9749/03

Paper 3 Longer Structured Questions **Thursday 16 September 2021**

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 or graphs.

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 about 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.

CLT Notice

Questions set on the Common Last Topic of the syllabus do not form part of the assessment. They will not be marked by the Examiners.

Do **not** answer the following questions:
Question 9 on page 22

Turn to the question and cross it out by drawing a line through the question.
In Section B you must answer Question 8. There is now no choice of question in this Section.
The total time allowed for this Question Paper has **not** been changed.
The total mark allowed for this Question Paper has **not** been changed.

For Examiner's Use	
Paper 1 Total	**/ 30**
Paper 2 Total	**/ 80**
Paper 4 Total	**/ 55**
Paper 3 Total	**/ 80**
1	
2	
3	
4	
5	
6	
7	
8	
Deduction	
Prelim	**/ 100**

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
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
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-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	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\varphi = -\frac{Gm}{r}$
temperature	T/K = T/°C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_o{}^2 - x^2}$
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	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \mu_0 \ni \frac{¿}{2r} ¿$
magnetic flux density due to a long solenoid	$B = \mu_0 \ni ¿ ¿$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 (a) A delivery company suggests using a remote-controlled aircraft to drop a parcel into the garden of a customer. When the aircraft is vertically above point P on the ground, it releases the parcel with a velocity that is horizontal and of magnitude 5.40 m s^{-1}. The path of the parcel is shown in Fig. 1.1.

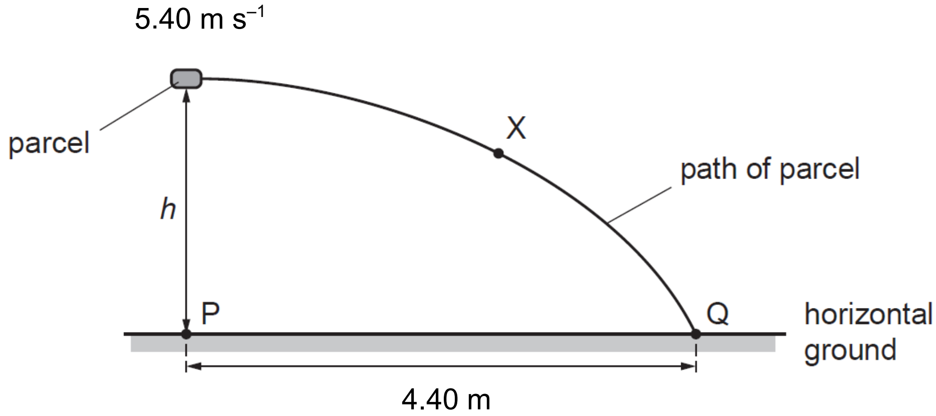


Fig. 1.1 (not to scale)

The parcel travels a horizontal distance of 4.40 m after its release to reach point Q on the horizontal ground.
Assume air resistance is negligible.

Determine the height h of the parcel above the ground when it is released.

h = ...m [2]

(b) Another parcel is accidentally released from rest by a different aircraft when it is hovering at a great height above the ground. Air resistance is now significant.

(i) On Fig. 1.2, draw arrows to show the directions of the forces acting on the parcel as it falls vertically downwards. Label each arrow with the name of the force.

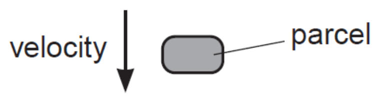


Fig. 1.2

[1]

(ii) By considering the forces acting on the parcel, state and explain the variation, if any,
of the acceleration of the parcel as it moves downwards before it reaches constant (terminal) speed.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) State and explain the effect of having a larger mass on the terminal velocity of the parcel.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iv) Describe the energy conversion(s) that occur(s) when the parcel is falling through the air

1. before it reaches constant speed

……………………………………………………………………………………………

……………………………………………………………………………………………

2. after it reaches constant speed.

……………………………………………………………………………………………

……………………………………………………………………………………………

[2]

[Total: 10]

2 **(a)** A student suggests that Newton's third law implies that the weight of a book resting on a table is equal to the support force that the table exerts on the book.

Explain why

(i) the student is wrong,

....

....

....

....

.... [2]

(ii) the two forces are equal and opposite.

....

....

.... [1]

(b) Use Newton's laws to deduce the principle of conservation of momentum.

[3]

(c) In space, an object of mass 28 kg travelling with velocity 88 m s^{-1} collides with a second object of mass 17 kg travelling in the same direction with a velocity of 53 m s^{-1}. The collision is inelastic.

After the collision, the 28 kg object continues to move in the original direction but with a velocity of 67 m s^{-1}.

Calculate the loss in kinetic energy in the collision.

loss in kinetic energy = ……………………………J [3]

(d) In **(c)**, the force exerted by the 28 kg object on the 17 kg object will not have a constant value during the time they are in contact with one another.

Sketch two graphs on the axes shown in Fig. 2.1 to show how the force varies with time if the collision in **(c)** is between

(i) two steel objects (label this line S),

(ii) two rubber objects (label this line R).

Fig. 2.1

[2]

[Total: 11]

3 **(a)** Determine the SI base units of the moment of a force.

SI base units : ………………………………. [1]

(b) A uniform square sheet of card ABCD is freely pivoted by a pin at a point P. The card is held in a vertical plane by an external force in the position shown in Fig. 3.1.

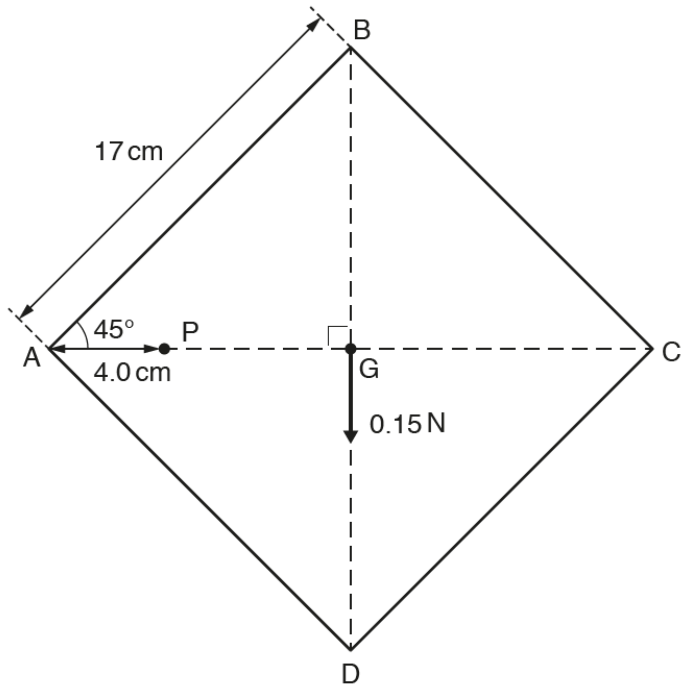


Fig. 3.1 (not to scale)

The card has weight 0.15 N which may be considered to act at the centre of gravity G. Each side of the card has length 17 cm. Point P lies on the horizontal line AC and is 4.0 cm from corner A. Line BD is vertical.

The card is released by removing the external force. The card then swings in a vertical plane until it comes to rest.

(i) Calculate the magnitude of the resultant moment about point P acting on the card immediately after it is released.

moment = ……………………………….N m [2]

(ii) Explain why, when the card has come to rest, its centre of gravity is vertically below point P.

....

....

....

.... [2]

(c) A spring is extended by a force. The variation with extension x of the force F is shown in Fig. 3.2.

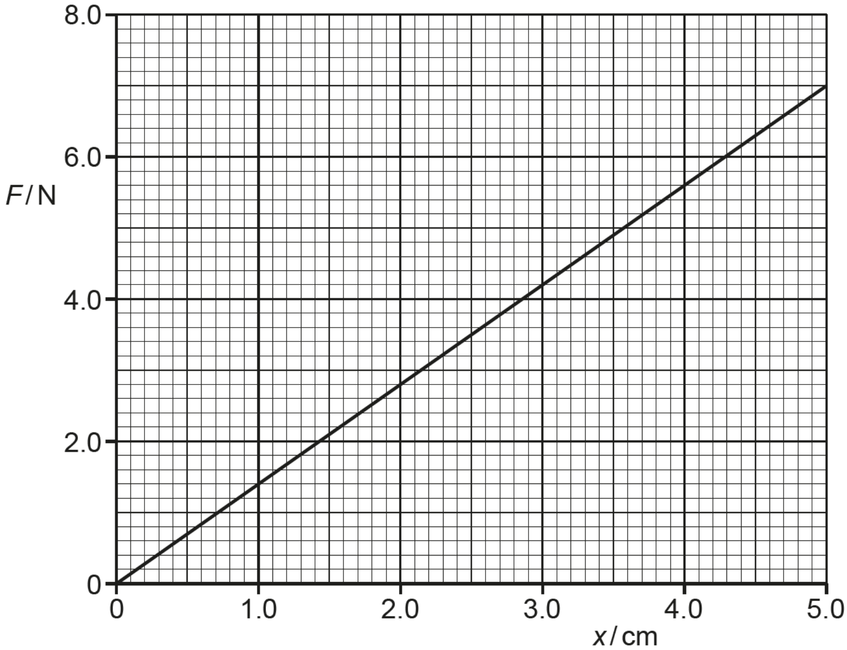


Fig. 3.2

One end of the spring is attached to a fixed point. A cylinder that is submerged in a liquid is now suspended from the other end of the spring, as shown in Fig. 3.3.

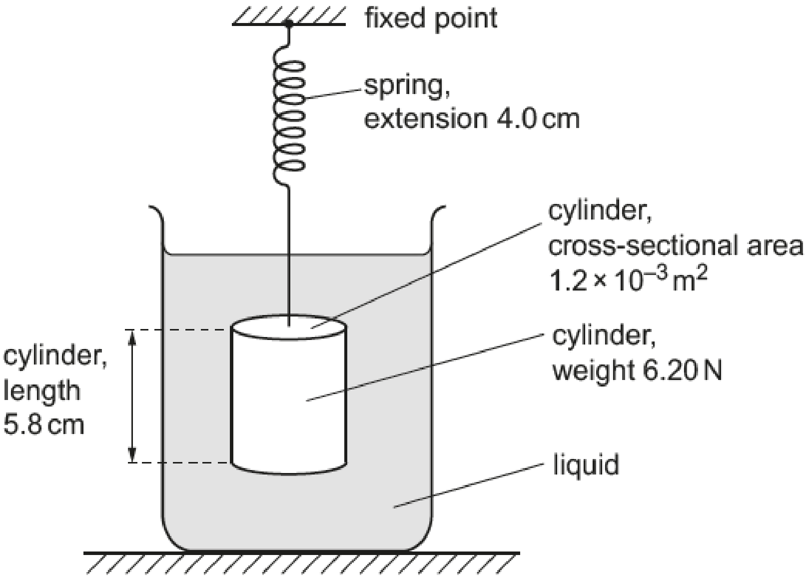


Fig. 3.3

The cylinder has length 5.8 cm, cross-sectional area 1.2×10^{-3} m^2 and weight 6.20 N. The cylinder is in equilibrium when the extension of the spring is 4.0 cm.

(i) Calculate the upthrust acting on the cylinder.

upthrust = …………………………….N [2]

(ii) Calculate the difference in pressure between the bottom face and the top face of the cylinder.

difference in pressure = …………………………….Pa [2]

(iii) The liquid in **(c)** is replaced by another liquid of greater density.

State and explain the effect, if any, of this change on the extension of the spring.

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

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

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

[Total: 11]

4 The conservation of energy is an important principle that features in all branches of Physics. Discuss how energy is conserved in the following scenarios.

(a) When water in an electric kettle is boiling, the temperature of the water remains the same.

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

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

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

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

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

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

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

(b) When coherent light passes through a thin slit and falls onto a screen, the centre of the screen has intensity I. When the light passes through two slits in a similar setup, the intensity at the centre of the screen becomes approximately $4I$.

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

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

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

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

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

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

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

[Total: 6]

5 An elastic cord has an unextended length of 13.0 cm. One end of the cord is attached to a fixed point C. A small mass of weight 5.0 N is hung from the free end of the cord. The cord extends to a length of 14.8 cm, as shown in Fig. 5.1.

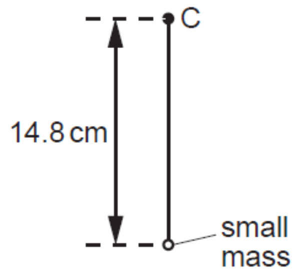
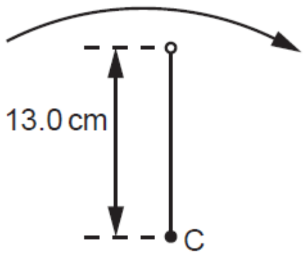


Fig. 5.1

The cord and mass are now made to rotate at constant angular speed ω in a vertical plane about point C. When the cord is vertical and above C, its length is the unextended length of 13.0 cm, as shown in Fig. 5.2.



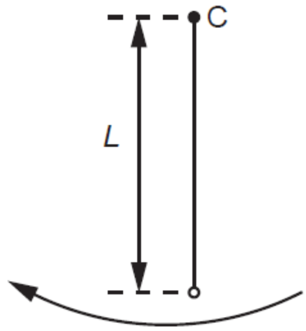


Fig. 5.2 **Fig 5.3**

(a) Show that the angular speed ω of the cord and mass is 8.7 rad s^{-1}.

[2]

(b) The cord and mass rotate so that the cord is vertically below C, as shown in Fig. 5.3.

Calculate the length *L* of the cord, assuming it obeys Hooke's law.

L = …………………………….cm [3]

[Total: 5]

6 **(a)** A light-dependent resistor (LDR) is connected to a variable resistor R_1 and a fixed resistor R_2, as shown in Fig. 6.1.

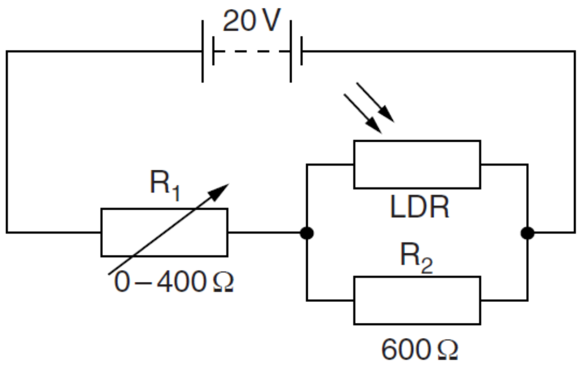


Fig. 6.1

When the light intensity is varied, the resistance of the LDR changes from 5.0 kΩ to 1.2 kΩ.

(i) For the maximum light intensity, calculate the total resistance of R_2 and the LDR.

total resistance = ... Ω [2]

(ii) Fig 6.2 shows the circuit when the LDR is removed.

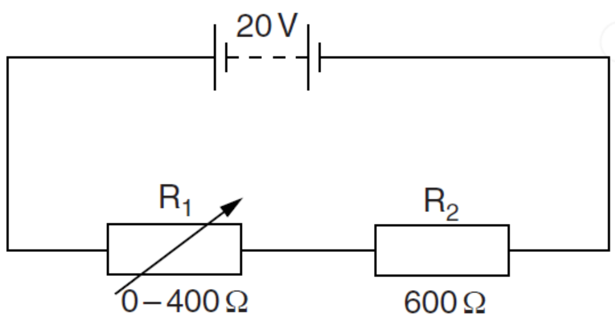


Fig. 6.2

The resistance of R_1 is varied from 0 to 400 Ω in the circuits of Fig. 6.1 and Fig. 6.2. State and explain the difference, if any, between the minimum potential difference across R_2 in each circuit. Numerical values are not required.

....

....

....

....

.... [3]

(b) In Fig. 6.3, XZ is a uniform metre wire and has a resistance of 10.0 Ω. E is a power supply of electromotive force (e.m.f.) 2.0 V with negligible internal resistance. The resistor R_1 has a resistance of 15.0 Ω and the resistor R_2 has a resistance of 5.0 Ω.

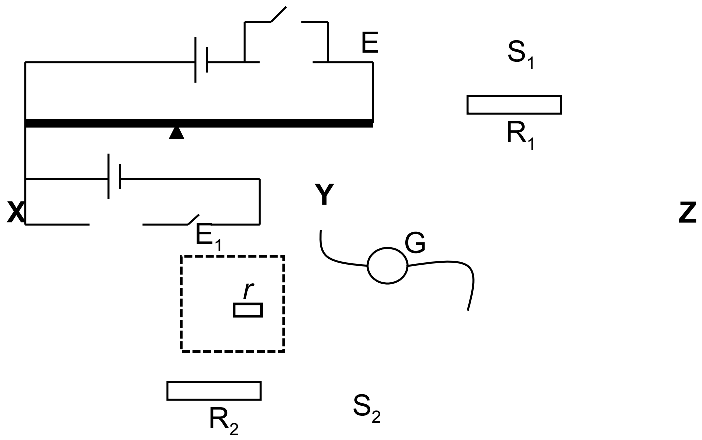


Fig. 6.3

With both switches S_1 and S_2 open, length YZ is 37.5 cm when galvanometer G registers null deflection.

When S_1 and S_2 are closed, length YZ is 90.0 cm when galvanometer G registers null deflection.

(i) Show that the e.m.f. of cell E_1 is 0.50 V.

[3]

(ii) Determine the internal resistance r of cell E_1.

r = …………………………….Ω [3]

[Total: 11]

7 **(a)** The output of a power supply is represented by:

$$V = 9.0 \sin 20t$$

where V is the potential difference in volts and t is the time in seconds.

Determine, for the output of the supply:

(i) the root-mean-square (r.m.s.) voltage, $V_{r.m.s.}$

$V_{r.m.s.}$ = …………………………….V [1]

(ii) the period T.

T = …………………………….s [1]

(b) The variations with time t of the output potential difference V from two different power supplies are shown in Fig. 7.1 and Fig. 7.2.

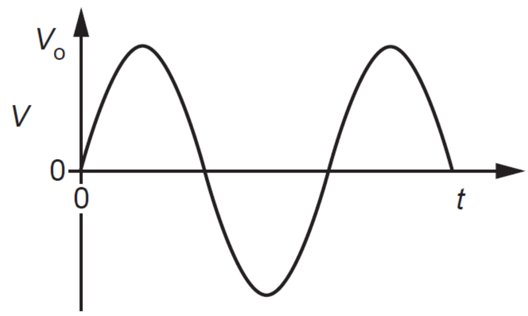


Fig. 7.1

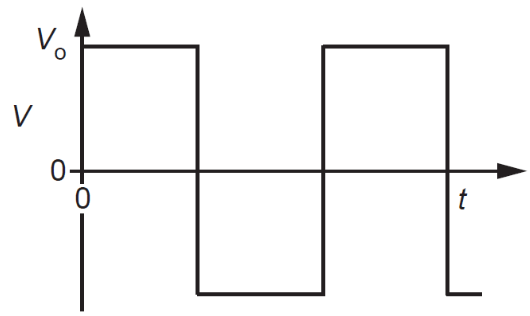


Fig. 7.2

The graphs are drawn to the same scale.

State and explain whether the same power would be dissipated in a 1.0 Ω resistor connected to each power supply.

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

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

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

(c) **(i)** The power supply in **(a)** is connected to a transformer. The input power to the transformer is 80 W.

The secondary coil is connected to a resistor. The r.m.s. voltage across the resistor is 120 V. The r.m.s. current in the secondary coil is 0.64 A.

Calculate the efficiency of the transformer.

efficiency = …………………………… [2]

(ii) State **one** reason why the transformer is not 100% efficient.

…………………………………………………………………………………………………

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

[Total: 6]

Section B

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

8 **(a)** A current-carrying rigid copper wire AB is held horizontally between the pole pieces of two magnets, as shown in Fig. 8.1.

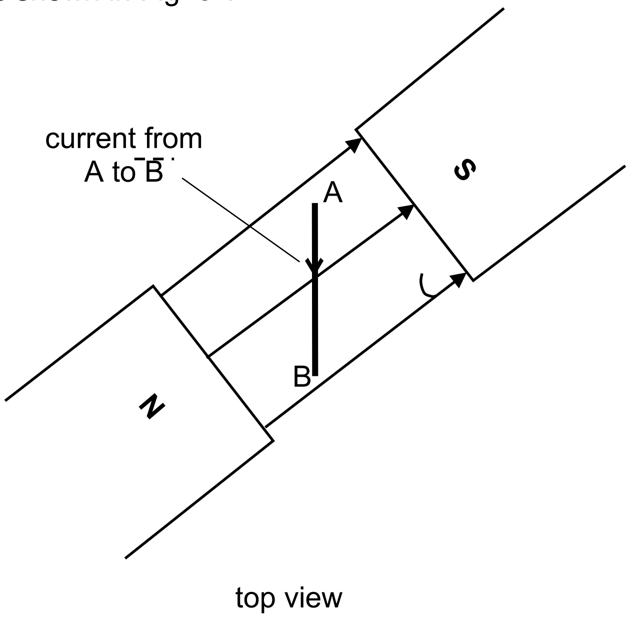


Fig. 8.1

(i) By reference to Fig. 8.1, state and explain the direction of the force by wire AB on the magnets.

....

....

....[2]

(ii) The angle θ is varied from 0 ° to 60 ° by rotating the magnet in the horizontal plane. Describe the changes in the force on the wire.

....

....

....[2]

(b) The magnet in **(a)** is fixed in position at θ = 0 ° such that its magnetic field is perpendicular to wire AB. The magnetic flux density between the poles of the magnet is 0.45 T. The current in the copper wire is now switched off.

The wire is moved at constant speed of 5.0 m s^{-1} vertically out of the plane to cut the region of magnetic field.

(i) The movement of the wire causes conduction electrons in the wire to experience magnetic force.

Show that the magnetic force acting on an electron is 3.6×10^{-19} N.

[1]

(ii) The magnetic force in **(b)(i)** causes conduction electrons in the wire to move, creating a potential difference across the ends of wire AB.

State and explain which end of the wire is at a higher potential.

....

....

....[2]

(iii) The conduction electrons will move until the potential difference across the ends of wire AB is large enough such that the electrons in the wire reach an equilibrium.

1. Explain why electrons in the wire reach an equilibrium.

....

....

....[2]

2. With reference to **(b)(i)**, calculate the electric field strength generated across the ends of the wire AB.

electric field strength = ... N C^{-1} [2]

3. The length of the wire within the region of field is 0.20 m. Using the answer in **(b)(iii)2.**, calculate the induced e.m.f across wire AB.

induced e.m.f = …………………………… V [1]

(c) A 2.0 cm square copper frame is moving on a smooth surface with a constant speed of 1.0 cm s^{-1} towards two uniform magnetic fields, as shown in Fig. 8.2.

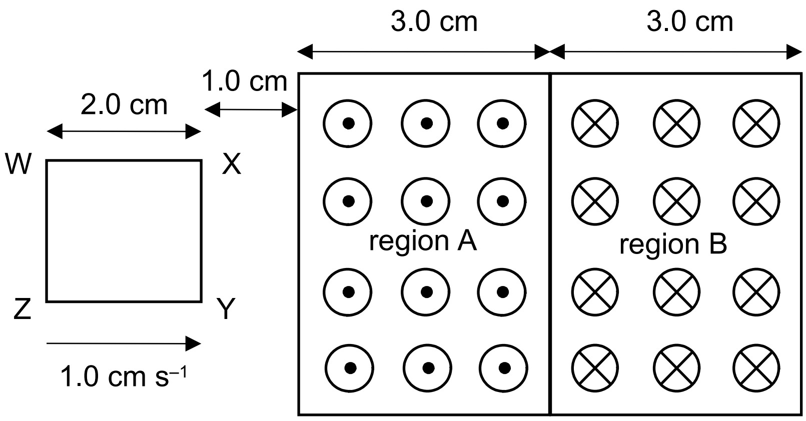


Fig. 8.2

An external force F is applied on the frame when necessary to ensure that the frame moves at a constant speed. The position of the frame in Fig. 8.2 is taken to be at t = 0 s.

The magnetic field in region A is directed out of the paper while the magnetic field in region B is directed into the paper. The magnetic flux density of both fields is 1.0 T. The resistance of the frame is 8.0 × 10^{-4} Ω.

A short instant later, the side XY of the frame enters region A.

(i) Explain why an external force F is necessary to maintain the constant speed of the frame as it enters region A.

....

....

....

....

....[3]

(ii) Determine the magnitude of the external force F at this instant.

F = …………………………… N [3]

(iii) On Fig. 8.3, sketch the variation of external force F with time t, from t = 0 s till the frame completely emerges from region B. The graph for region A has been drawn. Values on F axis are not required.

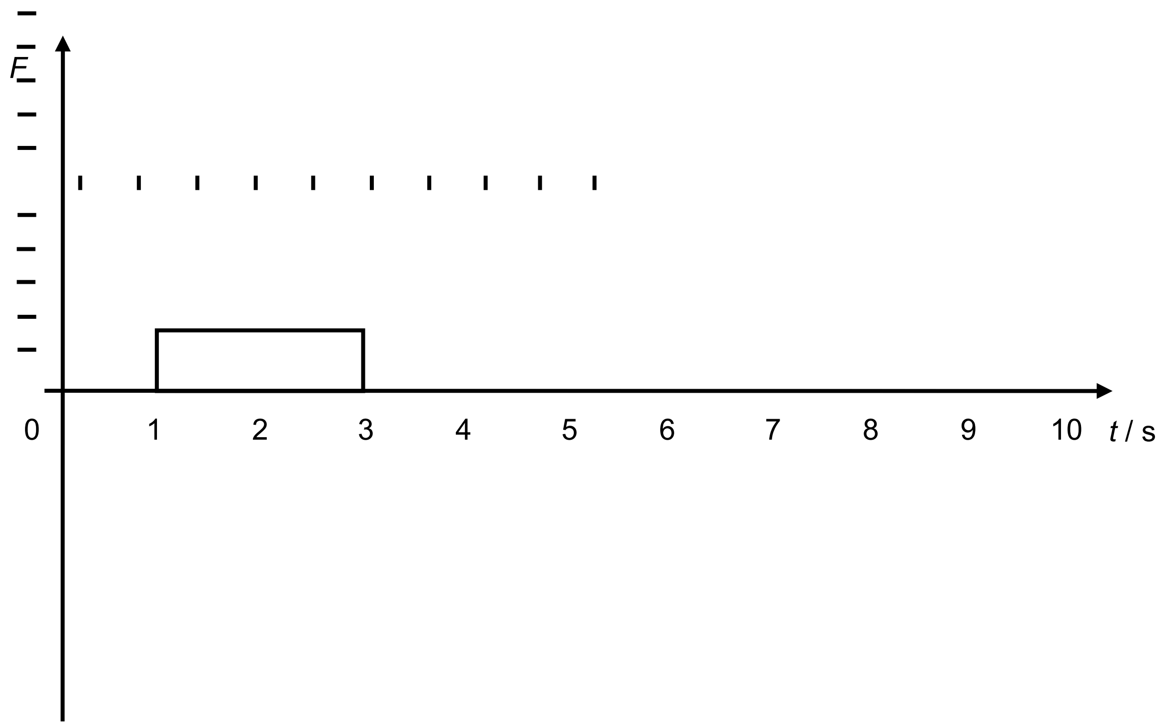


Fig. 8.3

[2]

[Total: 20]

[Turn Over

9 **(a)** **(i)** Fig. 9.1 shows the path of an alpha particle as it scatters off a gold nucleus in the Rutherford's scattering experiment.

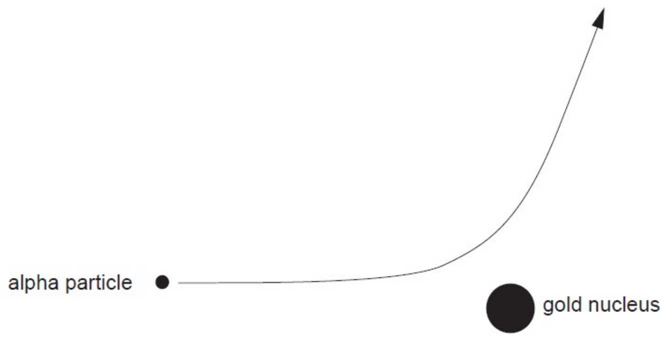


Fig. 9.1

1. Explain why the alpha particle follows the path as shown in Fig. 9.1

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

2. On Fig. 9.1, sketch the path of an alpha particle with the same initial path, but less kinetic energy. [2]

(ii) The alpha particles in this experiment originated from the decay of a radioactive nuclide. Suggest two reasons why beta particles from a radioactive source would be inappropriate for this type of scattering experiment.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) **(i)** In Fig. 9.2, an alpha

$$^{7}_{3}\mathrm{Li}$$

particle on path **Q** has a head-on collision with a lithium nucleus $^{7}_{3}\mathrm{Li}$.

This alpha particle gets to within a distance of 4.2 x10^{-15} m from the centre of the nucleus.

1. By discussing the energy changes of the alpha particle as it moves towards the centre of the nucleus, explain why it needs a **minimum** energy to get so close to the centre of the nucleus.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………[2]

2. Show that this minimum energy of the alpha particle is 3.3 × 10^{-13} J.

[2]

(ii) When the alpha particle gets to within 4.2 x10^{-15} m of the centre of the nucleus, the following nuclear reaction takes place.

$${}^{4}_{2}\mathrm{He} + {}^{7}_{3}\mathrm{Li} \rightarrow {}^{10}_{5}B + {}^{1}_{0}n$$

Fig. 9.3 gives the masses of the particles involved in the nuclear reaction.

particle	mass / u
${}^{4}_{2}\mathrm{He}$	4.0015
${}^{7}_{3}\mathrm{Li}$	7.0144
${}^{10}_{5}B$	10.0011
${}^{1}_{0}n$	1.0087

Fig. 9.3

1. Show that there is a decrease of mass of about 1 x 10^{-29} kg as a result of this reaction.

[2]

2. Calculate the maximum possible energy of a neutron ejected from the target when the alpha particles in the beam have an energy of 3.3 x 10^{-13} J.

maximum possible energy = ………………………….J[3]

(c) **(i)** Explain what is meant by the *binding energy* of a nucleus.

…………………………………………………………………………………………………

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

(ii) Fig. 9.4 shows the variation with nucleon number (mass number) A of the binding energy per nucleon E_B of nuclei.

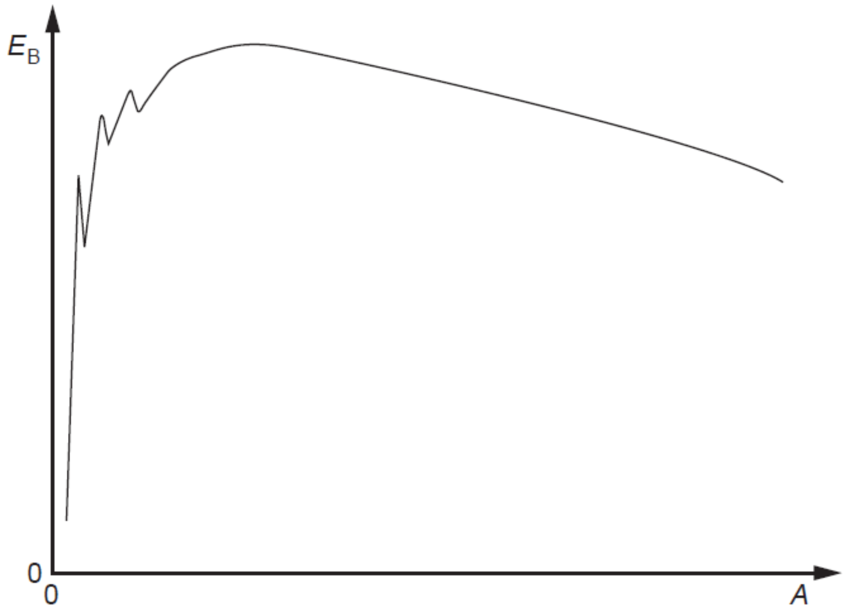


Fig. 9.4

One particular fission reaction may be represented by the nuclear equation

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}\mathrm{Ba} + ^{92}_{36}\mathrm{Kr} + 3\,^{1}_{0}n$$

On Fig. 9.4, label the approximate positions of

1. the uranium ($^{235}_{92}U$) nucleus with the symbol U,
2. the barium ($^{141}_{56}\mathrm{Ba}$) nucleus with the symbol Ba,
3. the krypton ($^{92}_{36}\mathrm{Kr}$) nucleus with the symbol Kr. [2]

(iii) The neutron that is absorbed by the uranium nucleus has very little kinetic energy. Explain why this fission reaction is energetically possible.

……………………………………………………………………………………………….

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

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

[Total: 20]