H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **8867/02**

Paper 2 Structured Questions

27 August 2024
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name 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 staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answers **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	**/ 5**
3	**/ 8**
4	**/ 16**
5	**/ 6**
6	**/ 10**
7	**/ 7**
Section B	
8	**/ 20**
9	**/ 20**
Total (80)	

[Turn over

This document contains **24** printed pages and **4** blank pages.

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	$1/R$	=	$1/R_1 + 1/R_2 + \ldots..$

Section A

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

1 An object is launched at a speed of 30 m s^{-1} at an angle of 60° above the ground as shown in Fig. 1.1. Ignore air resistance.

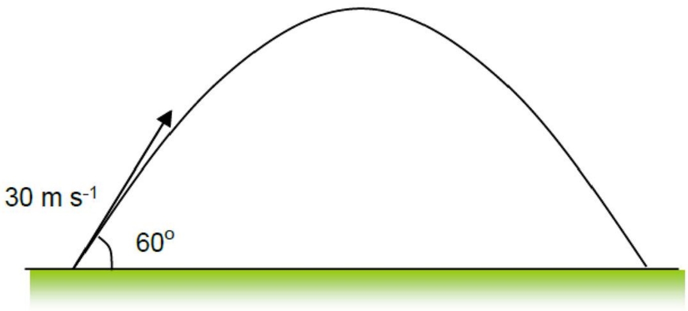

Fig 1.1

(a) Show that the time taken for the object to reach its maximum height is 2.65 s.

[1]

(b) Calculate the time taken for the object to hit the ground.

time = ………………… s [1]

(c) Hence or otherwise, calculate the horizontal distance travelled by the object from the point of launch to the point it first hits the ground.

horizontal distance = ………………… m [2]

(d) On Fig. 1.2, sketch the variation with time *t* of the vertical component of the velocity v_y from the time it leaves the ground to the time it hits the ground.

[2]

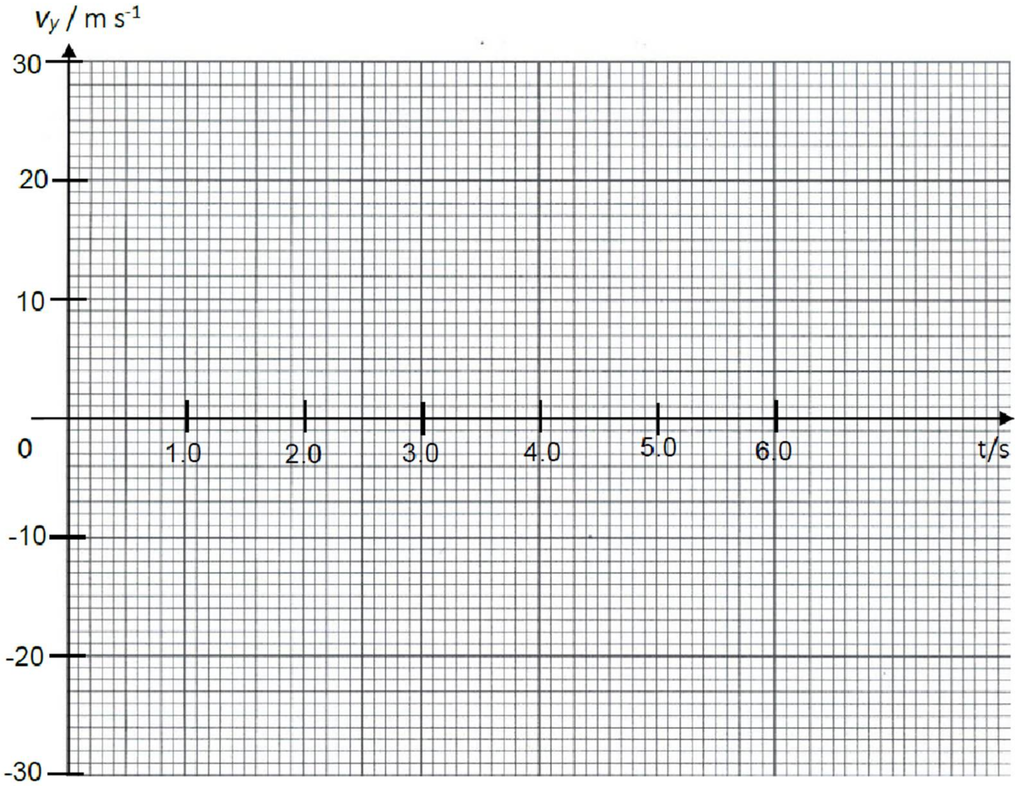

Fig. 1.2

(e) On Fig. 1.3, sketch the variation with time of

(i) the horizontal component of the velocity of the object for the duration of time in flight. Label this line **A**.

[1]

(ii) the horizontal component of the velocity of the object for the duration of time in flight if air resistance is not negligible. Label this line **B**.

[1]

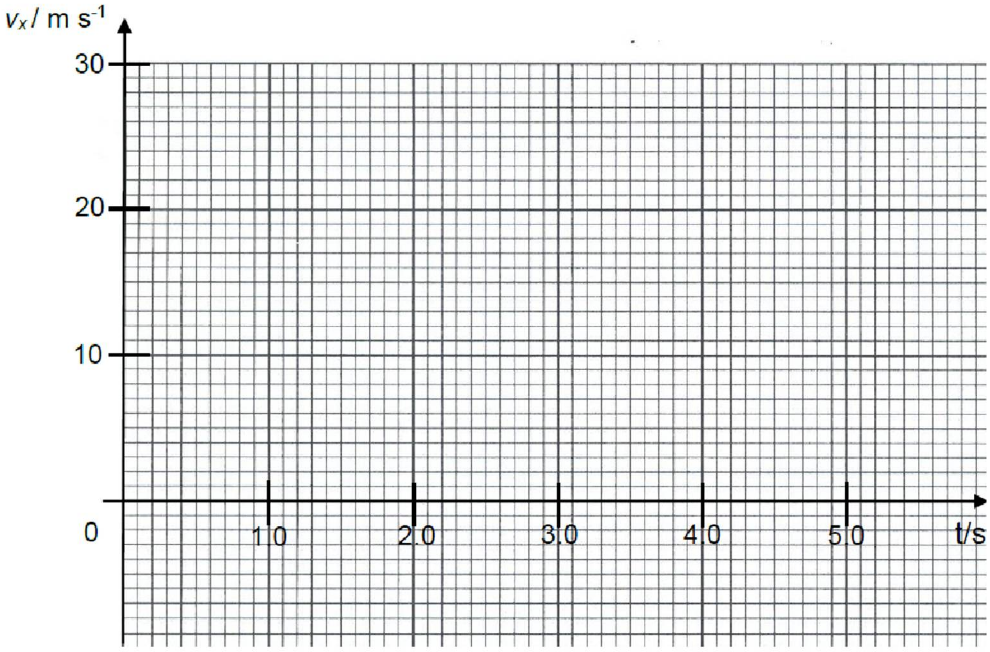

Fig. 1.3

[Total: 8]

2 An aeroplane of mass 1.5 x 10^5 kg moves horizontally with constant velocity. Fig. 2.1 shows the forces exerted on the aeroplane.

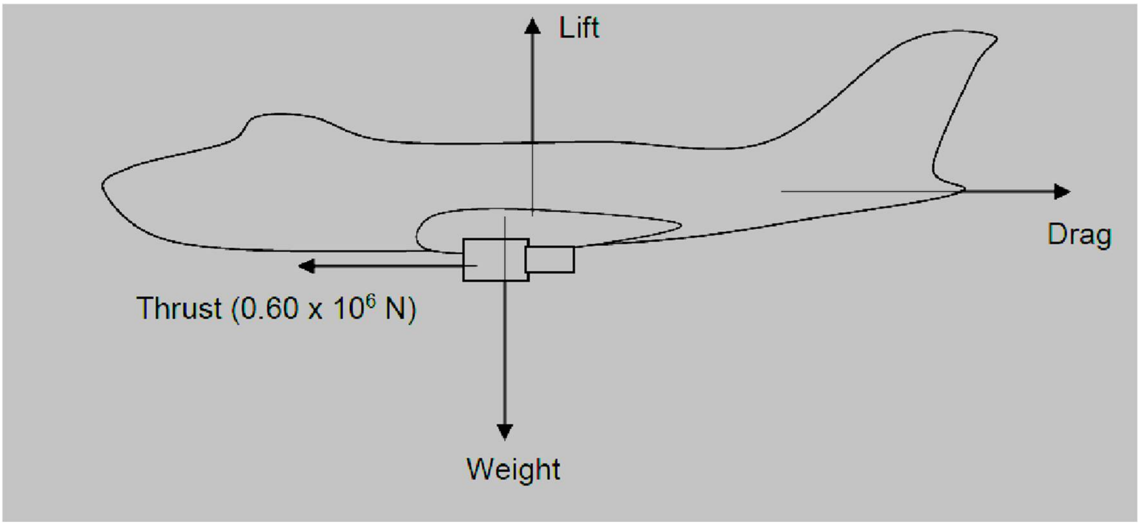

Fig. 2.1

(a) Calculate the magnitude of the lift and the drag.

lift = ……………………… N [1]

drag = ……………………… N [1]

(b) **(i)** Define *torque* of a couple.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(ii) The horizontal separation of the lines of action of lift and weight is 0.80 m. Using your answer to **(a)**, determine the vertical separation of the lines of action of the thrust and drag.

vertical separation = ………………… m [2]

[Total: 5]

[Turn over

3 **(a)** State the principle of conservation of linear momentum.

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

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

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

(b) Fig. 3.1 shows two discs, A and B, on a frictionless table collide head-on. Disc A has a mass of 0.36 kg and disc B has a mass of 0.18 kg. Before colliding, disc A has a velocity of 0.40 m s^{1} and disc B a velocity of 0.10 m s^{-1} in the opposite direction. On colliding they stick together.

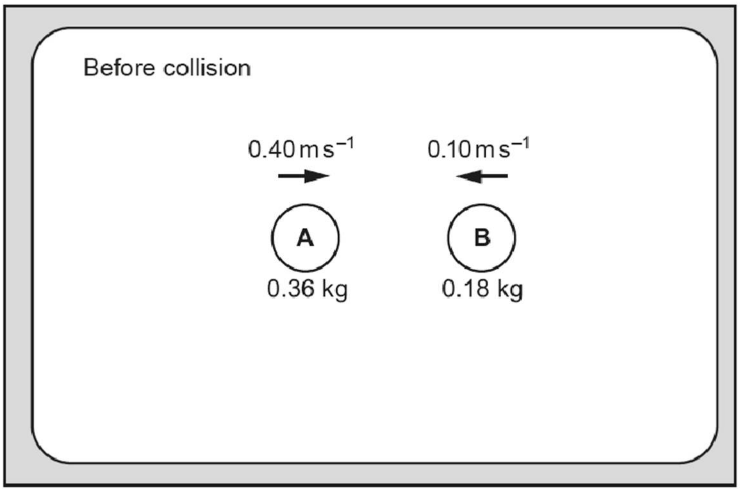

Fig. 3.1

Calculate

(i) the velocity of the discs after the collision.

velocity = ……………………… m s^{-1} [2]

direction = ……………………………… [1]

(ii) the kinetic energy lost during the collision expressed as a percentage of the initial kinetic energy of the two discs.

Percentage = ……………….[3]

[Total: 8]

4 A company rents out tower cranes of many different sizes.

A tower crane is illustrated in Fig. 4.1. This type of tower crane is called a flat-top tower crane because the jib and counter jib are horizontal.

A crane can be constructed to different arrangements of height, jib and counter-jib length, and balancing load.

The size of the base can be varied to cope with different maximum loads lifted by the crane.

Note: The masses of the loads in Fig. 4.1 and in Table 4.1 are given in tonnes (t). One tonne is 1000 kg.

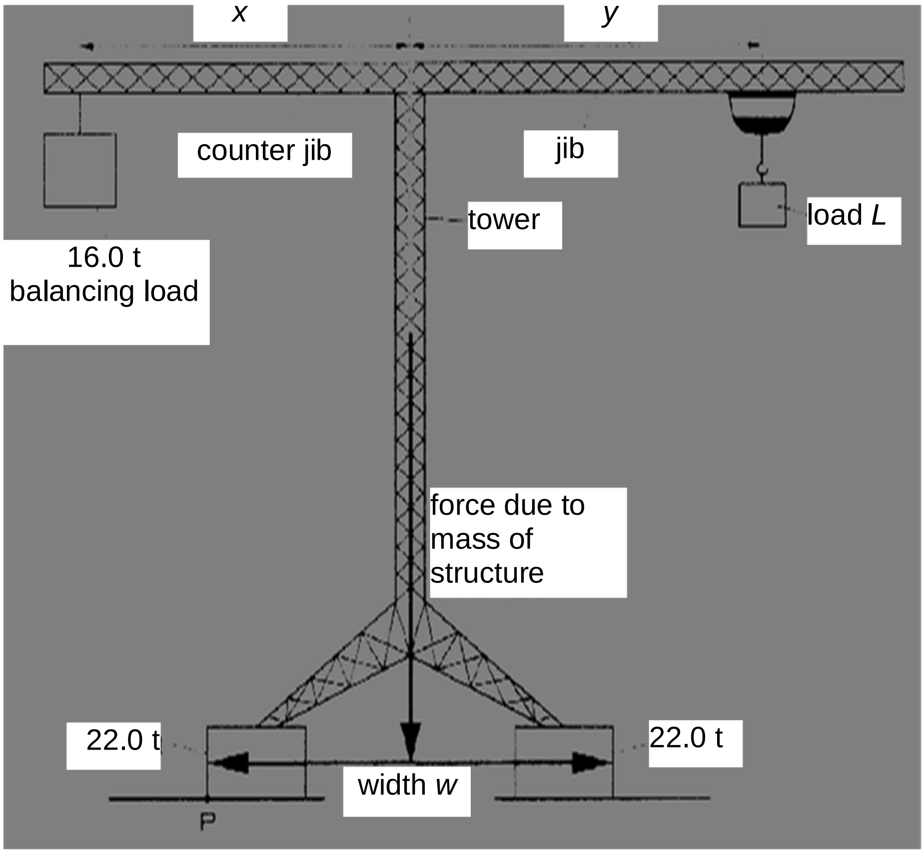

Fig. 4.1

Distance x is the fixed distance. This is a different distance for each different crane arrangement.

Distance y is variable and changes as the load L is moved in and out from the tower, along the jib.

Table 4.1 lists information for four different crane arrangements.

The maximum load L in tonnes that can be lifted for different distances y from the centre of the tower for each arrangement is also shown.

Table 4.1

crane arrangement	total length of jib and counter jib / m	distance x to 16.0 t balancing load / m	Maximum load L at different distances y / t		
			y = 30 m	y = 52 m	y = 75 m
A	95.0	17.3	8.48	4.31	2.60
B	75.0	19.4	9.79	5.15	–
C	75.0	21.1	10.81	5.77	–
D	55.0	22.3	11.53	–	–

(a) **(i)** Calculate the weight of the 16.0 t balancing load.

weight = ………………………. unit ……….. [2]

(ii) Using the data in Table 4.1, explain why there is no detail provided for crane D when y = 52 m.

…………………………………………………………………………………………………

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

(b) **(i)** Show, for crane A, that the load and the balancing load given in the table can never put the crane into equilibrium.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) When in use, crane A is in equilibrium. Suggest how this is achieved.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(c) The width *w* of the base of a crane is important in providing stability.

For crane C, the foundations of the base are two identical large cubic concrete masses, each of mass 22.0 t. These masses are firmly attached to the crane.

The total mass of the crane structure is 17.0 t and the force due to the mass of the crane acts through the centre of the legs.

The balancing load is 16.0 t and is 21.1 m from the centre of the tower.

By taking moments about point P in Fig. 4.1, determine, for zero load, the minimum possible value of *w* before the right hand concrete mass lifts from the ground.

minimum value of *w* = ………………….. m [3]

(d) **(i)** A motor on the crane lifts a load from the ground into position.

The motor needs to lift a load of 12000 kg a distance of 80 m.

Suggest a suitable time period for the duration of the lift and hence make a calculation to estimate the output power of the motor.

Suggested time = ………………….. s

output power = ……………………………. W [3]

(ii) The efficiency of the motor is 65%. Calculate the electrical power input required for your answer to **(d)(i)**.

Power input = ……………………….. W [2]

[Total: 16]

5 **(a)** Fig. 5.1 shows a drum of a top-loading washing machine that spins around a vertical axis.

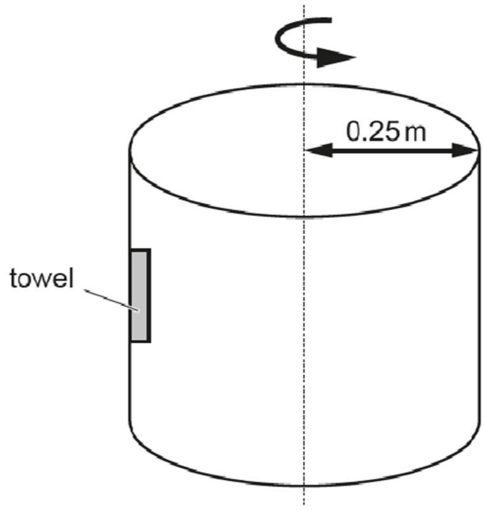

Fig. 5.1

The drum has a radius of 0.25 m and spins at a rate of 1200 revolutions per minute.

Determine the centripetal force on a damp towel, of mass 0.80 kg, on the inner wall of the drum.

centripetal force = …………….. N [2]

(b) Fig. 5.2 shows the drum of a front-loading washing machine, which also has a radius of 0.25 m and spins about a horizontal axis at the same rate of 1200 revolutions per minute.

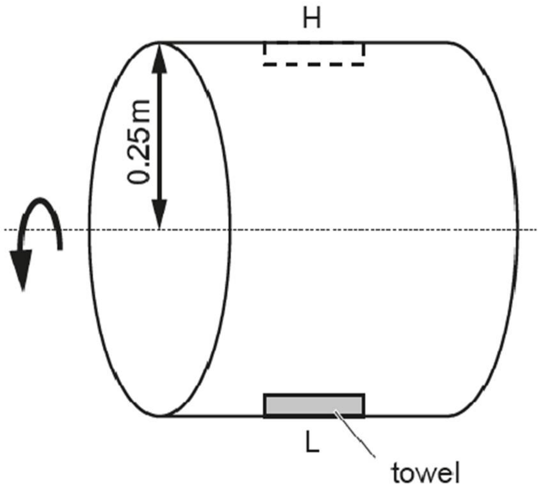

Fig. 5.2

By considering the forces on the towel, determine the normal contact force exerted by the wall of the drum on the towel, of mass 0.80 kg, when the towel is at its:

(i) lowest point in the rotation (L);

Normal contact force = ……………. N [2]

(ii) Highest point in the rotation (H).

Normal contact force = ……………. N [2]

[Total: 6]

6 **(a)** Fig. 6.1 shows a circuit with a network of resistors.

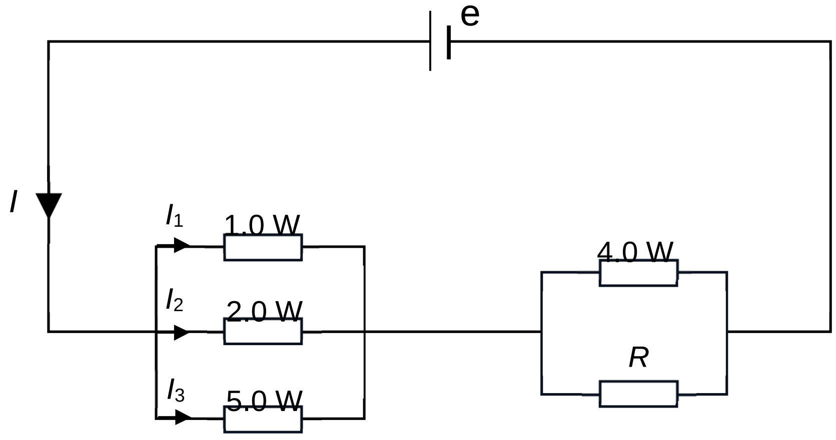

Fig. 6.1

The current from the cell is *I*.

(i) Determine the ratio of the currents $I_1 : I_2 : I_3$.

$I_1 : I_2 : I_3 =$ …………………………………… [2]

(ii) 1.0×10^{-3} mol of electrons flowed through the 4.0 ∧ resistor in a time interval of 320 s. During this time interval,

1. Show that the total charge that flowed through the 4.0 ∧ resistor is 96 C.

[1]

2. Show that the electrical energy dissipated in the 4.0 ∧ resistor is approximately 115 J.

[2]

3. The current through the 4.0 ∧ resistor is three times the current through resistor *R*. Determine *R*.

R = …………………………………… ∧ [2]

(b) Fig. 6.2 shows a circuit in which a non-ohmic device X is connected in series with a 20 ∧ resistor. The cell has e.m.f. 6.0 V and negligible internal resistance.

Fig 6.3 shows the I-V characteristics of X and the 20 ∧ resistor.

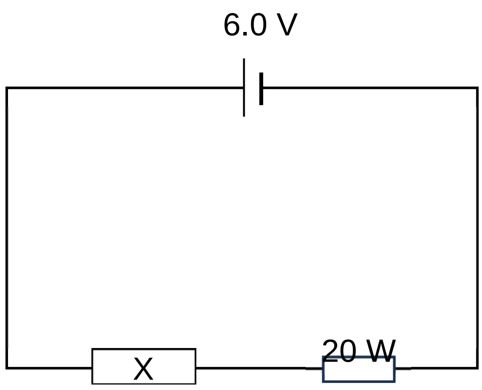

Fig. 6.2

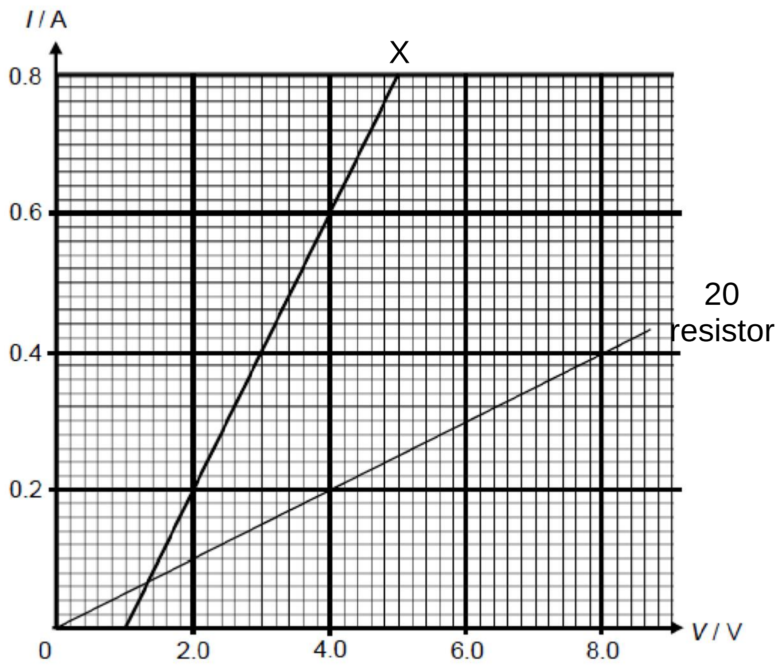

Fig. 6.3

(ii) Determine the current in the circuit.

current = …………………………………… A [1]

(iii) Device X consists of an ideal diode connected in series with a cell of negligible internal resistance and an ohmic resistor as shown in Fig. 6.4.

State the value of the e.m.f. of the cell and the resistance of the resistor that will give the I-V characteristics shown in Fig. 6.3.

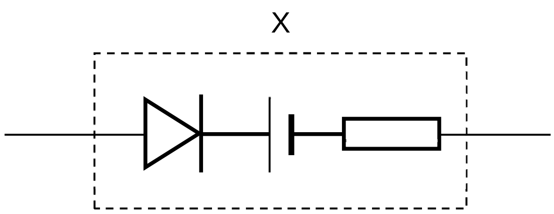

Fig. 6.4

e.m.f. = …………. V [1]

resistance = …………. ∧ [1]

[Total: 10]

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7 **(a)** A student performs an experiment to determine the half-life of a radioactive isotope.

(i) Define *half-life*.

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

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

(ii) A radiation detector is used to determine the background radiation. The total radiation count in 10.0 minutes with no radioactive source present is found to be 2400 counts.

Determine the background count rate.

background count rate = ……………………….. s^{-1} [1]

(iii) A sample of the radioactive source is placed close to the radiation detector. The count rate is determined once every hour.

The count rate *A*, corrected for background radiation, is recorded in Table 7.1.

Table 7.1

t / hours	A / s^{-1}	ln (A / s^{-1})
0.00	296	5.690
1.00	279	5.631
2.00	264	5.576
3.00	249	5.517
4.00	235	5.460

Determine the uncorrected count rate for t = 2.00 hours.

count rate = …………………… s^{-1} [1]

(b) Fig. 7.1 shows a graph of the data in Table 7.1

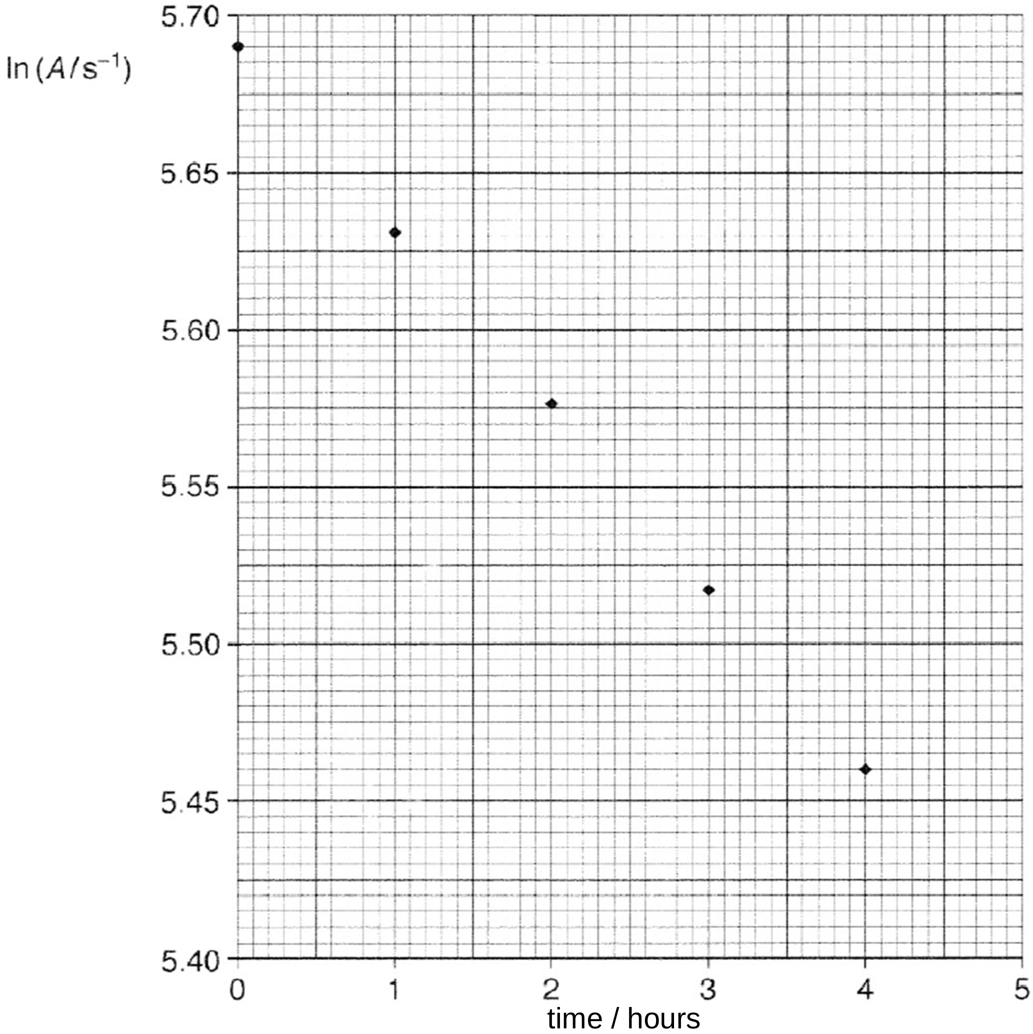


Fig. 7.1

(i) Add a line of best fit to the graph in Fig. 7.1.
[1]

(ii) The corrected count rate A is related to the time t by the equation

$$ln\ ln\left(A\ /\ s^{-1}\right) = -\frac{0.693}{\tau}t + k$$

where τ is the half-life and k is a constant.

Use the graph to calculate a value for the half-life of the radioactive source.

half-life = …………………….. hours [3]

[Total: 7]

Section B

Answer **one** question from this section.

8 **(a)** Fig. 8.1 shows a long straight conductor carrying a constant current into the page. Sketch three magnetic field lines due to the current. Indicate clearly the direction of the magnetic field. [2]

Top view
(Current flowing into the paper)

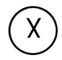


Fig 8.1

(b) Two long straight parallel wires are separated by a distance *d*. Each wire carries current *I* and the current flows in opposite directions. Explain, with the aid of a diagram, the origin of the magnetic forces that exist between the two wires and predict the directions of these forces.

……

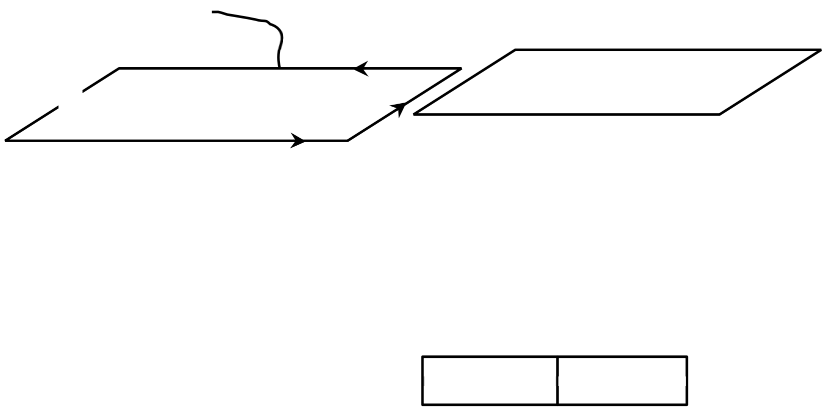
……

……

……

…… [3]

(c) In an experiment to determine the magnetic flux density due to a magnet, a wire frame ABCD supported on two knife edges P and Q is placed horizontally next to the magnet as shown in Fig. 8.2. Sides BC and AD are 5.0 cm and sides AB and DC are 8.0 cm. P and Q are at the midpoints of AB and DC respectively. When there is no current in the circuit, the frame is balanced horizontally.



A
D
B
C
Q
P
to battery
to battery

I
I
S
N
S
N
D
C
side view
Fig. 8.2
Q
I

(i) When there is a current flowing as shown in Fig 8.2, state the directions of the magnetic force, if any, on

1. side QC,

……………………………………………………………………………………… [1]

2. side BC.

……………………………………………………………………………………… [1]

(ii) A mass of 21.0 g has to be placed on side AD to balance the wire frame when the current is 2.0 A. Determine the magnetic flux density experienced by side BC.

magnetic flux density = ………………………… T [3]

(d) There are two situations in which a charged particle in a magnetic field does not experience a magnetic force.

State these two situations.

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

2. ……………………………………………………………………………………………… [1]

(e) Fig 8.3 shows a cyclotron comprising two D-shaped hollow metal conductors, known as the *dees*, separated by a very narrow gap.

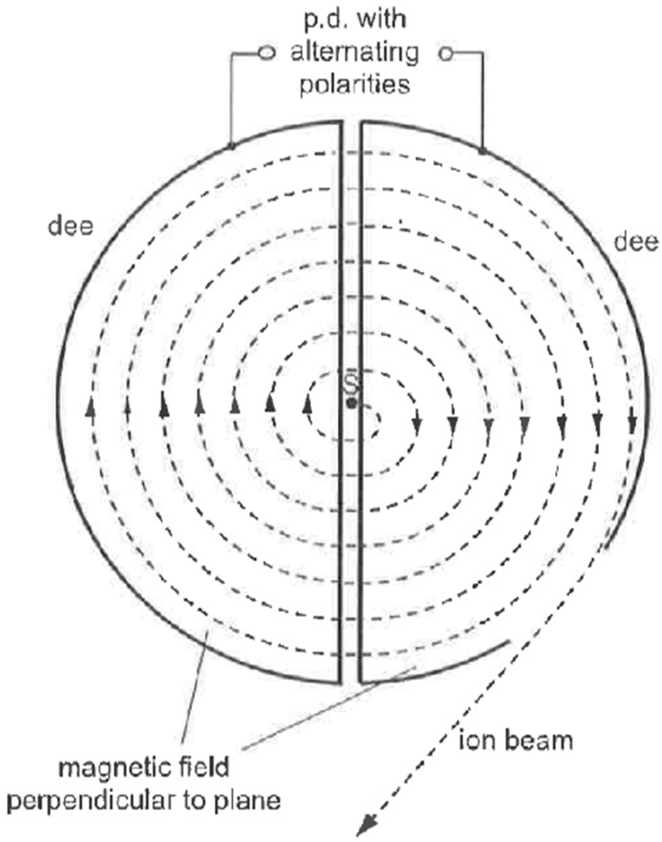


Fig. 8.3

Ions of mass m and charge q, are emitted from the source S. They maintain nearly circular paths due to the uniform magnetic field of flux density B in the *dees*.

Each time the ions enter the gap between the *dees*, they are accelerated by a constant potential difference (p.d.) applied between the *dees*. The polarity of the p.d. across the *dees* change every half cycle so that the ions are always accelerated when they cross the gap.

After many revolutions, the ions acquire high kinetic energy and exit the outer edge of the cyclotron.

(i) A small cyclotron is used to accelerate a proton of mass m and charge q.

1. By considering the magnetic force acting on the proton moving within the *dees*, show that the time T taken by the proton to complete one revolution is given by the expression

$$T = \frac{2\pi m}{qB}$$

where B is the magnitude of the magnetic flux density in the *dees*. You may use the expression $a = v\omega$ for the centripetal acceleration where v is the linear speed and ω is the angular speed of the proton.

[2]

2. The magnetic flux density in the *dees* is 1.7 T

Determine the frequency for the changing polarity of the p.d.

frequency = ……………… Hz [1]

(ii) The proton exiting the cyclotron is moving in a circular path of radius 0.25 m.

Show that the kinetic energy of the proton is 1.4×10^{-12} J.

[2]

(iii) The proton starts from rest at the centre of the cyclotron and complete 100 revolutions before it exits from the cyclotron.

1. Calculate the kinetic energy gained for each revolution.

Kinetic energy gained for each revolution = …………………….. J [1]

2. For each revolution, the proton crosses the gap between the *dees* twice and hence it is accelerated twice by the p.d. V across the gap. The kinetic energy gained each time it crosses the gap is given by qV where q is the charge on the proton.

Determine the p.d. applied across the *dees* as the proton crosses the gap between them.

V = ……………………. V [2]

[Total: 20]

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9 **(a)** V and X are different isotopes of helium.

State one similarity and one difference between a nucleus of V and a nucleus of X.

Similarity: …………………………………………………………………………………………

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

Difference: ………………………………………………………………………………………

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

(b) **(i)** The nuclear binding energy per nucleon varies with nucleon number.

On Fig 9.1, draw a graph showing this variation for nuclei with nucleon number from 1 to 250. Label the axes with appropriate values.

[3]

Fig. 9.1

(ii) Explain the significance of the nuclear binding energy per nucleon for nuclear fusion.

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

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

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

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

(c) A $24He$ nucleus is formed in this nuclear reaction:

$$12H\ +\ 23He\ \square\ 24He\ +\ \mathrm{Y}$$

(i) State **three** quantities that are conserved in all nuclear reactions.

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

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

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

(ii) Identify particle Y.

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

(iii) Explain, in terms of mass, why this nuclear reaction occurs.

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

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

(iv) Calculate the amount of energy released in the nuclear reaction.

mass of $12H$ is 2.0141 u

mass of $23He$ is 3.0160 u

mass of $24He$ is 4.0026 u

mass of Y is 1.0078 u

energy released = ………………… J [3]

(v) Calculate the number of $23He$ nuclei which must each fuse with a $12H$ nucleus per second in order to emit energy at a rate of 20.0 W.

Number = …………………………… s^{-1} [2]

(vi) In a house, there are fifteen lamps which consume electrical energy at a rate of 20.0 W each. The lamps are only switched on in the evenings.

Estimate the mass of $23He$ that is required in order for this reaction to release the same amount of energy as the lamps in the house consume in one year.

State any assumption made.

mass = …………………… kg [3]

[Total: 20]

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