RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 3
PAPER 3

13 SEPTEMBER 2022

2 HOURS

CANDIDATE NAME										
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	2	1	J							

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.
Candidates answer on the Question Paper.

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 **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

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

FOR EXAMINERS' USE	
Section A – do all questions	
1	**/ 6**
2	**/ 9**
3	**/ 7**
4	**/ 8**
5	**/ 9**
6	**/ 5**
7	**/ 8**
8	**/ 8**
Section B – do ONE question only	
9	**/ 20**
10	**/ 20**
Deduction	
TOTAL	**/ 80**

This document consists of **25** printed pages.

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	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	T / K = T / °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,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the space provided

1 The velocity-time graph in Fig. 1.1 shows the first 1.6 s of the motion of a ball which is thrown vertically downwards at an initial speed of 4.0 m s^{-1}.

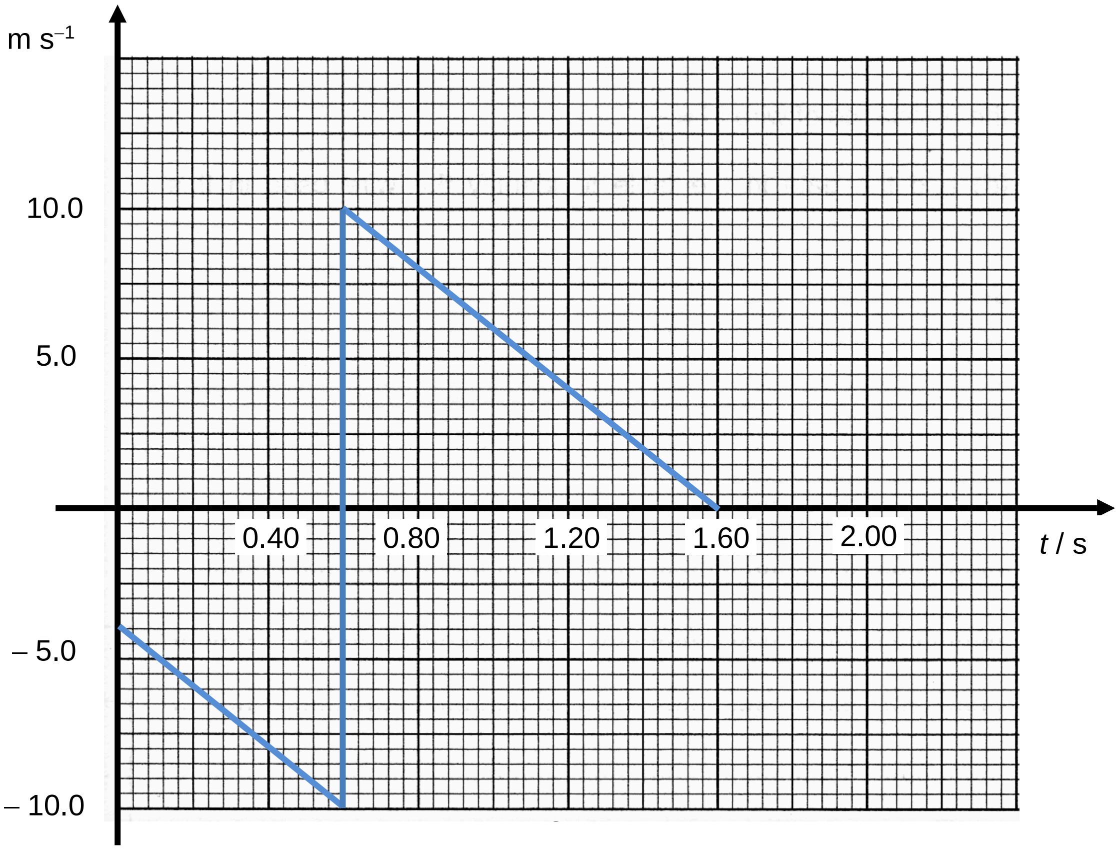

Fig. 1.1

(a) Calculate the distance travelled by the ball before hitting the ground.

distance travelled ………………….. m [2]

(b) Determine the maximum height attained by the ball above its original release position after it hits the ground.

height = ………………….. m [2]

(c) With reference to Fig. 1.1, determine the magnitude of the acceleration of the ball when it is in the air.

acceleration = ………………….. m s^{-2} [1]

(d) Determine the time at which the ball next reaches the ground.

time = ………………….. s [1]

2 Block A with mass *m* and speed of 10 m s^{-1} collides head-on with block B of mass 5*m* that has a speed of 2.0 m s^{-1} in the same direction.

(a) After the collision, the block B travels in the original direction with a speed of 4.5 m s^{-1}.

(i) Calculate the velocity of the block A immediately after the collision.

velocity = ………………….. m s^{-1} [2]

(ii) Consider block A and block B as a system.

Determine the percentage of kinetic energy lost by the system after the collision.

percentage = ………………….. % [3]

(b) If no kinetic energy were lost during the collision, determine the velocity of block A and block B immediately after they have collided.

velocity of block A = ………………….. m s^{-1}

velocity of block B = ………………….. m s^{-1} [4]

3 Block P of mass 2.0 kg is connected to a spring of spring constant 200 N m^{-1} that has one end fixed to the wall as shown in Fig. 3.1. Block P is in turn connected to block Q of mass 4.0 kg via an inextensible string.

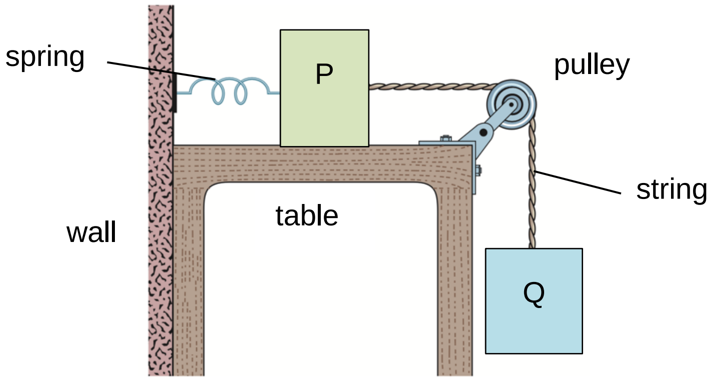

Fig. 3.1

The horizontal surfaces between block P and the table, and the pulley are frictionless. The pulley has negligible mass.

The blocks are released from rest with the spring being unstretched.

(a) Consider the spring, mass P and Q as a system.

State the energy conversion in the system just after block Q starts to move downwards.

....

....

.... [1]

(b) **(i)** Calculate the combined kinetic energy of the two blocks when block Q has fallen by 9.0 cm.

kinetic energy = ………………….. J [2]

(ii) Calculate the kinetic energy of the block Q after it has fallen by 9.0 cm.

kinetic energy = ………………….. J [2]

(c) Determine the distance that block Q has fallen before it first comes to rest.

distance = ………………….. cm [2]

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.

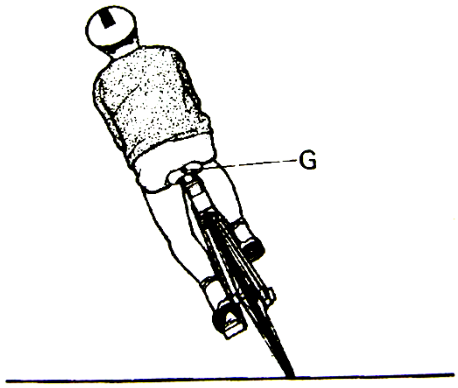

Fig. 4.1

(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.

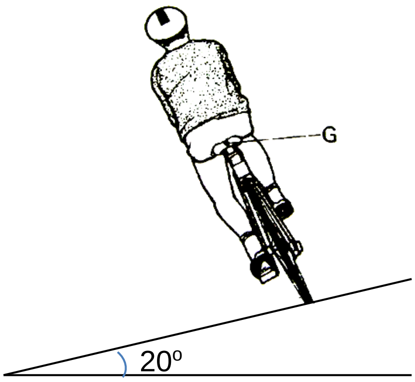

Fig. 4.2

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]

5 **(a)** A 5.0 mg particle rotates counterclockwise in a circle of radius 3.00 m with a constant period of 0.785 s. At t = 0, the particle has an x-coordinate of +2.00 m and is moving to the right.

Take rightward as positive.

(i) The x-coordinate of the particle can be expressed in the form of

$$A\cos(\omega t - B)$$

Determine the values of A, ω and B.

A = ………………………….. m

ω = ………………….. rad s^{-1}

B = ……………………… rad [3]

(ii) Hence or otherwise, determine the maximum velocity and acceleration of the particle.

maximum velocity = …………………….. m s^{-1}

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

(iii) In Fig. 5.1. sketch the variation with time of the kinetic energy E_k of the particle along the x-axis.

Indicate in your sketch, the magnitude of the maximum kinetic energy.

[2]

(b) With reference to the energy of the system, state and explain how the amplitude of a damped oscillating system will vary with time when at resonance.

....

....

.... [2]

6 A lamp has a value of 100 W and 240 V marked on it.

(a) Explain what is meant by “100 W and 240 V” when applied to the lamp.

....

....

.... [1]

(b) Calculate the number of electrons that enter and leave the filament of the lamp every second when a D.C. supply of 280 V is connected across the filament.

number of electrons per second =...................... s^{-1} [2]

(c) Explain in terms of the movement of charged particles whether the resistance of the electric filament lamp changes when connected to an external power supply for 30 minutes.

....

....

....

....

.... [2]

7 Many radioisotopes have important industrial, medical and research applications. One of these is ^{60}Co, which has a half-life of 5.2 years and each ^{60}Co nucleus decays by emission of a beta particle (energy of 0.31 MeV) and two gamma photons (energies of 1.17 MeV and 1.33 MeV respectively).

A scientist wishes to prepare a ^{60}Co sealed source that will have an activity of at least 3.7×10^{11} Bq after 30 months of use.

(a) Show that the initial minimum activity of ^{60}Co when the scientist is preparing the radioisotopes is 5.2×10^{11} Bq

[2]

(b) Hence, calculate the minimum initial mass of ^{60}Co required.

minimum initial mass =...................... g [3]

(c) Determine the rate at which the source will emit energy after 30 months.

rate of energy emission =...................... W [3]

8 Fig. 8.1 shows a potential divider circuit with a 9.0 V supply. A variable resistor of resistance R_1 is connected in series with a fixed resistor of resistance R_2. A voltmeter is connected across the fixed resistor.

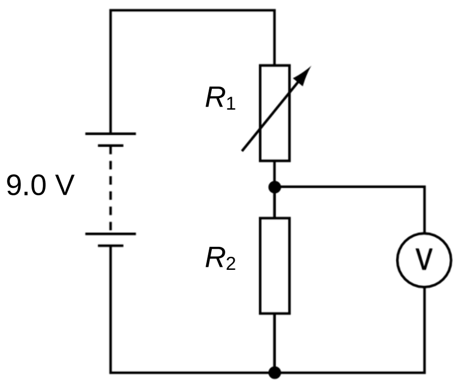

Fig. 8.1

(a) **(i)** The battery has negligible internal resistance and the voltmeter has infinite resistance.

If the fixed resistor R_2 has a resistance of 470 Ω, determine the reading in the voltmeter if the variable resistor is adjusted to 1650 Ω.

voltmeter reading = ………………….. V [1]

(ii) The variable resistance R_1 has a range of 0 to 2.0 kΩ.

In Fig. 8.2, sketch the variation of the voltmeter reading with resistance R_1. Label the appropriate values in your axes.

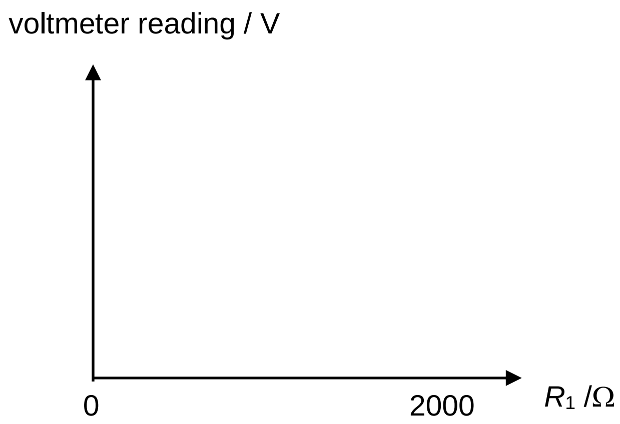

Fig. 8.2

[2]

(b) **(i)** In practice, the voltmeter does not have infinite resistance.

If the voltmeter has a resistance of 0.10 MΩ, determine the percentage change in your answer in **(a)(i)**. You may assume the battery to have negligible internal resistance.

percentage change = ………………….. % [3]

(ii) Over time, the battery may develop some internal resistance usually in the order of a few ohms.

Suggest an explanation why the effect of internal resistance can be ignored in the calculation in **(a)(i)**.

....

....

.... [2]

Section B

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

9 **(a)** In an electron microscope, an electron lens has two cylinders which are at potentials of +500 V and −100 V respectively. An electron beam passes at high speed into the lens from the top.

A cross-section of the two cylinders is shown in **full scale in Fig. 9.1**. The dotted lines are equipotential lines.

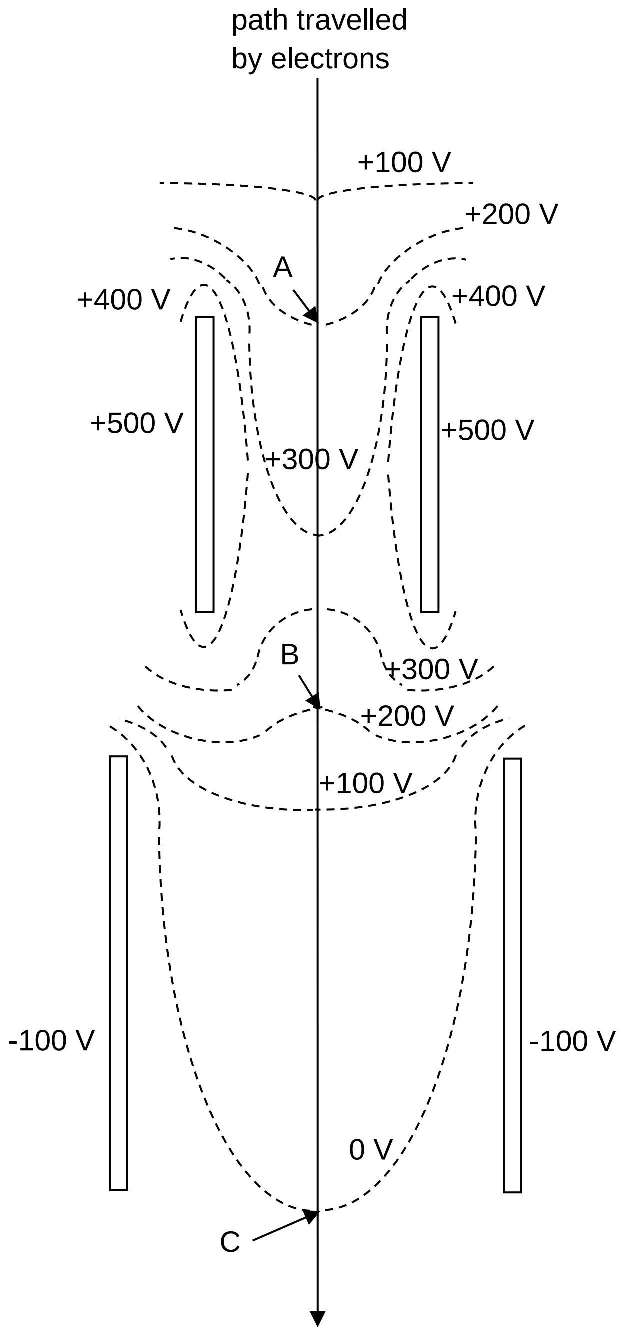

Fig. 9.1 Equipotential lines drawn to scale

(i) Define *electric field strength*.

....

....

.... [1]

(ii) With reference to Fig. 9.1, describe how the speed of an electron changes while moving from A to B.

....

....

....

.... [2]

(iii) Calculate the change in kinetic energy of an electron moving from A to C.

change in kinetic energy =...................... J [2]

(iv) Estimate the electric field strength at B.

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

(v) Show the direction of electric field strength at B in Fig. 9.1. [1]

(vi) Hence, determine the magnitude and direction of the electric force on an electron at B.

magnitude of electric force =...................... N

direction of electric force =...................... [2]

(b) The space observatory SOHO orbits the Sun in a circular orbit as shown in Fig. 9.2.

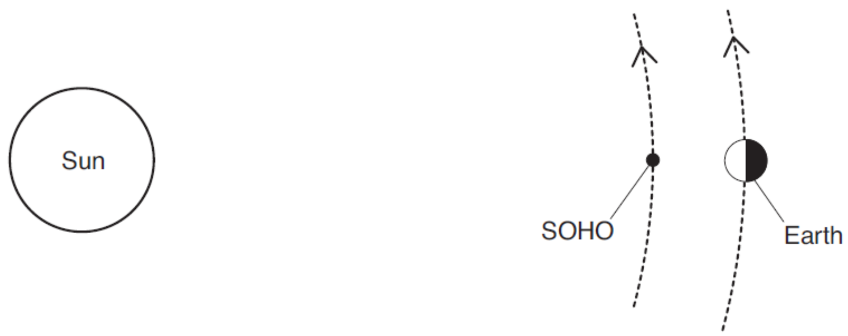

Fig. 9.2

(i) Show that the angular speed ω of an object in a circular orbit of radius R about the Sun is given by

$$\omega = \sqrt{\frac{GM}{R^3}}$$

where M is the mass of the Sun. Explain your working clearly.

[1]

(ii) On Fig. 9.2, draw and label arrows showing all the forces acting on SOHO. [1]

(iii) SOHO has the same angular speed as Earth about the Sun

Using your answer in **(b)(i)** and **(b)(ii)**, explain how this is possible.

....

....

....

.... [2]

(iv) "*A SOHO with larger mass will have a longer orbital period about the Sun.*"

By considering the forces on SOHO, explain whether the above statement is true. Clearly define any symbols that are used in the explanation.

....

....

.... [1]

(c) Another space observatory satellite orbits the Earth in a circular orbit at a height of 7.0×10^3 km above Earth's surface. The mass of the Earth is 6.0×10^{24} kg.

(i) Determine the orbital speed of this satellite.

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

(ii) A stone of mass 12 kg is to be projected directly opposite to the motion of satellite as shown in Fig. 9.3 such that it can totally escape from Earth's gravitational field.

Determine the minimum speed of projection of the stone.

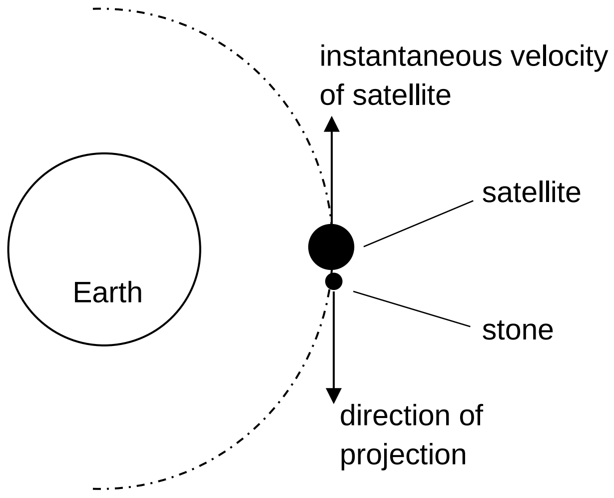

Fig. 9.3

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

(iii) Explain whether projecting the stone from the satellite in a direction away from the centre of the Earth will result in the lowest speed to escape from the Earth's gravitational field.

....

....

.... [1]

10 **(a)** A cyclotron is a device used to accelerate ions to very high speeds. Fig. 10.1 shows a diagram of a cyclotron viewed from above.

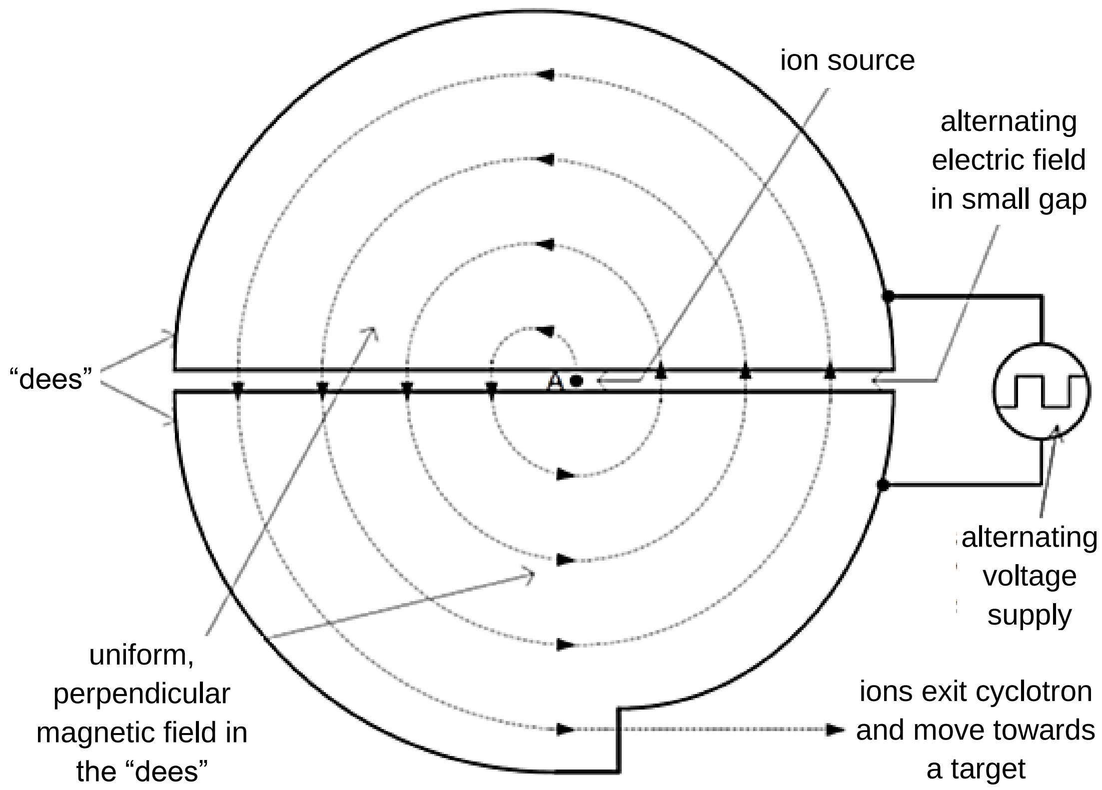

Fig. 10.1

During operation, the voltage supply provides an alternating potential difference to the small gap between the two semi-circular electrodes known as “dees”. This will ensure that the ions are accelerated each time they cross the gap.

On entering the “dees”, the uniform magnetic field caused the ions to move in a circular path. As the ions speed up, they travel in ever larger circles within the “dees”. Once the ions reach a sufficiently large speed, they exit through an outlet in one of the “dees”.

(i) Show that the time T for an ion to complete one revolution is $\dfrac{2\pi m}{qB}$.

[2]

A helium nucleus of mass 6.88×10^{-27} kg and charge $2e$ is accelerated in the cyclotron by applying an alternating potential difference of 450 V across the "dees". The magnetic flux density through the "dees" is 0.850 T.

(ii) State the direction of the magnetic field within the dees such as to produce a path as shown in Fig. 10.1.

.... [1]

(iii) Determine the frequency of the alternating voltage supply so that the helium nucleus is accelerated each time it crosses the gap between the "dees".

f = ………………….. Hz [2]

(iv) Determine the gain in kinetic energy of the helium nucleus after one revolution.

gain in K.E = ………………….. J [2]

(v) Hence, determine the speed of v of the helium nucleus after three revolutions.

v = ………………….. m s^{-1} [2]

(vi) In Fig. 10.2, sketch the variation with time of the speed of the ion during the three revolutions. Note that values are not required.

Fig. 10.2

[2]

(vii) Suggest an advantage of a cyclotron over linear accelerators which uses straight tubes with potential differences applied across them to accelerate ions.

....

.... [1]

(b) A rolling axle of length 1.5 m is pushed along a pair of horizontal rails at a constant speed of 3.00 m s^{-1}. A 4.0 Ω resistor is connected to the rails at points a and b as shown in Fig. 10.3. A 0.080 T uniform magnetic field is acting vertically downwards.

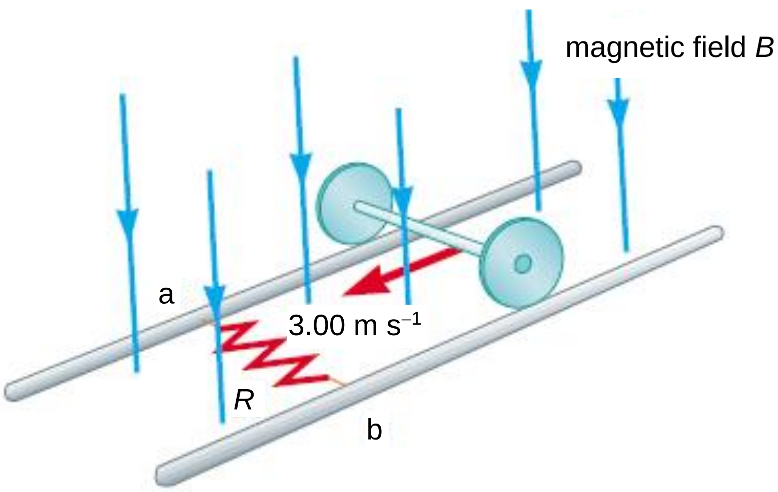

Fig. 10.3

(i) Assuming that the rails and axle have negligible resistance, determine the induced current flowing through the resistor.

current = ………………….. A [2]

(ii) Label on Fig. 10.3, the end of the resistor with higher potential with a positive sign. [1]

(iii) With reference to Lenz's law, explain why a horizontal force is required to keep the rod moving at constant speed.

....

....

....

.... [2]

(iv) Hence, state how energy is conserved during the moving of the rod.

....
...

....

.... [1]

(v) Determine the horizontal force that needs to be applied to the axle to keep it moving at a constant speed.

force = ………………….. N [2]

End of Paper