Catholic Junior College

JC2 Preliminary Examination

Higher 1

CANDIDATE NAME	
CLASS	**2T**

PHYSICS **8867/2**

Paper 2 Structured Questions **23 August 2024**

2 hours

Candidates answer on the Question Paper.

No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
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 any **one** question.

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.

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 7			
Q2	/ 7			
Q3	/ 7			
Q4	/ 8			
Q5	/ 8			
Q6	/ 7			
Q7	/ 16			
Q8	/ 20			
Q9	/ 20			
PAPER 2 (WEIGHTAGE: 67%)	/ 80			
PAPER 1 (WEIGHTAGE: 33%)	/ 30			
TOTAL	%			

Data

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

1 (a) A student writes down the following equation to describe the forces acting on a sphere falling under gravity through a medium of liquid,

$$6\pi\eta r v^2 = \frac{4}{3}\pi r^3 \left(\rho - \rho_L\right) g$$

whereby

r is the radius of the sphere,
v the velocity,
g the acceleration of free fall,
η the coefficient of viscosity of the liquid with units: kg m^{-1} s^{-1},
ρ and ρ_L the densities of the sphere and the liquid respectively.

By checking the homogeneity of the equation, deduce whether the equation is correct.

[2]

(b) The drag force *F* experienced by a steel sphere of radius *r* dropping at speed *v* through a liquid is given by

$$F = Br^2 \rho v^2$$

where *B* is a constant.

A student obtained the following set of data for a steel sphere dropping through a fluid.

F = (8.0 ± 0.1) mN
r = (3.0 ± 0.1) cm
ρ = (1.00 ± 0.01) × 10^3 kg m^{-3}
v = (24 ± 1) cm s^{-1}

(i) Random errors are associated with the measurement of the diameter of the steel sphere.

1. Explain what is meant by a *random error*.

....

.... [1]

2. Hence, explain how such a random error can be minimized in this experiment.

....

.... [1]

(ii) Using the data given, determine the value of *B* together with its associated uncertainty.

B = ... ± .... [3]

[Total: 7]

2 A ball was kicked over a wall of height *h* as shown with a velocity 16.4 m s^{-1} at an angle of 50° above the horizontal. At the highest point of the trajectory, the ball managed to just go over the wall. It landed into a pit 2.0 m deep.

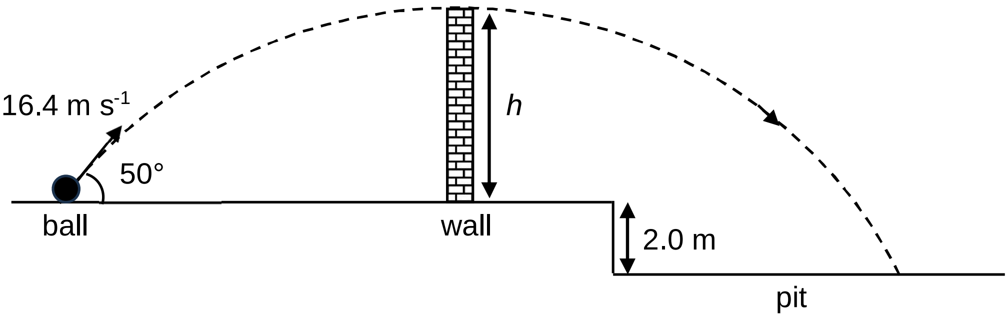


Fig. 2.1

(a) Calculate the height *h* of the wall.

h = …..…………………..……..... m [2]

(b) Calculate the time of flight of the ball when it just hits the pit.

time = …..………………..……..….. s [3]

(c) Calculate the vertical velocity of the ball just before it hits the pit.

vertical velocity = …..………….……..….. m s^{-1} [2]

[Total: 7]

3 **(a)** Three co-planar forces act on a body that is in equilibrium.

(i) By drawing a vector diagram, describe how a vector diagram can be used to represent these forces.

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

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

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

(ii) Explain why the vector triangle cannot be used to show that a body is in rotational equilibrium.

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

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

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

(b) Fig. 3.1 shows a uniform thin rod of weight W = 1000 N, being towed at angle of 30° to the ground by a force T. It is moving at a constant horizontal velocity.

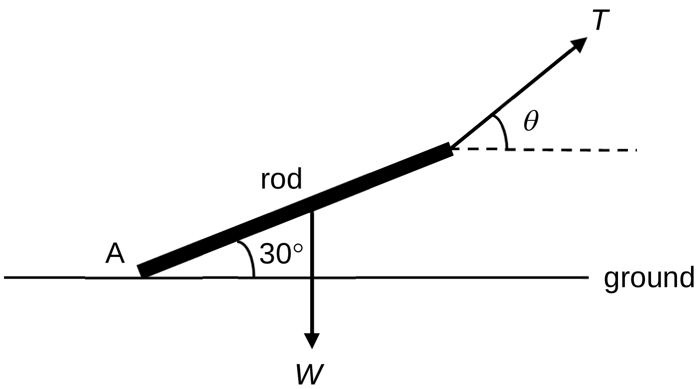


Fig. 3.1

(i) On Fig. 3.1, indicate the direction of the reaction force R acting on the rod by the ground at point A. [1]

(ii) The force T is applied on the rod at an angle θ of 46° with respect to the horizontal.

Determine T.

T = ……………………………………….. N [3]

[Total: 7]

4 (a) State Newton's law of gravitation.

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

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

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

(b) Two stars of mass M and $2M$, a distance of $3R$ apart, rotate in circles about their common centre of mass O. They form a binary star system as shown in Fig. 4.1.

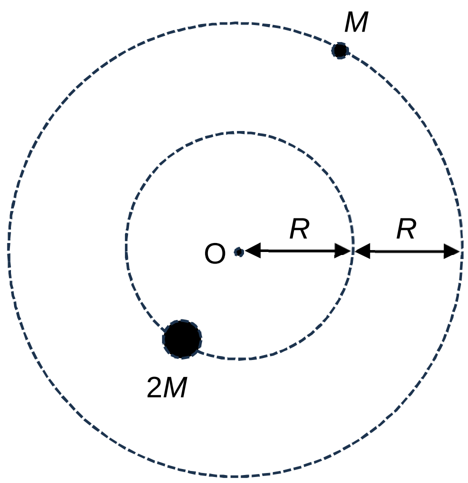


Fig. 4.1

The period of this binary star system is 3.42×10^5 s. The value of M is 3.14×10^{30} kg.

(i) Express the gravitational force of attraction between the two stars in terms of R.

[1]

(ii) Calculate the angular speed for each star.

angular speed = …………………………… rad s^{-1} [2]

[Turn over

(iii) Determine the distance R.

R = …….……….……………..…..... m [3]

[Total: 8]

5 A dry cell of e.m.f. 12.0 V and internal resistance 1.0 Ω is connected in series to a uniform wire XY of length 120 cm and diameter 1.3 mm, as shown in Fig. 5.1. The resistivity of the material of the wire is 1.2×10^{-6} Ω m.

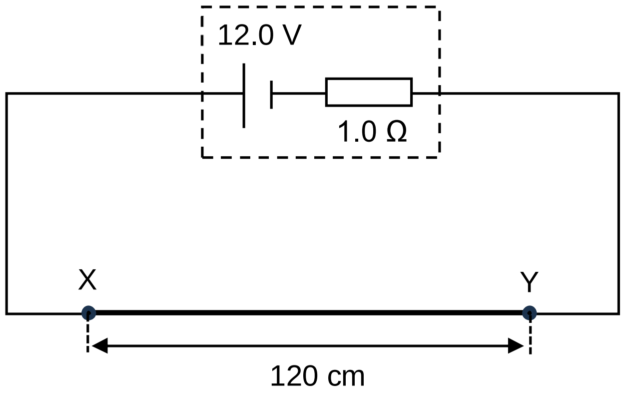


Fig. 5.1

(a) Define *resistivity* of a material.

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

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

(b) **(i)** Calculate the resistance of the wire.

resistance = …………………………………… Ω [1]

(ii) Show that the terminal voltage of the dry cell is 6.2 V.

[2]

(iii) Calculate the percentage of energy dissipated as heat in the dry cell.

percentage = ……………………………………… % [2]

(c) **(i)** If wire XY can be changed, suggest a value of the resistance of wire XY such that maximum power can be delivered to it.

…………………………………………………………………………………………………

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

(ii) Hence, state the percentage efficiency of the dry cell when maximum power is being delivered to wire XY.

…………………………………………………………………………………………………

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

[Total: 8]

6 Uranium-235 nuclei when bombarded by neutrons may undergo random nuclear reactions. One such reaction is

$$^{235}_{92}\text{Ur} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + \boxed{}$$

For the nuclear reaction, the binding energy per nucleon of Uranium-235 is approximately 7.5 MeV and that of Barium-144 is approximately 8.5 MeV.

(a) Complete the equation for this nuclear reaction. [1]

(b) Determine the binding energy per nucleon of Krypton-90, given that the minimum energy released for this reaction is 227 MeV.

binding energy per nucleon = ……………………………….. MeV [3]

(c) Explain the relevance of binding energy per nucleon to nuclear fission and nuclear fusion.

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

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

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

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

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

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

[Total: 7]

7 In a coal-fired power plant, burning coal is used to boil water and produce high-pressure steam, which then turns the turbine of an electric generator, thus producing electricity. Hydroelectric power plants use falling water to directly turn the turbines of the generators. Reservoirs hold water just behind dams while the turbines are usually located at the base of a dam as shown in Fig. 7.1.

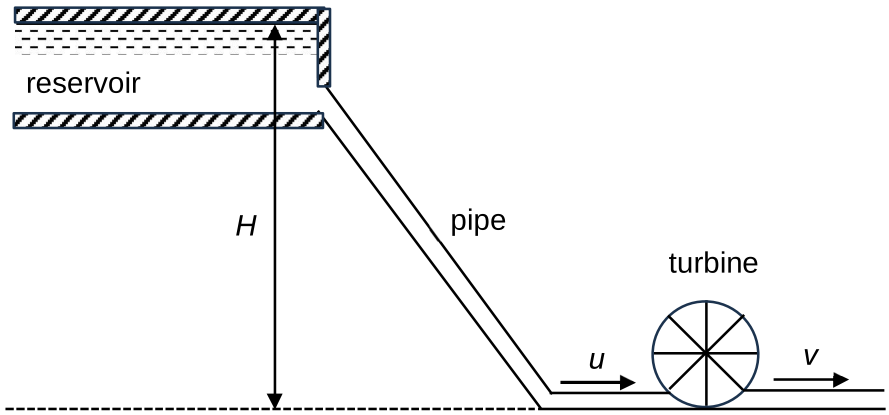


Fig. 7.1

The water emerges from the bottom of the dam through a circular pipe with speed u and hits the blades of the turbine with this speed. After colliding with the blades of the turbine, the water moves in the same direction with speed v.

Table 7.2 below shows the data for a given hydroelectric power plant.

Table 7.2

Difference in height H between water level in the reservoir and turbine	220 m
Diameter d of the pipe	0.060 m
Density ρ of water	1000 kg m^{-3}
Speed v of water after hitting the blades of the turbine	10 m s^{-1}
Temperature of water	15 °C

(a) State two advantages of generating electricity in hydroelectric power plants over coal-fired power plants.

1 ....

....

2 ....

.... [2]

(b) **(i)** The kinetic energy of the water leaving the pipe is assumed to be equal to the potential energy of the water at the surface of the reservoir.

Neglect any losses due to resistive forces, calculate the speed *u* of the water as it leaves the pipe.

u = …………………………… m s^{-1} [3]

(ii) Show that the mass of water flowing through the pipe per unit time is 186 kg s^{-1}.

[3]

(iii) Calculate the power carried by the water before hitting the blades of the turbine.

power = ………………………………. W [2]

(iv) Calculate the maximum possible force the water could exert on the turbine blades.

maximum force = …..……….………….……... N [2]

(v) Determine the maximum possible power imparted to the turbine.

maximum power = …..……….……….……... W [3]

(c) Suggest a possible reason why a low temperature of water of 15 ^{0}C is used.

……………………………………………………………………………………………

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

[Total: 16]

Section B

Answer **ONE** question from this section.

8 **(a)** A student makes the following statements of Newton's first and third laws of motion:

"First Law: Every body continues in its state of motion unless it is acted upon by a resultant external force."

"Third Law: Action and reaction forces always occur in pairs and are equal in magnitude and opposite in direction."

(i) The statement of the first law is incomplete in two aspects.

Identify the two aspects and hence rewrite it with the appropriate amendments.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(ii) The statement of the third law is correct but fails to emphasize an important aspect of the action and reaction forces.

Identify this aspect and rewrite this third law to make this emphasis.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(b) State Newton's second law of motion.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(c) A small metal sphere of mass 5.0 g is accelerated from rest to a speed of 120 m s^{-1} in a tube. A force is applied over a period of 20 ms as shown in Fig. 8.1.

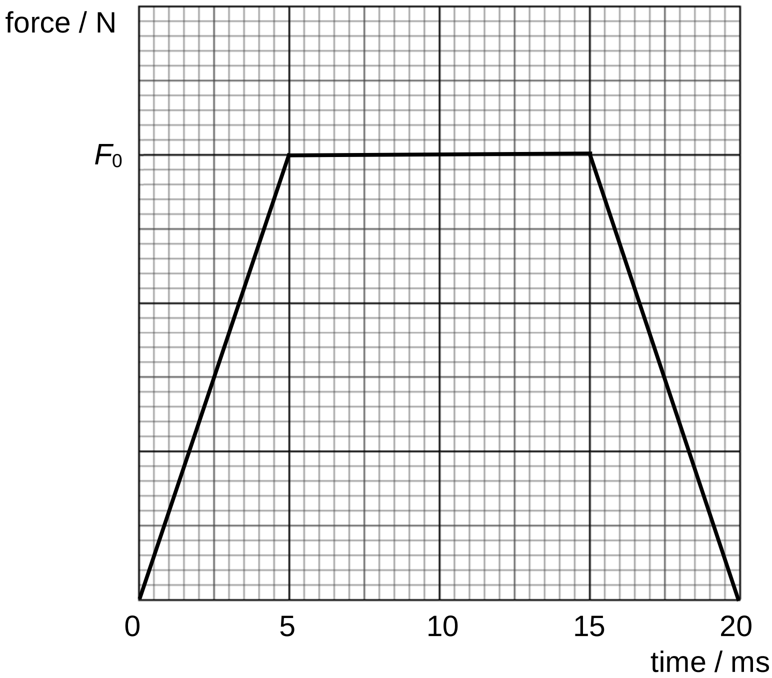


Fig. 8.1

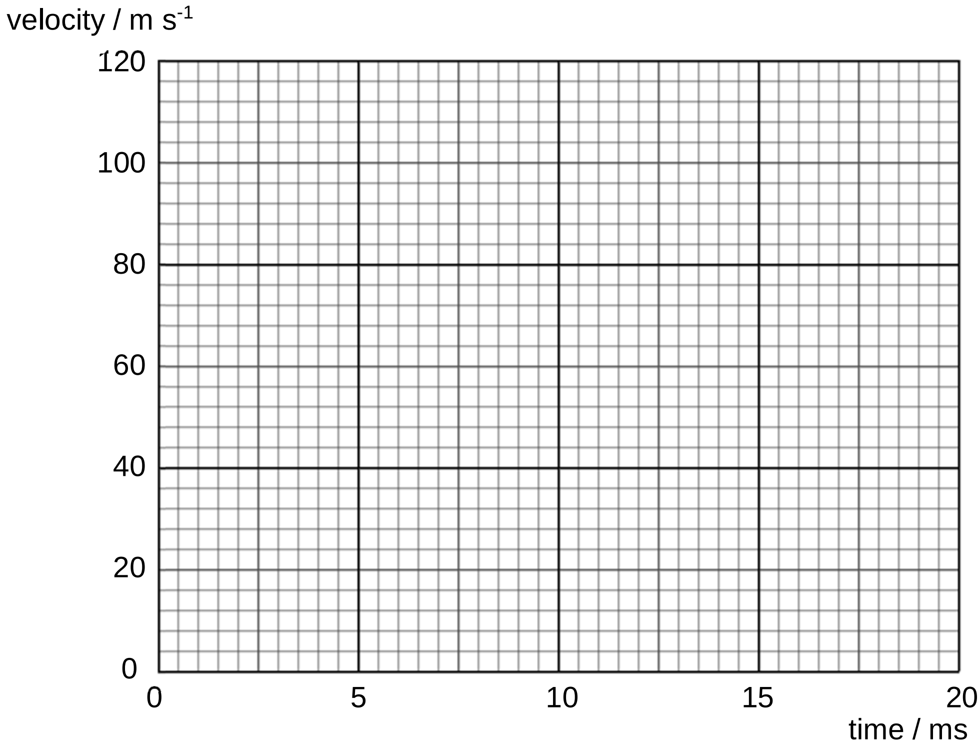
(i) Calculate the final momentum of the metal sphere.

momentum = …………………………….. kg m s^{-1} [2]

(ii) Calculate the maximum value of the applied force F_0.

F_0 = ……………………………………. N [3]

(iii) On Fig. 8.2, sketch a graph to show how the velocity of the metal sphere varies during the acceleration.



[3]

Fig. 8.2

(d) The metal sphere in **(c)** is projected horizontally towards a stationary sphere B of mass *M* as shown in Fig. 8.3. It collides elastically with sphere B. After the collision, the metal sphere in **(c)** and sphere B move off with velocities v_A and v_B respectively, in the direction as shown.

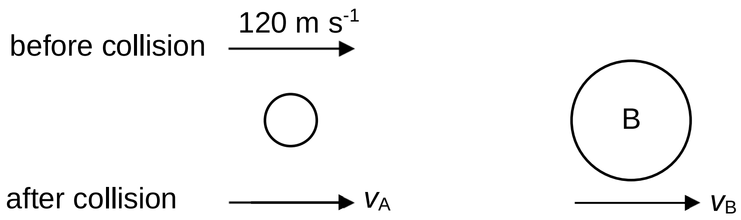


Fig. 8.3

(i) Show that $v_A = 120\left(\dfrac{0.0050 - M}{0.0050 + M}\right)$.

[3]

[Turn over

(ii) Using the equation in **(d)(i)**, show that the fractional loss of kinetic energy of the metal sphere in **(c)** is given by $\dfrac{0.020M}{(0.0050+M)^2}$.

[3]

[Total: 20]

9 A negatively charged particle of mass, $m = 3.32 \times 10^{-23}$ g and charge $-q = -1.6 \times 10^{-19}$ C is travelling with a velocity of $v = 8.43 \times 10^{4}$ m s^{-1} in a vacuum. It enters a region of uniform magnetic field of flux density 0.50 T as shown in Fig. 9.1. The magnetic field is normal to the path of the charged particle and is into the plane of the paper.

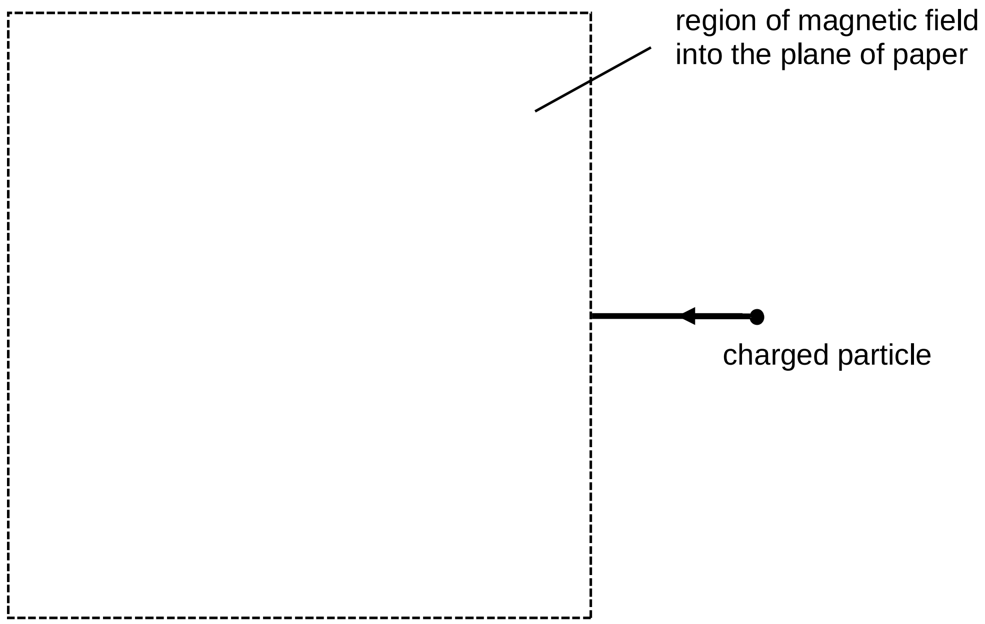


Fig. 9.1

(a) Define magnetic flux density.

……

……

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

(b) Calculate the radius of the path of the charged particle in the magnetic field.

radius = ………………………………………… m [3]

(c) **(i)** On Fig. 9.1, sketch the path of the charged particle as it passes through, and beyond the region of the magnetic field. [2]

(ii) Explain the motion of the charged particle upon leaving the magnetic field.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(d) A uniform electric field is now also applied in the region so that the same charged particle can pass undeflected through the field.

On Fig. 9.1, draw an arrow labelled *E* to show the direction of the electric field. [1]

(e) **(i)** Explain how the combination of magnetic and electric fields allows the charged particle of only one speed to pass undeflected through the field.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) Hence, deduce an expression for v in terms of the magnetic flux density B and the electric field strength E.

[2]

(f) The charged particle is replaced by other particles. The electric and magnetic fields remain unchanged.

State and explain the effect, if any, on the path of a particle that has

(i) mass m, charge $-q$ and speed $2v$,

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) mass m, charge $+q$ and speed v.

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

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

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

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

(g) The direction of the magnetic field is now changed such that it is now pointing upwards as shown in Fig. 9.2. With the application of an appropriate electric field, a charged particle now moves in a circular motion.

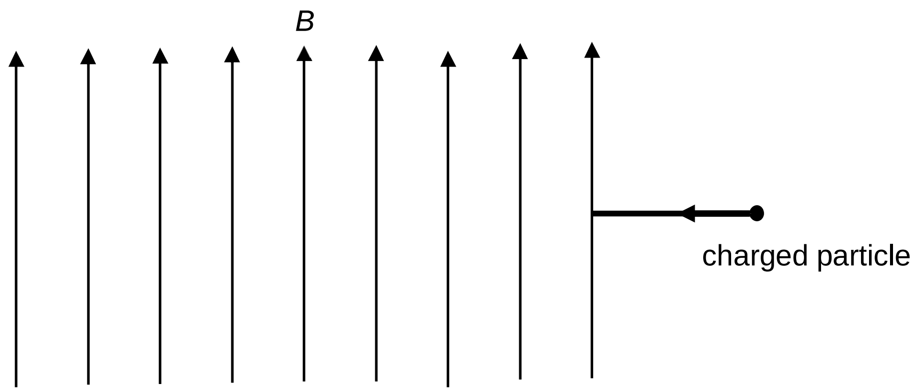


Fig. 9.2

If the electric field is removed, explain why the path taken by the charged particle is no longer circular.

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

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

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

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

[Total: 20]

-- END OF PAPER 2 --

BLANK PAGE