Candidate Name ………………………………………… CTG …………..

YISHUN JUNIOR COLLEGE
JC 1 PROMOTIONAL EXAMINATION 2015

PHYSICS **9646/02**

HIGHER 2

Paper 2

6 October 2015
Tuesday
2 hours

YISHUN JUNIOR COLLEGE
FLORESCAT CONCORDIA

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Write your name and CTG in the spaces provided on the cover page.

Answer **all** questions.

Show your working clearly in the spaces provided.

Paper 1	
	/30
Paper 2	
Q1	**/10**
Q2	**/10**
Q3	**/10**
Q4	**/9**
Q5	**/16**
Q6	**/10**
Q7	**/10**
Q8	**/5**
Penalty	
Sub-Total	**/80**
Total	
	/110
	%

This question paper consists of 16 printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\,\pi)) \times 10^{-9}$ Fm^{-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	=	ρgh
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{\left(x_o{}^2 - x^2\right)}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	=	$\exp(-2kd)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m\left(U-E\right)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{0.693}{t_{\frac{1}{2}}}$

Answer all questions. Show your workings clearly in the spaces provided.

1 **(a)** A student wishes to measure the length of a metal plate. The only equipment available is an electronic timer controlled by a light beam and a rod 2.00 m long. Using the rod, the student positions the plate so that its lower edge is 2.00 m above the light beam, as shown in Fig. 1.1.

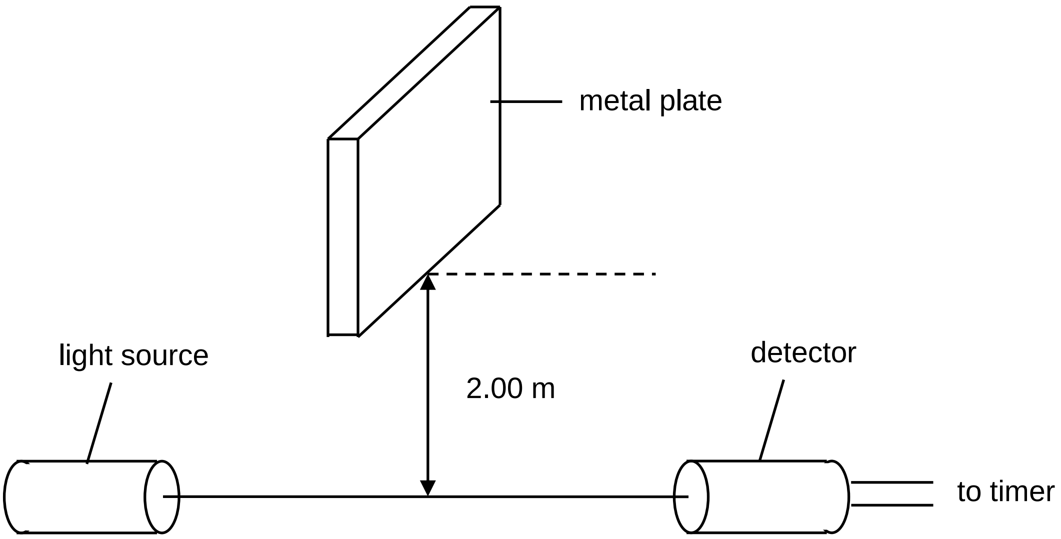

Fig. 1.1

The metal plate is released and the plate falls vertically. The timer starts to record when the light beam is cut. The total time for the plate to pass through the beam is 0.10 s.

(i) Determine the time taken for the bottom edge of the plate to reach the light beam after it is released.

$s_y = u_y t + ½ a_y t^2$
$2.00 = 0 + ½ (9.81) (t^2)$ [1]
$t = 0.63855 = 0.639$ s [1]

Time = ………………………………. s [2]

(ii) Hence using the answer in **(i)**, calculate the length of the plate.

$s_y = u_y t + ½ a_y t^2$
$= 0 + ½ (9.81) (0.639 + 0.10)^2$ [1]
$= 2.6787$ m

length of plate = 2.6787 – 2.00 = 0.679 m [1]

Length of plate = ………………………………. m [2]

(b) A stone is projected from horizontal ground at an angle of 60° to the horizontal with a speed u, as shown in Fig. 1.2. The stone takes 6.00 s to strike the ground again.

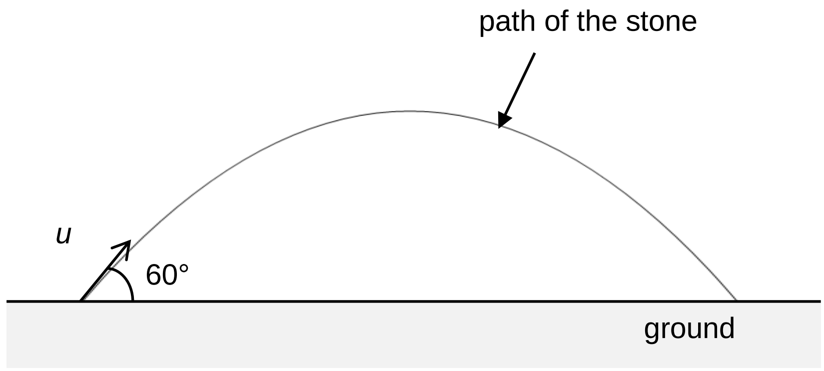

Fig. 1.2

(i) Calculate the initial speed u.

$s_y = u_y t + ½ a_y t^2$
$0 = (u \sin 60°)(6) + ½ (-9.81)(6)^2$ [1]
$u = 33.982 = 34.0 \text{ m s}^{-1}$ [1]

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

(ii) Calculate the horizontal distance between the point from which the ball was projected and the point where it strikes the ground.

$s_x = u_x t$
$= (34.0 \cos 60°)(6)$ [1]
$= 102$ m [1]

Horizontal distance =…………………………. m [2]

(iii) Calculate the maximum height of the stone from the ground.

$v_y^2 = u_y^2 + 2 a_y s_y$
$0 = (34.0 \sin 60°)^2 + 2(-9.81)(s_y)$ [1]
$s_y = 44.2$ m [1]

Maximum height = ……………………………… m [2]

2 **(a)** **(i)** Define *linear momentum*.

The linear momentum of a body is the product of its mass and velocity.

[1]

(ii) State whether linear momentum is a vector or a scalar quantity.

Vector

[1]

(b) State the *principle of conservation of momentum*.

The total momentum in a system remains constant [1] if the net external force acting on the system is zero [1].

[2]

(c) The principle can be applied in different types of interaction. These are illustrated by the following examples.

(i) Inelastic collision: A piece of plasticine of mass 0.20 kg falls to the ground and hits the ground with a velocity of 8.0 m s^{-1} vertically downward. It does not bounce but sticks to the ground.

1. Calculate the momentum of the plasticine just before it hits the ground.

mv = 0.20 x 8.0 = 1.6 Ns [1]

Momentum = ………………N s [1]

2. State what happens to the momentum and kinetic energy of the plasticine as a result of the collision.

The momentum of the plasticine before collision is transferred to the momentum of the ground [1] and the kinetic energy is lost as heat and sound [1]

[2]

(ii) Elastic collision: a neutron of mass 1.00 u travelling to the right with velocity 6.50×10^5 m s^{-1} collides head on with a stationary carbon atom of mass 12.00 u as shown in Fig. 2. The carbon atom moves off to the right with velocity 1.00×10^5 m s^{-1}.

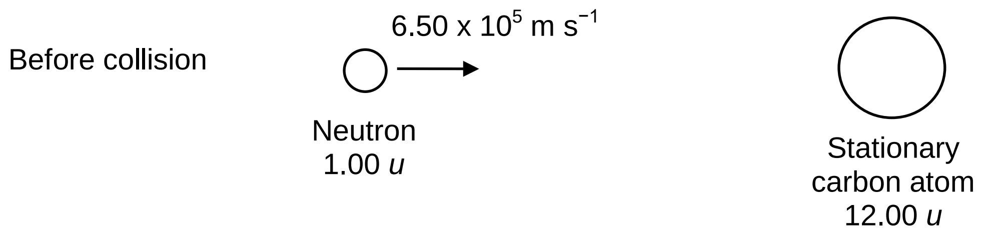

Fig. 2

1. Calculate the magnitude and determine the direction of the velocity of the neutron after the collision.

By principle of conservation of momentum,
1.0 u (6.50×10^5) + 0 = 12.00 u (1.00×10^5) + 1.00 u (v)
v = 5.5×10^5 [1]
To the left / negative direction [1]

Velocity = ... m s^{-1} to the .... (direction) [2]

2. State what happens to the total kinetic energy of the system as a result of this collision.

The total kinetic energy of the system of neutron and carbon remains the ....
same. .... [1]

3 A student placed a block with dimensions 0.20 m × 0.20 m × 0.10 m in a pool of water as shown in Fig. 3.1**.** He then measured the depth of immersion *h* of the block in water. The densities of the block and water are 560 kg m^{-3} and 1000 kg m^{-3} respectively.

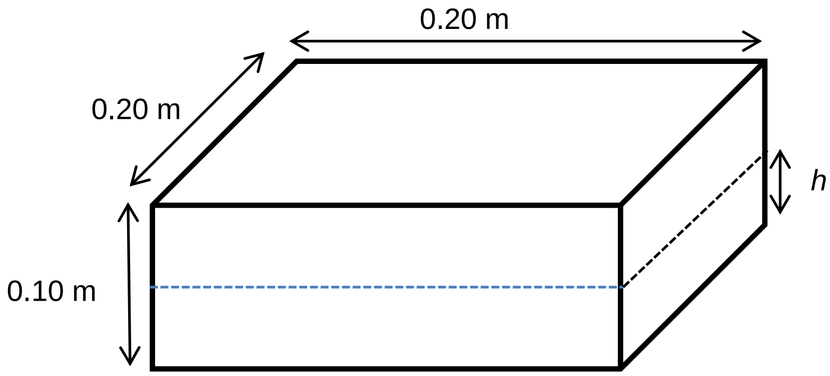

Fig. 3.1

(a) Calculate the value of *h.*

For the block to be floating,
Upthrust = weight of the block [1]
$0.20 \times 0.20 \times h \times 1000 \times 9.81 = 0.20 \times 0.20 \times 0.10 \times 560 \times 9.81$ [1]
$h = 0.056$ m [1]

h = ………………………… m [3]

(b) The student took a 1.0 m long uniform plank of mass 1.5 kg and placed it on the same floating block in Fig. 3.1. When the student is standing at 0.010 m from the pivot, the plank becomes horizontal.

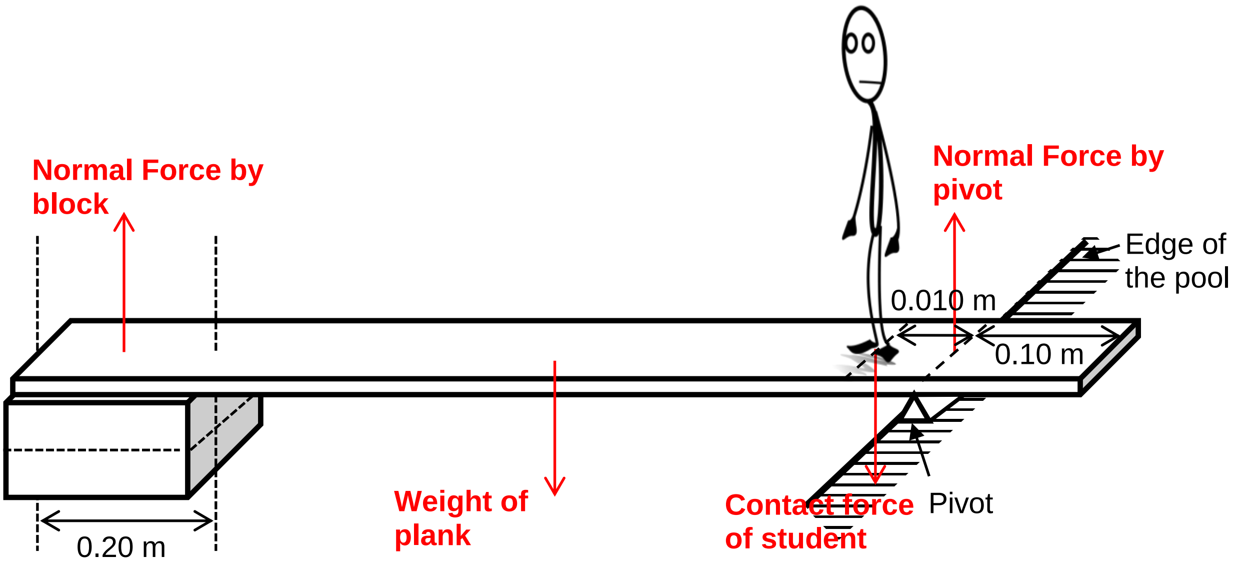

Fig. 3.2

(i) Draw and name the forces acting on the plank in Fig. 3.2. [2]

(ii) Given that the mass of the student is 40.0 kg, calculate the normal contact force exerted by the block on the plank.

Taking moments about the pivot, cwm = acwm
(40 x 9.81)(0.010) + (1.5 x 9.81)(0.40) = N x 0.80 [1]
N = 12.26 N = 12.3 N [1]

Normal contact force = ………………………… N [2]

(iii) Determine the new depth of immersion *h'* of the block in water, assuming that the block stays upright in the water.

Looking at FBD of the block,
$\Sigma F = 0$
U = N + W ----- [1] ability to show the correct FBD
$\rho_{water} V g = N + \rho_{block} V g$
1000 (0.20 x 0.20 x h')(9.81) = 12.26 + (560)(0.20 x 0.20 x 0.10)(9.81) [1]
h' = 0.087 m [1]

h' = ………………………… m [3]

4 **(a)** Define *work done* by a force on a body.

The work done by a force <u>on</u> a <u>body</u> is the <u>product</u> of that <u>force</u> and the <u>displacement</u> [1] of the body in the <u>direction of</u> the force [1].

……………………………………………………………………………………… [2]

(b) Fig. 4.1 shows an object of mass *m* sliding down a **smooth** plane inclined at angle *θ* from rest. The object travels *L* metres down the inclined plane before it hits the spring and compresses it before coming to a stop. The spring has a spring constant *k*.

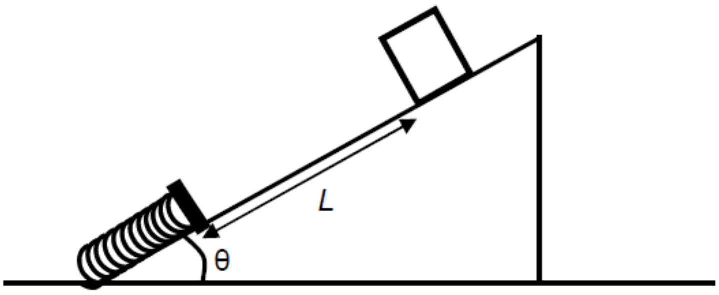

Fig. 4.1

(i) Taking the amount of compression of the spring to be e, show that the loss of gravitational potential energy of the object from the start of its motion until it comes to rest upon compressing the spring is

$$mg\,(L + e)\sin\theta.$$ [2]

The object will travel a total of (L + e) after compressing the spring and coming to rest.

Hence, the total vertical height it has fallen through
$= (L + e)\sin\theta$ [1]
Loss in GPE = mgh [1]
$= mg\,(L + e)\sin\theta$

(ii) If m = 2.0 kg, θ = 30.0°, L = 0.50 m, and k = 1500 N m^{-1}, determine e.

By Conservation of Energy
Loss in GPE = Gain in EPE
$mg\,(L + e)\sin\theta = \frac{1}{2}ke^2$ [1]
$\frac{1}{2}(1500)e^2 = (2.0)(9.81)(0.5 + e)\sin 30°$ [1]
$750e^2 - 9.81e - 4.905 = 0$

e= 0.0877, e = -0.0746 (N.A.)
Hence, e = 0.0877 m [1]

e = ………………………….. m [3]

(iii) State and explain what will happen to the answer in **(b)(ii)** if the plane is rough.

Smaller e. [1] There is energy loss in overcoming friction along the slope,

hence the gain in elastic potential energy is lesser. [1]

……………………………………………………………………………………… [2]

5 **(a)** Define *gravitational potential* at a point.

Gravitational potential is the work done per unit mass in bringing a point mass from infinity to that point. [1]

(b) Explain why is the gravitational potential at a distance from an isolated point mass always negative.

The forces between masses are always attractive [1]. The external force required to bring another point mass from infinity to that point is in the opposite direction as the displacement, hence there is negative work done. [1]

OR Maximum GPE at infinity is taken to be zero [1]. GPE at any point nearer to point mass than infinity will be less than zero, hence negative [1] [2]

(c) A 50 kg satellite is orbiting around planet M at a distance of 7.87×10^6 m above the surface of the planet. The radius of the planet is 8000 km and the satellite takes 30 hours to complete one revolution**.**

(i) Determine the angular velocity of the satellite.

$\omega = 2\pi/(30 \times 3600)$ [1]
$= 5.82 \times 10^{-5}$ rad s^{-1} [1]

Angular velocity = ………………………….. rad s^{-1} [2]

(ii) Determine the kinetic energy of the satellite.

$v = r\omega = (7.87 \times 10^6 + 8000 \times 10^3)(5.82 \times 10^{-5})$ [1]
$= 923.6$ m s^{-1}

$KE = ½ m v^2$
$= ½ (50)(923.6)^2$
$= 2.13 \times 10^7$

Kinetic energy = ………………………….. J [2]

(iii) Explain why the kinetic energy of the satellite remains constant although there is net force acting on the satellite.

The net force is always perpendicular to the displacement or linear velocity [1].

Hence the work done by the net force is zero. [1]

.... [2]

(iv) Show that the mass of planet M is 2.03 x 10^{23} kg. [2]

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \quad [1]$$

$KE = \frac{GMm}{2r} = 2.13 \times 10^7$ [1 mark to show correct substitution]

Mass of planet = 2.03 x 10^{23} kg

(v) Hence, determine the potential of a point at the surface of planet M.

ϕ = -GM/r = 1.69 x 10^6 J kg^{-1} [1]

Potential at the surface = ……………………….... J kg^{-1} [1]

(vi) An object is projected vertically from the surface of planet M so that it reaches a height of 1000 km above the planet's surface. Calculate, for this object, the minimum speed of projection from the planet's surface, assuming air resistance is negligible.

GPEi + KEi = GPEf + KEf
KEi = GPEf – GPEi

$$\frac{1}{2} m v^2 = \left(-\frac{G(2.03\times10^{23})(m)}{9000\times10^3} + \frac{G(2.03\times10^{23})(m)}{8000\times10^3}\right) \quad [1]$$

v = 613 m s^{-1} [1]

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

(vii) Explain why the equation $v^2 = u^2 + 2as$ is not appropriate for the calculation in **c(vi)** even though air resistance is assumed to be negligible.

It is not appropriate since the acceleration is not constant [1] as the gravitational field strength decreases as the object is further away from the surface of the Earth. [1] [2]

6 **(a)** State the similarity between *electric potential* and *electric potential energy*.

Both are work done on point charge to bring from infinity to that point. OR

Both are scalars. [1]

(b) An oil droplet remains stationary between two metal plates across which there is a potential difference, V. The distance between the two plates is d. The arrangement is shown in Fig. 6.1.

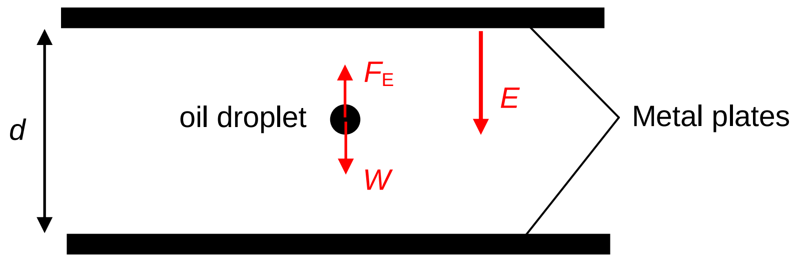

Fig. 6.1

Assume that the arrangement is in a vacuum,

(i) Draw and label the forces acting on the oil drop in Fig. 6.1. [2]

(ii) If the oil droplet is negatively charged, indicate in Fig. 6.1 the direction of the electric field between the plates. [1]

(iii) If the mass and charge of the oil droplet is *m* and *q* respectively, show that

$$V = \frac{mgd}{q}$$

where *g* is the acceleration due to gravity. [2]

E = V/d [1]
mg = qE [1]
mg = q(V/d)
V = mgd/q

(iv) State and explain what would happen if

1. the drop acquires additional charge of the same sign,

The electric force on the charge will increase [1] and hence

resultant force on the charge is upwards.

It accelerates upwards [1] [2]

2. the plates move further apart while the potential difference remains the same.

The electric force on the charge will decrease [1] and hence the

resultant force on the oil droplet is downwards.

It accelerates downwards.[1] [2]

7 **(a)** Define *magnetic flux density*.

Magnetic flux density is defined as the force exerted on a unit length of conductor carrying a unit current placed at right angles to the field. [1]

(b) A proton moving at a speed of 1.6×10^{6} m s^{-1} enters a uniform magnetic field of flux density, 6.68×10^{-3} T, pointing out of the plane of paper, as shown in Fig. 7.1. The magnetic field has the shape of a square with side 5.0 m and the proton enters the field perpendicularly at the mid-point of one side.

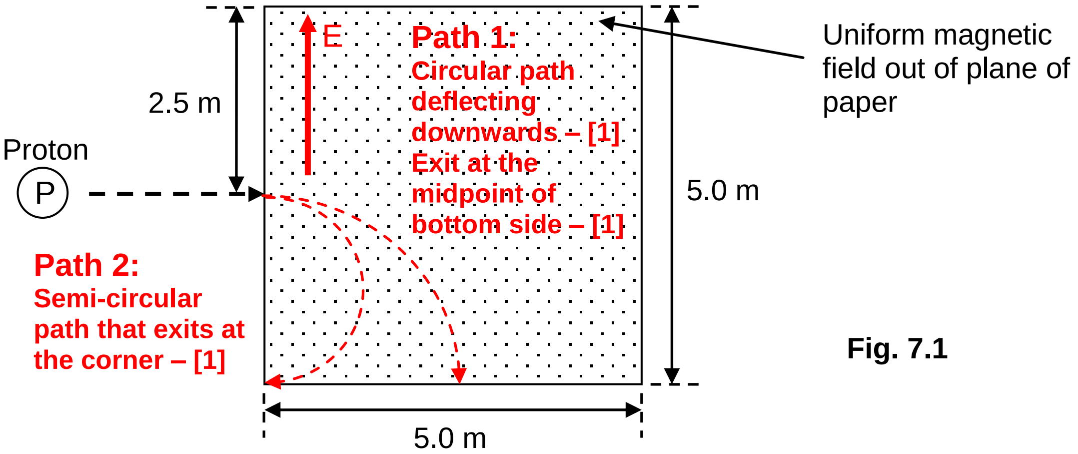

Fig. 7.1

(i) When the proton enters the magnetic field, it experiences magnetic force and moves in a circular path. Calculate the radius of the path.

$\Sigma F = m a$

$B q v \sin\theta = m v^2 / r$

$r = m v / B q$ [1]

$= (1.67 \times 10^{-27})(1.6 \times 10^{6}) / (6.68 \times 10^{-3})(1.6 \times 10^{-19})$
$= 2.5$ m [1]

Radius = …………………. m [2]

(ii) With reference to your answer in **b(i)**, sketch the path of the proton within the magnetic field and label it "Path 1". [2]

(iii) If the magnetic flux density is doubled, sketch the new path of the proton within the magnetic field and label it "Path 2". [1]

(iv) Explain why the path of the proton is circular.

The magnetic force always acts perpendicular to the velocity of proton and hence serves as the centripetal force to keep it in circular path. [1]

(v) If a student wishes to keep the proton moving horizontally in the magnetic field, instead of moving in a circular path, he can set up a uniform electric field in the same region as the magnetic field. Draw an arrow in Fig. 7.1 to illustrate the direction of the electric field lines and label it "E". [1]

(vi) Determine the electric field strength required to keep the proton moving through the fields undeflected.

B q v sinθ = E q

E = B v [1]

= $(6.68 \times 10^{-3})(1.6 \times 10^{6})$
= 1.1×10^{4} N C^{-1} [1]

Electric field strength = ………………… N C^{-1} [2]

8 Fig. 8 shows a voltmeter of infinite resistance connected across the terminals of a battery. When switch S is opened, the voltmeter reads 8.2 V. When switch S is closed, the voltmeter reads 7.7 V. The external resistor *R* is 4.5 Ω.

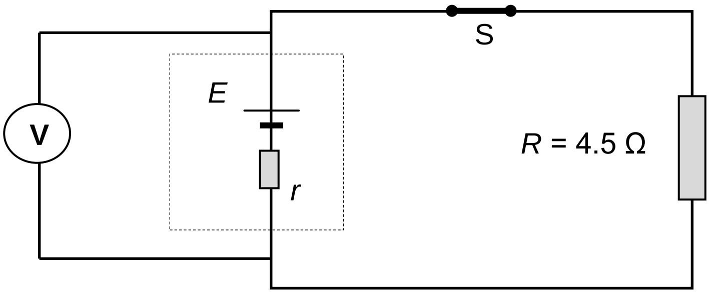

Fig. 8

(a) Determine the e.m.f *E* of the battery.

When switch is opened, $I = 0$,
$E = 8.2$ V [1]

E = ……………. V [1]

(b) Calculate the internal resistance *r* of the battery.

$E = V + I r$
$8.2 = 7.7 + I r$ [1]
$8.2 = 7.7 + (7.7/4.5)\, r$
$r = 0.29$ Ω [1]

r = ……………. Ω [2]

(c) Determine the percentage of the total power which is dissipated in the battery.

Percentage = $[(I^2 r) / (I E)]$ (100%) [1]
= $[(7.7/4.5)^2 (0.29) / (7.7/4.5)(8.2)]$ (100%)
= 6.1% [1]

Percentage = ……………. % [2]

End of Paper 2