12 ATAR Physics

EM1 Test 2017 Score: ______ / 50

Student name: MARKING KEY

Weighting : 3%

Instructions:
Ignore Earth's magnetic field unless question explicitly asks you to consider for realistic situations or qualitative arguments.

1. Describe TWO similarities and TWO differences between the gravitational field of a point mass and the electric field of a point charge. [4]

Similarities

(a) BOTH ARE RADIAL FIELDS ✓

(b) Both field strengths are inversely proportional to the square of separation (distance)
$E \propto \frac{1}{d^2}$ ✓

Differences

(a) Unlike electric charges ATTRACT & like electric charges REPEL

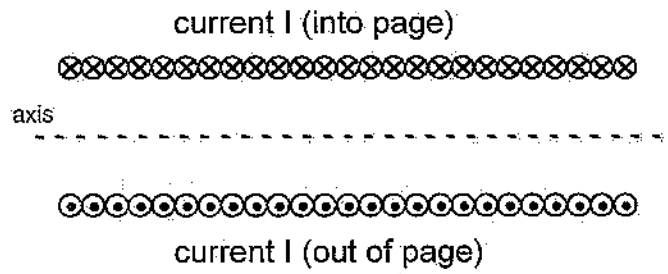
(b) Gravitational field is linked to MASS whereas electric field is linked to CHARGE ✓

OR

gravitational field is ALWAYS ATTRACTIVE whereas electric field can be either ATTRACTIVE OR REPULSIVE ✓

Circle ONLY ONE correct answer for Multiple Choice Questions 2 to 5.

2.



A cross section of a long solenoid that carries current I is shown above.
All of the following statements about the magnetic field **B** inside the solenoid are correct except

A. Magnetic field **B** is directed to the left.
B. The magnitude of **B** is proportional to the current I.
C. The magnitude of **B** is proportional to the number of turns of wire per unit length.
D. The magnitude of **B** is proportional to the distance from the axis of the solenoid. [1]

3. A rod-shaped positively-charged insulator is brought near a conducting sphere, and the sphere is momentarily grounded as shown in Figure 1A.

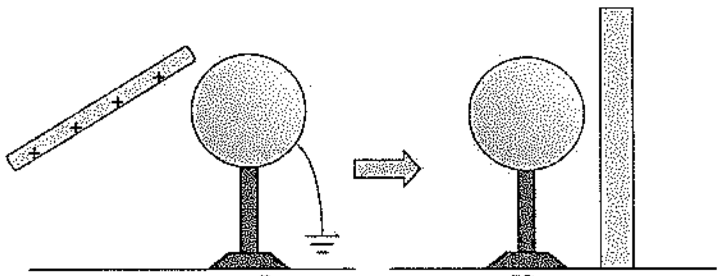


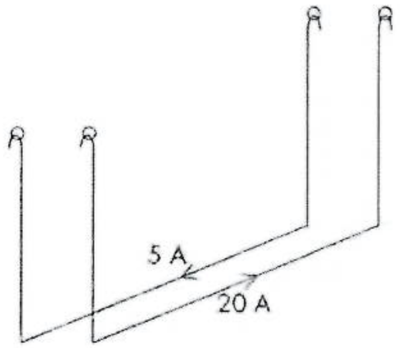
Figure 1A Figure 1B

The conducting sphere is then placed near a nonconducting plane as shown in Figure 1B. Which of the following statements is true for Figure 1B?

A. The conductor has a negative charge and is attracted to the nonconducting plane.
B. The conductor has a negative charge and is not attracted to the nonconducting plane.
C. The conductor has a positive charge and is attracted to the nonconducting plane.
D. The conductor has a positive charge and is not attracted to the nonconducting plane.
E. The conductor has no charge. [1]

wires are identical
swing apart symmetrically

4.



Note: To simplify the diagram, the external circuit has not been shown.

In an experiment to demonstrate the force between two wires carrying current, two identical long parallel wires are suspended from supports in such a way that a force between them will cause them to swing towards one another or away from one another.

A current of 5 A is then passed through wire A and 20 A through wire B.

If the currents flow in opposite directions, what will happen to the wires? [2]

A. A force of repulsion will appear between the wires and the wires will swing apart by equal amounts. √√

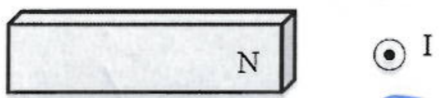
Newton's 3rd Law states action & reaction are equal & opposite and act on different bodies

B. A force of repulsion will appear between the wires and the wires will swing apart, but wire B will swing out furthest.

C. A force of repulsion will appear between the wires and the wires will swing apart, but wire A will swing out furthest.

D. A force of attraction will appear between the wires and they will move towards one another by equal amounts.

5. The diagram shows a stationary conductor carrying current *I* amperes out of the page near to the magnet. In what direction will a magnetic force act on the conductor



A. South B. West C. North D. East [2]

√√

6. **Figure 2** below shows two identical negatively charged conducting spheres. The spheres are tiny and each is suspended from a nylon thread.

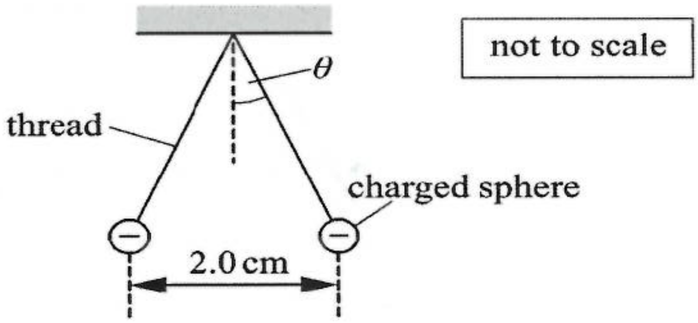


Figure 2

Each sphere has a mass of 6.0×10^{-5} kg and -4.0×10^{-5} C. The separation between the centres of spheres is 2.0 cm.

a) Explain clearly why the spheres are separated as shown in **Figure 2**? [2]

The charges repel each other (as they are LIKE charges) ✓

Each charge is in equilibrium under the action of three forces ✓

a) downward weight b) horizontal Electric force
c) tension in string

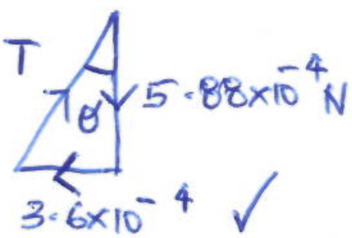
b) Calculate the angle θ made by each thread with the vertical. [4]

$$F = \frac{kq_1q_2}{d^2}$$

$$= \frac{9\times10^{9} \times (4.0 \times 10^{-9})^2}{(0.02)^2}$$

$$= 3.6 \times 10^{-4} \text{ N} \checkmark$$

$$W = mg$$
$$= 6\times10^{-5} \times 9.8$$
$$= 5.88 \times 10^{-4} \text{ N} \checkmark$$



$$\tan\theta = \frac{3.6\times10^{-4}}{5.88\times10^{-4}}$$

$$\theta = 31.5^\circ \checkmark$$

7. **Figure 3** below shows two parallel vertical metal plates connected to a battery.

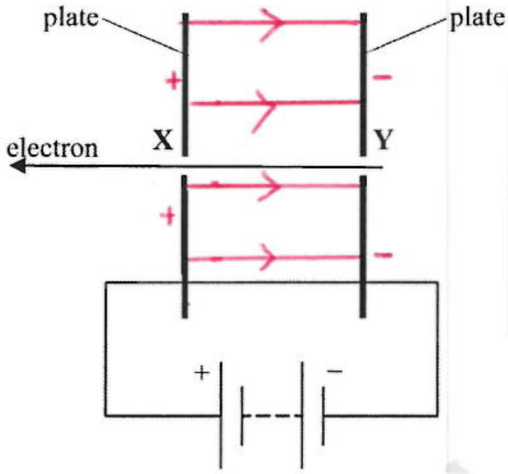


Figure 3

The plates are placed in a vacuum and have a separation of 1.2 cm. The **uniform** electric field strength between the plates is 1500 V m^{-1}. An electron travels through tiny holes **Y** and **X** in the plates. The electron has a horizontal velocity of 5.0 x 10^{6} m s^{-1} when it enters hole **Y**.

a) Draw ~~five~~ four lines on **Figure 3** to represent the electric field between the parallel plates. [2]

parallel & equidistant lines ✓ direction → ✓

b) Calculate the **final speed** of the electron as it leaves hole **X**. [3]

Work done $= F \times d$

$= qEd$

$= 1.6\times10^{-19} \times 1500 \times 1.2\times10^{-2}$

$= 2.88 \times 10^{-18}$ J ✓

$KE_{final} = KE_{initial} - \text{Work done}$ ✓

$\frac{1}{2}(9.11\times10^{-31})v^2 = \frac{1}{2}(9.11\times10^{-31})(5\times10^{6})^2 - (2.88\times10^{-18})$

$v = 4.3\times10^{6}$ ms^{-1} ✓

8. **Figure 4** shows the circular track of a positron (having a positive charge) in a uniform magnetic field.

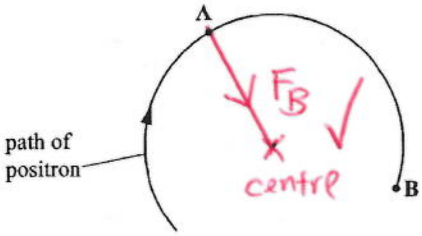


Figure 4

a) At point A, **indicate the direction of the magnetic force** acting on the positron. [1]

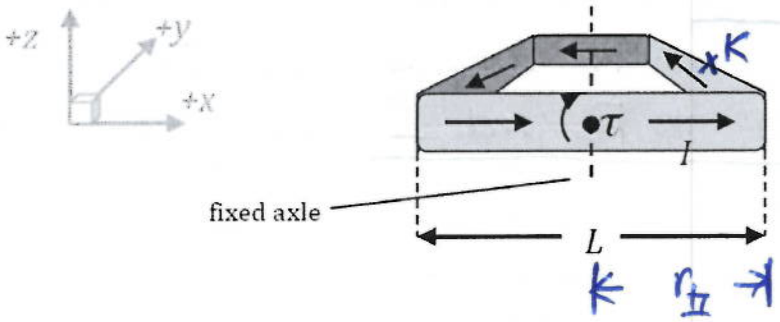
b) State the direction of the uniform magnetic field. [1]

perpendicularly out of page or ⊙ ✓

c) Does the magnetic force change the speed of the positron? Justify. [2]

The force is perpendicular to motion
OR
there is no component of force ✓
in direction of motion
Hence no work done on particle ✓
∴ NO change of speed of positron

9.



A square loop of wire, with sides of length L, is oriented in the x-y plane, and able to rotate in a clockwise direction about an axle along the y-axis and running through the middle of the loop, as shown.

The loop carries a current I in the direction indicated, and a constant magnetic field B is applied so as to create a clockwise torque.

a) State the direction of the magnetic field? Justify. [2]

At wire along K, $I \otimes$

$F \downarrow$

magnetic field $B \rightarrow$ (in $+x$ direction)

using Right Hand Palm Rule

b) Calculate the maximum magnitude of ~~this~~ total torque in terms of L , B and current I ? Show clearly your working. [5]

(i) on 1 arm, $\tau_{max} = F_B \times r_{\perp}$ ✓

$= BIL \times r_{\perp}$ ✓ ($\theta = 90^\circ$, $\sin\theta = 1$)

$= \frac{1}{2} BIL^2$

$B\sin\theta$, B, θ, I, F out of page

(ii) Total $\tau = 2 \times \tau_{1\,arm}$ ✓ as both arms contribute & in ↻ direction to a couple

$= 2 \times BIL(\frac{1}{2}L)$

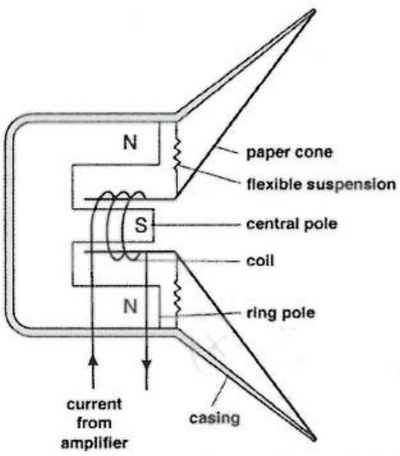
$= BIL^2$ ✓

10. The motor effect is used in a range of applications.

a) What is the motor effect? [2]

It is the force on a current carrying wire when placed in an external magnetic field Force is ⊥ to B and I using Right Hand Palm Rule. ✓

b) A labelled diagram of a loudspeaker is given below.



alternate answer
In loudspeakers, the coil is circular & elongated. The surrounding magnetic field is radial, // to the plane of each turn in coil. The motor effect produces forces ⊥ to plane of the coil but in same dirn for each part of circular turns of coil. Coil then moves in dirn of force, changes dirn with changes in I direction coil motion changes air pressure, create sound waves

A Physics student has written the first statement to explain how a loudspeaker converts electrical signals into sound waves. Complete his explanation. [4]

- An alternating electrical current is applied to the coil in the loudspeaker.

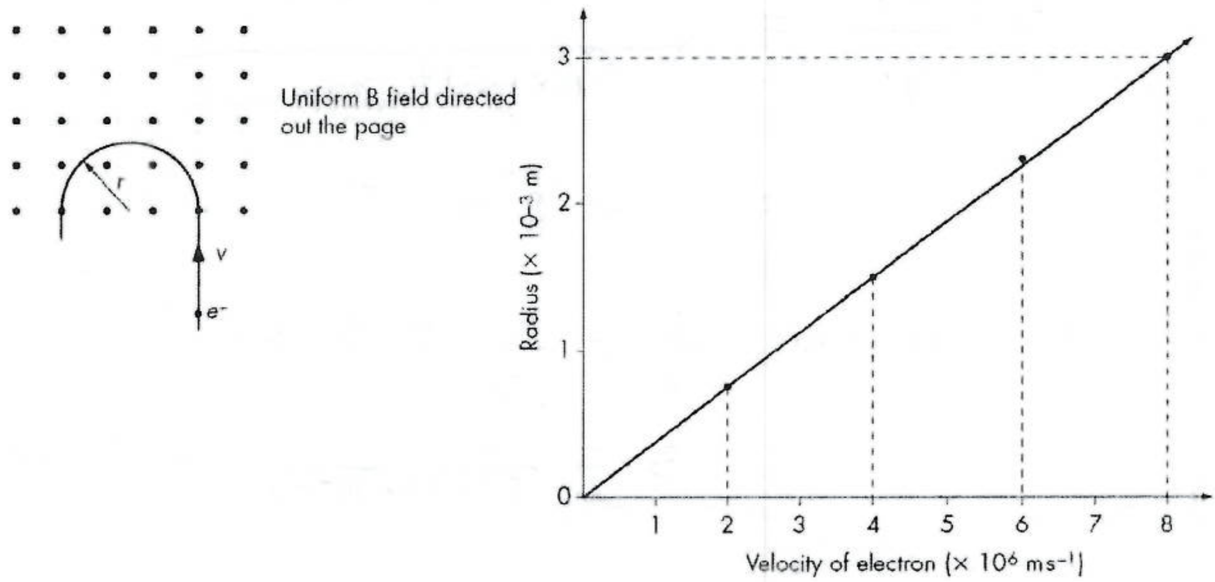
* Because coil is in a magnetic field, I flowing in coil will produce a motor effect. ✓ ✓

* Force moves coil in and out (vibrates) making paper cone / diaphragm move in and out ✓

* Motion of cone / diaphragm changes air pressure creating sound waves ✓

11. A student uses a cathode gun to accelerate **electrons** to different velocities and then measures the radius of curvature of the path the electrons take in a magnetic field.

The electrons enter the magnetic field at right angles to the field. A diagram of the experiment and a graph of the results obtained by the student are shown below.



a) By equating the centripetal force and magnetic force on a charge moving perpendicularly to a magnetic field at a constant speed (v) derive a general expression for the radius of curvature of the charge in the field. [2]

$$F_C = F_B$$

$$\frac{mv^2}{r} = qvB \quad ✓$$

$$\boxed{r = \frac{mv^2}{Bqv}} \quad \text{or} \quad \frac{mv}{Bq} \quad ✓$$

b) Find the gradient of the graph. [2]

$$\text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{3\times10^{-3}}{(8\times10^{6})} = 3.75\times10^{-10}$$

✓ ✓

units s^{-1}

Question 11 (continued)

c) Calculate the strength of the magnetic field used in this experiment. [2]

$$B = \frac{mv}{qr} = \frac{9.1\times10^{-19} \times 8\times10^{6}}{1.6\times10^{-19} \times 0.003}$$ ✓

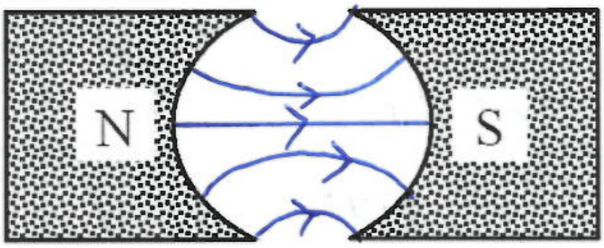
$$= 0.015 \text{ T}$$ ✓

or $\text{gradient} = \frac{r}{V} = \frac{m}{qB} = 3.75\times10^{-10}$

$$B = \frac{m}{q(3.75\times10^{-10})} = 0.015 \text{ T}$$

d) (i) In the diagram below, sketch the magnetic field between the two poles.

[1]



correctly sketch at least 3 lines ✓

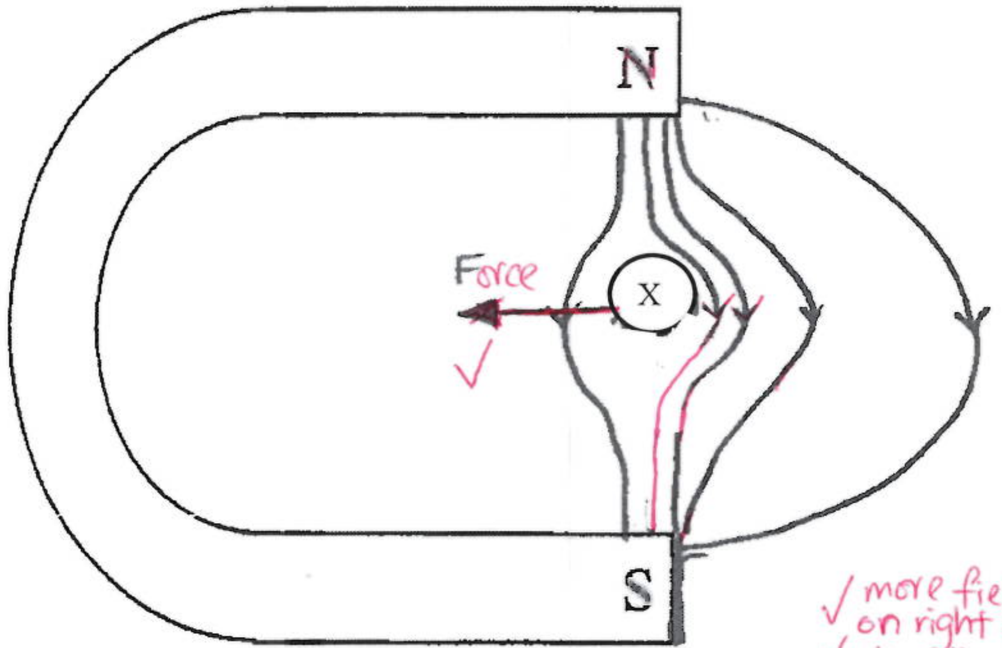
(ii) Identify the reason for using the above field in a motor. [1]

torque is maximised ($\cos 90^\circ = 1$) ✓

also accept curved surfaces provide a radial field so that coil/wire is always aligned with field line; smooth, strong (maximum) torque

12. A wire carrying **an electric current** is placed **between the poles** of a horseshoe magnet. The 6.35 cm long conductor carries a current 4.8 A and the magnetic field between the poles of the magnet has a strength of 0.54 T.

a) On the diagram, carefully illustrate the resultant magnetic field and the direction of the force experienced by the conductor? [3]



✓ more field lines on right of conductor
✓ direction
North out
south IN

b) Determine the magnitude of the force experienced by the conductor wire? [2]

$F_m = BIL$

$= 0.54 \times 4.8 \times \frac{6.35}{100}$ ✓

$= 0.16\ N$ ✓

13. Calculate the force on a small airplane which has acquired a net charge of 1550 μC and moves with a speed of 120 m s^{-1} [3]

a) parallel to the Earth's magnetic field of 5 x 10^{-5} T ?

$F_m = Bqv$ $(\vec{B} \parallel v)$

$= 0$ N ✓

b) perpendicular to the Earth's magnetic field of 5 x 10^{-5} T ?

$F_m = Bqv$

$= 5 \times 10^{-5} \times 1550 \times 10^{-6} \times 120$ ✓

$= 9.3 \times 10^{-6}$ N ✓

END OF TEST