HOLY CROSS COLLEGE
Life to the Full

Western Australian Certificate of Education
ATAR course examination, 2017

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Test 4 - Electromagnetism

Student Number: In figures

Mark: $\overline{}$ / 52 In words

Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: sixty minutes

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens, (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

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

Similarities

(a) Both are radial fields (1)

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

Differences

(a) Electric charges attract or repel, depending on the type of charge. (1)

(b) Gravitational field is always attractive.
Gravitational field is linked to mass, whereas electric field is linked to charge.
Either (1)

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

2.

current I (into page)

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axis

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current I (out of page)

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) [1 mark]

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

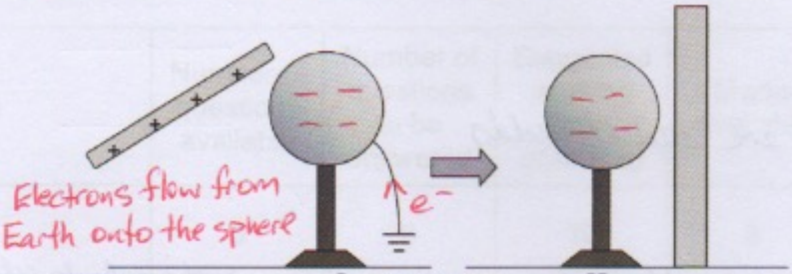
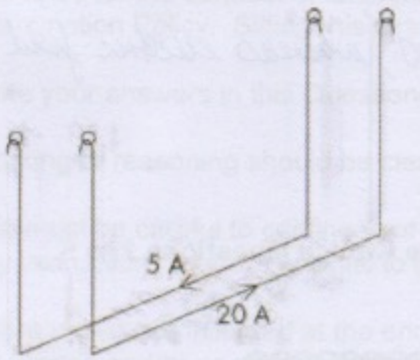


Figure 1A Figure 1B

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

(1)
A. The conductor has a negative charge and is attracted to the non-conducting plane.
B. The conductor has a negative charge and is not attracted to the non-conducting plane.
C. The conductor has a positive charge and is attracted to the non-conducting plane.
D. The conductor has a positive charge and is not attracted to the non-conducting plane.
E. The conductor has no charge. [1 mark]

4.



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

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 wil cause them to swing towards one another or away from one another.

A current of 5.0 A is then passed through wire A and 20.0 A through wire B.

If the currents flow in ***opposite directions***, what will happen to the wires? [1 mark]

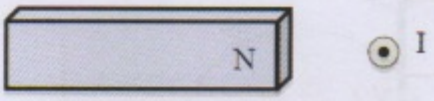
(1)
A. A force of repulsion will appear between the wires and the wires will swing apart by equal amounts.

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 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 [1 mark]

(1)

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

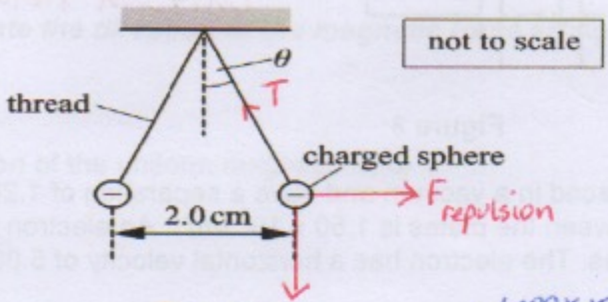


Figure 2

-4.00×10^{-9} C.

Each sphere has a mass of 6.00 x 10^{-5} kg and - 4.00 x 10^{-5} C. The separation between the centres of spheres is 2.00 cm.

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

- Spheres have the same charge. (1)
- Charges repel each other and the system comes to equilibrium with $\Sigma F = 0$. (1)

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

$$F_{rep} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{d^2}$$

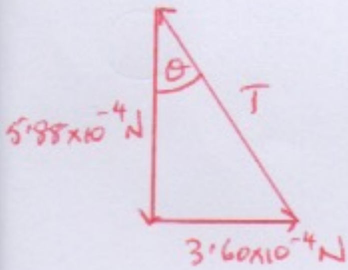
$$= \frac{1}{4\pi(8.85\times10^{-12})} \cdot \frac{(4.00\times10^{-9})^2}{(2.00\times10^{-2})^2} \quad (\tfrac{1}{2})$$

$$= 3.60 \times 10^{-4}\ \text{N}. \quad (1)$$

$$F_w = mg$$

$$= (6.00\times10^{-5})(9.80)$$

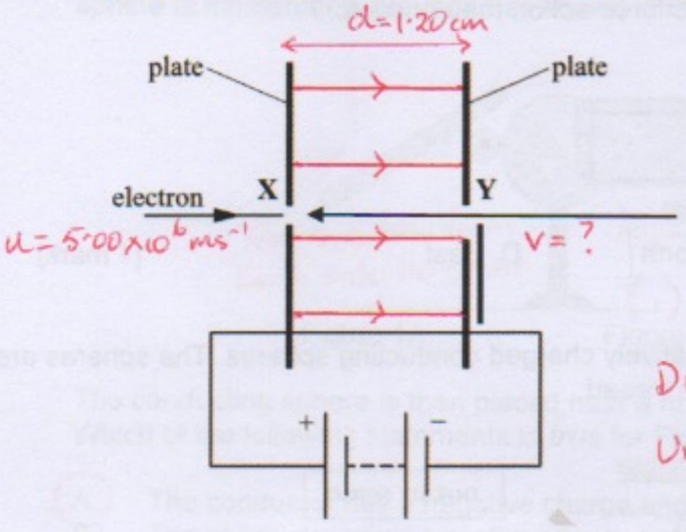
$$= 5.88 \times 10^{-4}\ \text{N} \quad (1)$$



$$\tan\theta = \frac{3.60\times10^{-4}}{5.88\times10^{-4}} \quad (\tfrac{1}{2})$$

$$\Rightarrow \underline{\theta = 31.5^\circ} \quad (1)$$

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



Note: To simplify the diagram, the external circuit for upper plates connected to battery terminals has not been shown.

Figure 3

The plates are placed in a vacuum and have a separation of 1.20 cm. The **uniform** electric field strength between the plates is 1.50×10^3 Vm^{-1}. An electron travels through tiny holes **Y** and **X** in the plates. The electron has a horizontal velocity of 5.00×10^6 ms^{-1} when it enters hole **Y**.

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

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

For parallel plates: $E = \frac{V}{d}$

$\Rightarrow V = Ed$

To accelerate the electrons:

$W = Vq = \Delta E_K$

$\Rightarrow Eqd = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ (1)

$\Rightarrow (1.50\times10^3)(1.60\times10^{-19})(1.20\times10^{-2}) = \frac{1}{2}(9.11\times10^{-31})v^2 - \frac{1}{2}(9.11\times10^{-31})(5.00\times10^6)^2$ (1)

$\Rightarrow v^2 = 3.132\times10^{13}$

$\Rightarrow \underline{v = 5.60\times10^6 \ ms^{-1}}$ (1)

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

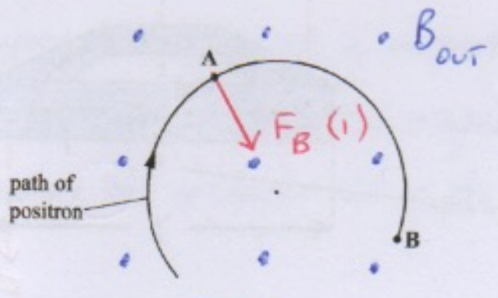


Figure 4

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

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

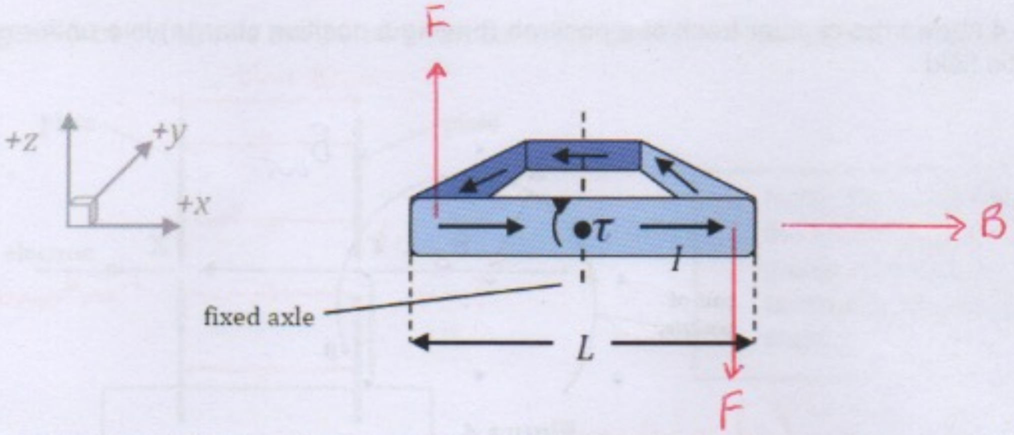
• B_{OUT} (1)

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

• No. (1)

• The force is perpendicular to the motion. (1)

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 your answer. [2 marks]

- B is to the right. (1)
- On RHS, I is into the page and F is down.
  ⇒ B must be to the right for a suitable interaction between B and the magnetic field due to I. (1)

(b) In terms of **L**, **B** and current ***I***, derive an equation for:

(i) the magnitude of the torque on the arm in the +y direction. [3 marks]

Assuming only 1 loop:

$$\tau = Fr$$
$$= I\ell B r \quad (1)$$
$$= ILB\frac{L}{2} \quad (1)$$
$$= \underline{\frac{1}{2}IL^2B} \quad (1)$$

(ii) the maximum magnitude of ***total torque*** exerted. [2 marks]

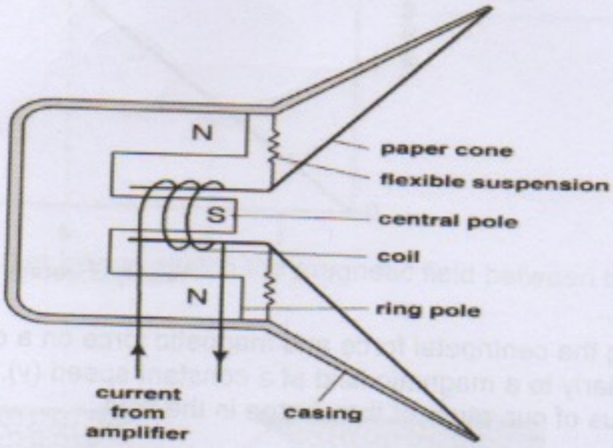
$$\text{Total } \tau = 2 \times \tau(\text{each side}) \quad (1)$$
$$= 2 \times \frac{1}{2}IL^2B$$
$$= \underline{IL^2B} \quad (1)$$

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

(a) What is the "motor effect"? [2 marks]

- A current-carrying wire generates a magnetic field. (1)
- This field interacts with an external magnetic field, producing a force that pushes the conductor out of the external field. (1)

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

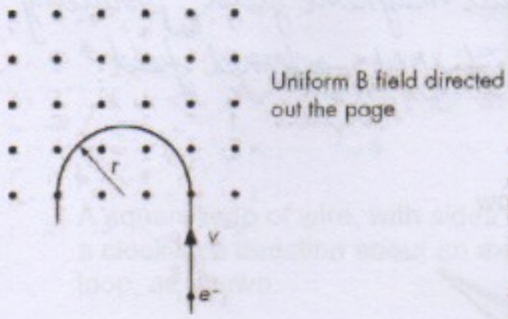


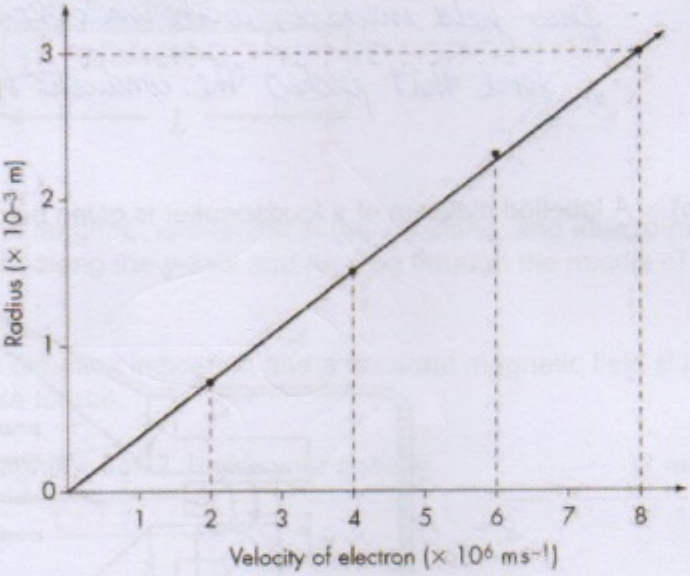
A Physics student has written the first statement to explain how a loudspeaker converts electrical signals into sound waves. Complete her explanation. [4 marks]

- An alternating electrical current is applied to the coil in the loudspeaker.
- The current in the coil produces a magnetic field. (1)
- This field interacts with the external magnetic field, causing the coil to move out of the field. (1)
- The coil is attached to the cone, which moves as the coil moves. (1)
- As the current changes, the motion of the coil and cone changes, causing the cone to push on the air and produce sound. (1)

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 marks]

$$F_B = F_c$$

$$\Rightarrow qvB = \frac{mv^2}{r} \quad (1)$$

$$\Rightarrow r = \frac{mv}{qB} \quad (1)$$

(b) Find the gradient of the graph.

[2 marks]

$$\text{gradient} = \frac{\Delta r}{\Delta v}$$

$$= \frac{(3.0-0.0)\times 10^{-3}}{(8.0-0.0)\times 10^{6}} \quad (1)$$

$$= \underline{3.7\times 10^{-10}\ s} \quad (1)$$

(c) Using your answer to part (b), or otherwise, calculate the strength of the magnetic field used in this experiment. [2 marks]

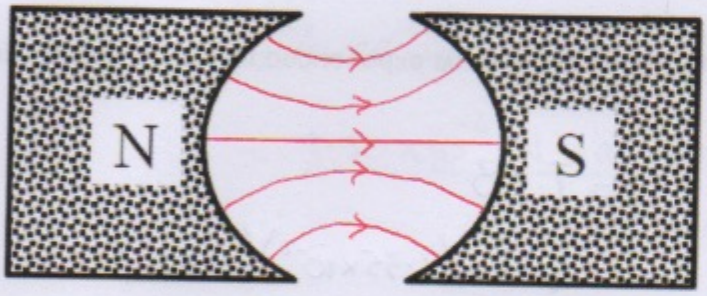
$r = \frac{mv}{qB}$ gradient $= \frac{r}{v} = \frac{m}{qB}$

$\Rightarrow B = \frac{m}{q \times \text{gradient}}$ (1)

$= \frac{(9.11 \times 10^{-31})}{(1.60 \times 10^{-19})(3.7 \times 10^{-10})}$

$= \underline{1.5 \times 10^{-2}\ T}$ (1)

(d) (i) In the diagram below, sketch the magnetic field between the two poles. [1 mark]



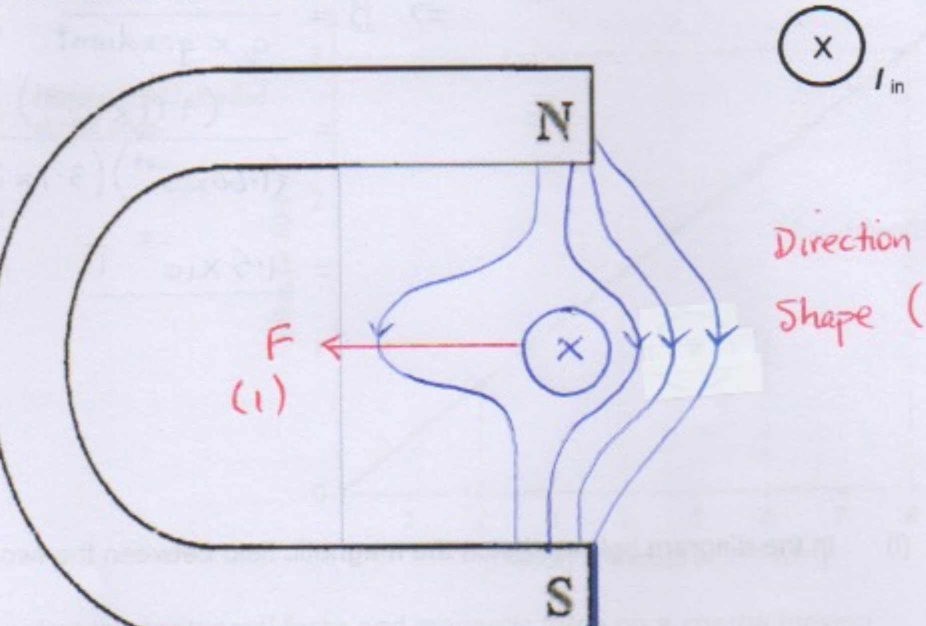
Direction ($\frac{1}{2}$)
Shape ($\frac{1}{2}$)

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

- Consistent maximum torque. ($\frac{1}{2}$)
- The sides of the coil cut the magnetic field continuously at 90° as it rotates. ($\frac{1}{2}$)

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 4.80 A and the magnetic field between the poles of the magnet has a strength of 0.540 T.

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



Direction (1)

Shape (1)

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

$F = I\ell B$

$= (4.80)(6.35\times10^{-2})(0.540)$ (1)

$= \underline{0.165\ N}$ (1)

13. Calculate the force on a small airplane, which has acquired a nett charge of 1.55×10^3 μC and moves with a speed of 1.20×10^2 ms^{-1}:

[3 marks]

(a) parallel to the Earth's magnetic field of 5.00×10^{-5} T.

$$F = qvB$$
$$= 0 \text{ N} \quad (1) \quad \text{(since the plane moves parallel to B)}$$

(b) perpendicular to the Earth's magnetic field of 5.00×10^{-5} T.

$$F = qvB$$
$$= (1.55 \times 10^{-3})(1.20 \times 10^{2})(5.00 \times 10^{-5}) \quad (1)$$
$$= 9.30 \times 10^{-6} \text{ N}$$ at right angles to B and the direction of movement. (1)