# ALL SAINTS' COLLEGE

**Ewing Avenue, Bull Creek, Western Australia**

Year 12 Physics ATAR | Electromagnetism | 2017

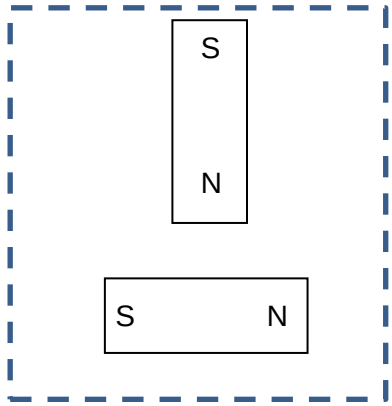
Time allowed: 50 minutes
Total marks available: 50
Show calculation answers to 3 significant figures

Student Name: **SOLUTIONS**

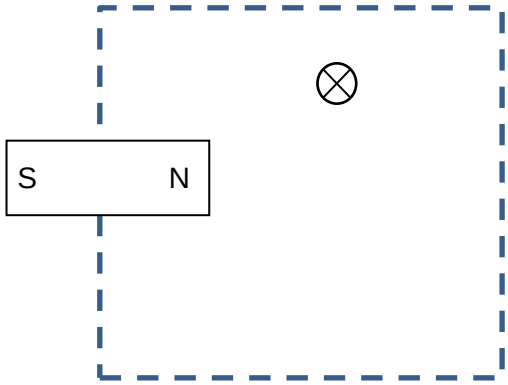
**Question 1** **(4 marks)**

Consider the areas identified by the hatched boxes in the diagrams below. Within each box sketch the **overall** magnetic field with **at least 6** magnetic field lines. You can assume that the magnets and wires are fixed in position and the Earth's magnetic field is negligible.

a)

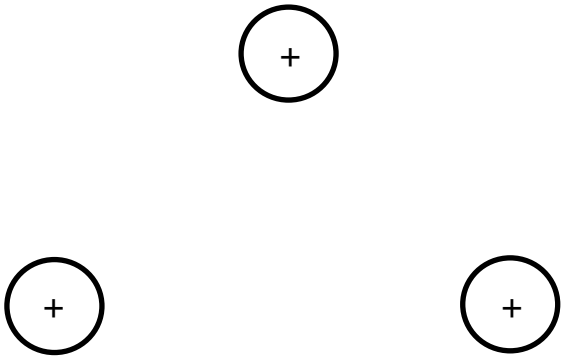



b)




**Question 2** **(3 marks)**

Draw the electric field between the three positively charged spheres shown below. You must draw **at least 6** electric field lines.

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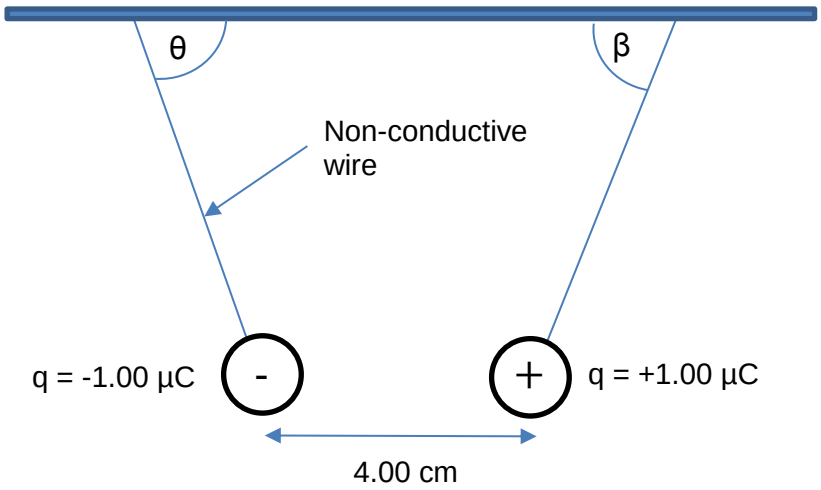
**Question 3** **(9 marks)**

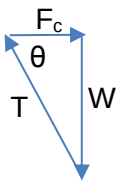
As shown in the diagram below, two small, electrically charged spheres, hang from a roof by non-conductive wires. Each sphere has a mass of 5.00 kg and the distance between the centre of each sphere is 4.00 cm. The charge of the left sphere is -1.00 μC and the charge of the right sphere is +1.00 μC.




(a) Calculate the number of electrons required to produce a charge of -1.00 μC. (2 marks)

| Description | Marks |
|---|---|
| $n(e^-) = \frac{total\ charge}{charge\ of\ electron}$ $= \frac{-1.00\times10^{-6}}{-1.60\times10^{-19}}$ | 1 |
| $n(e^-) = 6.25\times10^{12}\ electrons$ | 1 |
| **Total** | 2 |

(b) Calculate the angle $\theta$ that the negative sphere makes with the horizontal. (4 marks)

| Description | Marks |
|---|---|
| $F_c = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ $= \frac{1}{4\pi\times8.85\times10^{-12}}\frac{1.00\times10^{-6}\times1.00\times10^{-6}}{(0.04)^2}$ $F_c = 5.62\ N$ | 1-2 |
| $W = 5.00\times9.8 = 49\ N$ | 1 |
| As sum of the forces are zero $\theta = \tan^{-1}\left(\frac{49}{5.62}\right) = 83.5^o$   | 1 |
| **Total** | 4 |

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(c) Both spheres are recharged so that the left sphere has a charge of $-0.500\ \mu C$ and the right sphere has a charge of $+2.00\ \mu C$. Would the angle that the left sphere makes with the horizontal (θ) now be greater than, less than, or equal to the angle that the right sphere makes with the horizontal (β). Circle your answer and provide an explanation. (3 marks)

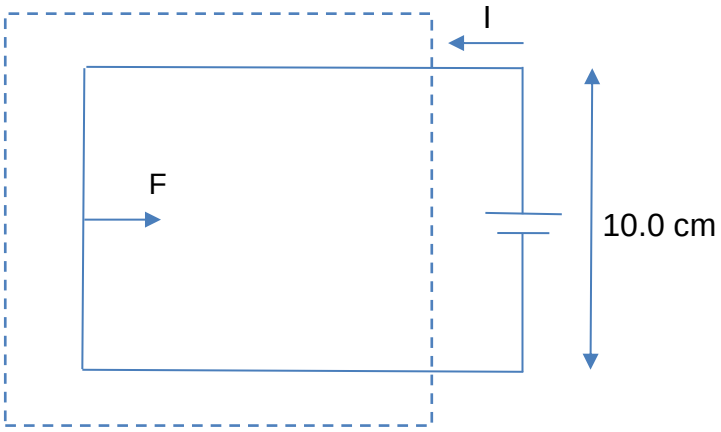
greater less equal

Explanation

| Description | Marks |
|---|---|
| Equal | 1 |
| The electro-static force on each sphere is the same (Newton's 3rd Law)<br>As the electro-static force is the same on each sphere and the weights are same the angles are the same. | 1-2 |
| **Total** | 3 |

**Question 4** **(3 marks)**

A rectangular wire loop is placed into a uniform magnetic field which acts within the boundary of the broken line shown in the diagram. The plane of the loop is perpendicular to the magnetic field. The wire carries a current I of 2.50 A which produces a force of 3.20 N to the right on the loop.




(a) Indicate the direction of the magnetic field on the diagram. (1 mark)

(b) Calculate the magnitude of the magnetic field strength. (2 marks)

| Description | Marks |
|---|---|
| (a) Into the page | 1 |
| (b)<br>$F = ILB$<br>$B = \frac{F}{IL}$<br>$= \frac{3.20}{0.250 \times 0.1}$ | 1 |
| $B = 12.8\ T$ | 1 |
| **Total** | 3 |

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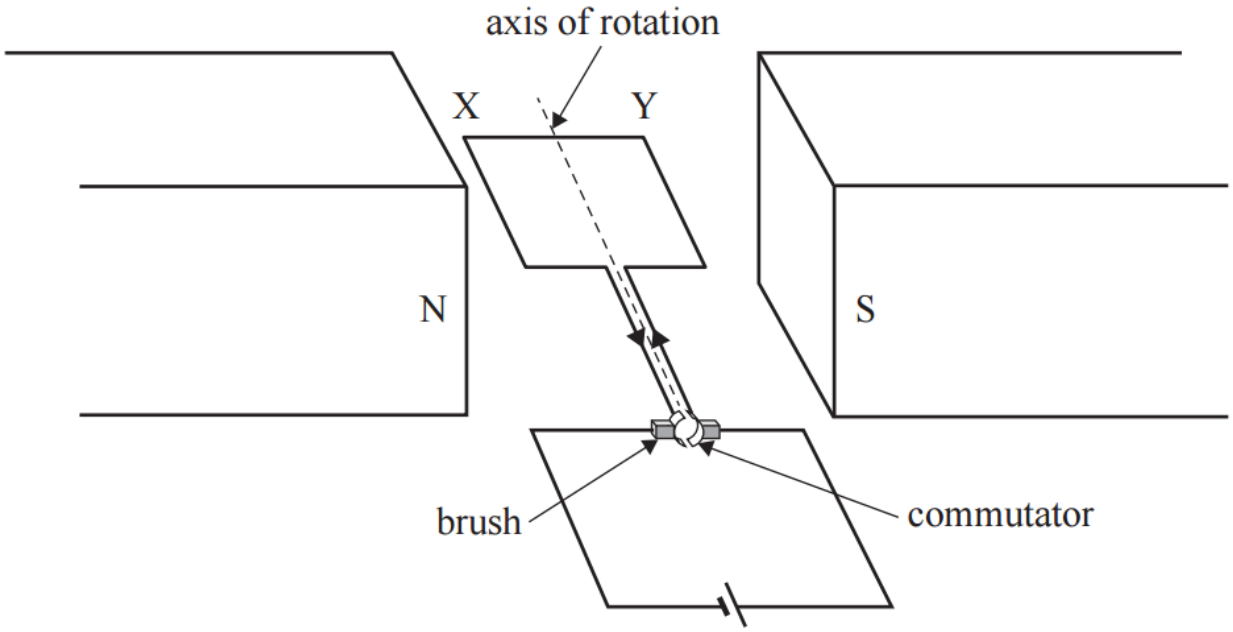
**Question 5** **(11 marks)**

The diagram shows a small DC motor connected to a battery. A uniform magnetic field of strength 0.500 T exists between the magnetic poles. The coil has a length (*l*) of 8.00 cm, a width (w) of 5.00 cm and 80 turns of wire. The coil draws a current of 3.85 A from the battery.




(a) Indicate the direction of rotation of the coil on the diagram. (1 mark)

(b) Explain the function of the commutator in a DC motor. (2 marks)

| Description | Marks |
|---|---|
| (a) Clockwise | 1 |
| (b)<br>Allows current to flow from brush to coil.<br>Reverses the direction of current in the coil every 180 deg. | 1-2 |
| **Total** | 3 |

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(c) Calculate the maximum torque produced by the motor. (2 marks)

| Description | Marks |
|---|---|
| $T_{max} = INBA$<br>$= 3.85 \times 80 \times 0.500 \times (0.08 \times 0.05)$ | 1 |
| $= 0.616\ Nm$ | 1 |
| **Total** | 2 |

(d) Calculate the rotation angle of the coil from the horizontal if the torque produced by the motor is 40.0 % of the maximum torque. (3 marks)

| Description | Marks |
|---|---|
| $T = T_{max} \cos\theta$<br>$\cos\theta = \frac{T}{T_{max}}$<br>$= 0.4$ | 1-2 |
| $\theta = \cos^{-1}(0.4) = 66.4^{o}$<br><br>Note: angle used for torque calculation is between lever arm and force and equals 90 – rotation angle | 1 |
| **Total** | 3 |

(e) Explain why the torque produced by the motor varies as the coil rotates. (3 marks)

| Description | Marks |
|---|---|
| As the coil rotates the force stays the same and the component of the radius perpendicular to the force ($r_{\perp}$) changes length.<br>As $T = r_{\perp}F$ the change in $r_{\perp}$ changes T. | 1-3 |
| Accept a similar argument for the angle between the force and radius r. | |
| **Total** | 3 |

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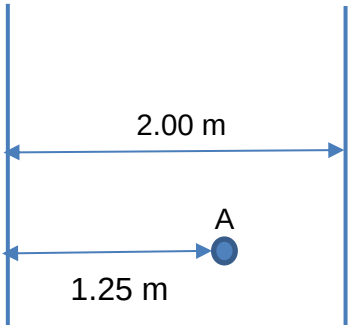
**Question 6** **(3 marks)**

Two long, parallel wires carry current in the direction shown. If the current in Wire 1 ($I_1$) is 7.00 A and the current in Wire 2 ($I_2$) is 5.00 A, calculate the magnitude of the magnetic flux density at A.

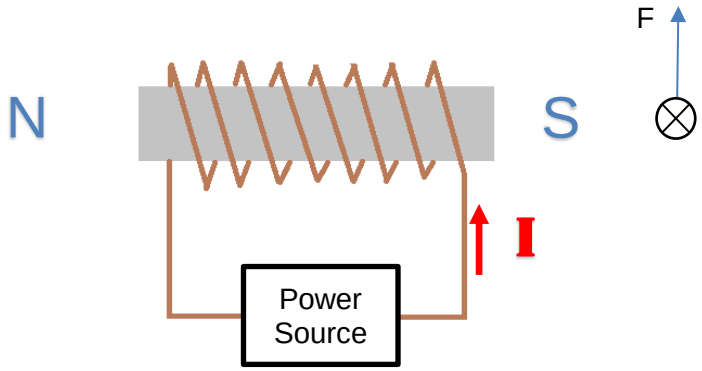



| Description | Marks |
|---|---|
| $B_1 = \frac{\mu_0}{2\pi}\frac{I_1}{r_1}$<br>$= \frac{4\pi\times10^{-7}}{2\pi}\frac{7}{1.25}$<br>$= 1.12\times10^{-6}\ T$ out of the page | 1 |
| $B_2 = \frac{\mu_0}{2\pi}\frac{I_2}{r_2}$<br>$= \frac{4\pi\times10^{-7}}{2\pi}\frac{5}{0.75}$<br>$= 1.33\times10^{-6}\ T$ into the page | 1 |
| $B_T = 1.33\times10^{-6} - 1.12\times10^{-6}$<br>$= 2.13\times10^{-7}\ T$<br>The magnitude of $B_T$ is $2.13\times10^{-7}\ T$ | 1 |
| **Total** | 3 |

, $I_2$

**Question 7** **(4 marks)**

The diagram below shows a wire carrying current into the page and an electromagnet connected to a power source. The wire feels a force F in the upwards direction.




On the diagram above

(a) indicate the effective north and south poles of the electromagnet. (1 mark)

(b) draw the magnetic field produced by the electromagnet using **at least 4** magnetic field lines. (2 marks)

(c) indicate the direction of the conventional current flow through the coil. (1 mark)

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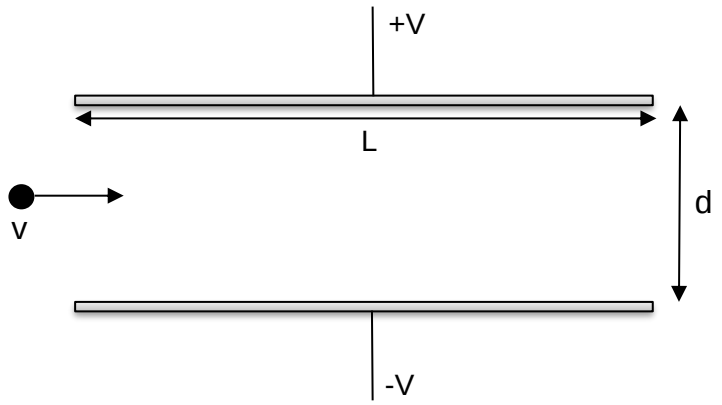
**Question 8** **(13 marks)**

Ink drop generators in inkjet printers can 'fire' over 100,000 droplets per second. Some of these droplets are charged and can be steered to different points on the paper by electric fields. The diagram shows an ink droplet of mass m and charge q entering the deflecting plates at speed v. The plates are a distance d apart, have a length L and the potential difference between them is V. The top plate is positively charged and the bottom plate is negatively charged.




(a) Draw the electric field lines between the plates. You must draw **at least 4** electric field lines. (2 marks)

(b) Describe the motion of the charged droplet

(i) as it moves between the deflecting plates. (2 marks)

(ii) as it moves beyond them. (1 mark)

| Description | Marks |
|---|---|
| (a)<br>Four lines<br>From positive plate to the negative plate. | 1-2 |
| (b) (i)<br>The charge will move towards the negative plate<br>The shape of the path will be a parabola (curve) | 1-2 |
| (b) (ii)<br>The charge will continue to move in a straight line at the angle at which is moves the plates. | 1 |
| **Total** | 5 |

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(c) Show that the vertical acceleration of the droplet is $a = \frac{qV}{md}$. You can assume that gravitational forces are negligible. You must refer to the equations stated on the data sheet in your derivation. (3 marks)

| Description | Marks |
|---|---|
| Data sheet gives $E = \frac{F}{q} = \frac{V}{d}$<br>The electric force on the charge is derived as<br>$F = qE$<br>or<br>$F = \frac{qV}{d}$<br>Using Newton's second law<br>$F = ma$ (data sheet)<br>$\frac{qV}{d} = ma$<br>to give<br>$a = \frac{qV}{md}$ | 1-3 |
| **Total** | 3 |

(d) Calculate the **speed** of the droplet once it has been accelerated through a vertical distance of 3.00 mm by the charged plates. Assume that the speed that the droplet enters the electric field is 2.00 x $10^3$ m $s^{-1}$ to the right, the charge on the droplet is 0.200 C and the mass of the droplet is 0.100 g. The potential difference between the plates is 2.00 kV and the plate separation distance is 2.00 cm. You must consider both velocity components.

(5 marks)

| Description | Marks |
|---|---|
| The vertical acceleration of the droplet towards the neutral plate is given by<br>$a = \frac{qV}{md} = \frac{0.200 \times 2.00 \times 10^3}{0.1 \times 10^{-3} \times 0.02}$<br>$= 2.00 \times 10^8\ m/s^2$ | 1-2 |
| Vertical velocity<br>$v^2 = u^2 + 2as$<br>$v = \sqrt{2as}$<br>$= \sqrt{2 \times 2.00 \times 10^8 \times 3 \times 10^{-3}}$<br>$= 1095\ m\ s^{-1}$ | 1-2 |
| Particle speed<br>$v = \sqrt{v_v^2 + v_h^2}$<br>$= \sqrt{2000^2 + 1095^2} = 2280\ m\ s^{-1}$<br><br>Note must refer to 2D nature of problem if using equations of motion otherwise -2 for concept error. **It is possible to get the correct answer by mistake.** | 1 |
| **Total** | 5 |

Note can also be solved by: $W = Vq = \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

But the Potential difference is only $\frac{3\ mm}{2\ cm} \times 2000\ V = 300\ V$

If 2000 V is used this gives 3464 m $s^{-1}$ (subtract 2 marks for concept error)

If 300 v is used $Vq = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$300 \times 0.2 = \frac{1}{2}0.1 \times 10^{-3}v^2 - \frac{1}{2}0.1 \times 10^{-3}2000^2$

$v = 2280\ m\ s^{-1}$

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