ALL SAINTS' COLLEGE

Ewing Avenue, Bull Creek, Western Australia

Year 12 Physics ATAR   Electromagnetism Test 1   2016

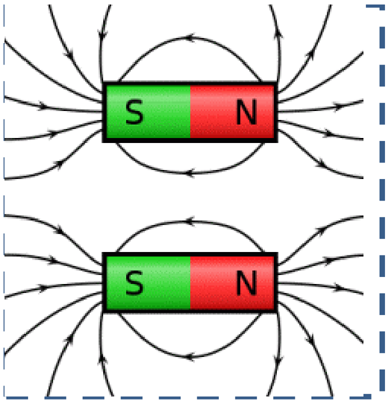
Time allowed: 50 minutes Total marks available: 50 Show calculation answers to 3 significant figures

Student Name:________________________

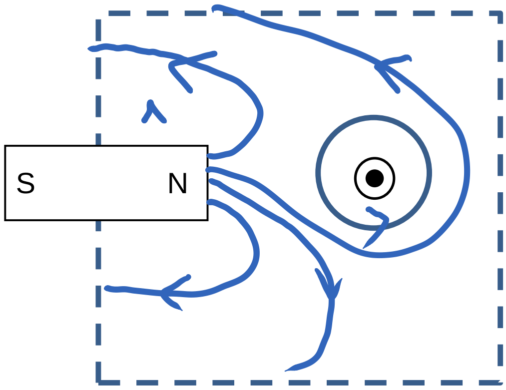
Question 1 **(4 marks)**

Consider the areas identified by the hatched boxes in the diagrams below. Within each box sketch the **overall** magnetic field with at least 5 magnetic field lines. You can assume that the magnets and wires are fixed in position and the Earth's magnetic field is negligible.

a)

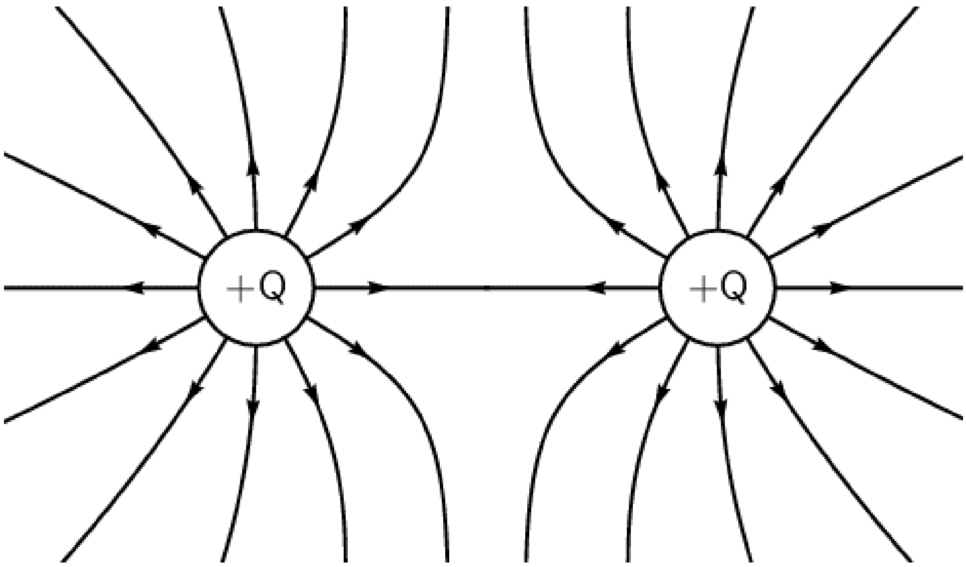


b)



Question 2 **(2 marks)**

Draw the electric field between the two positively charged spheres shown below. You must use at least 10 electric field lines.



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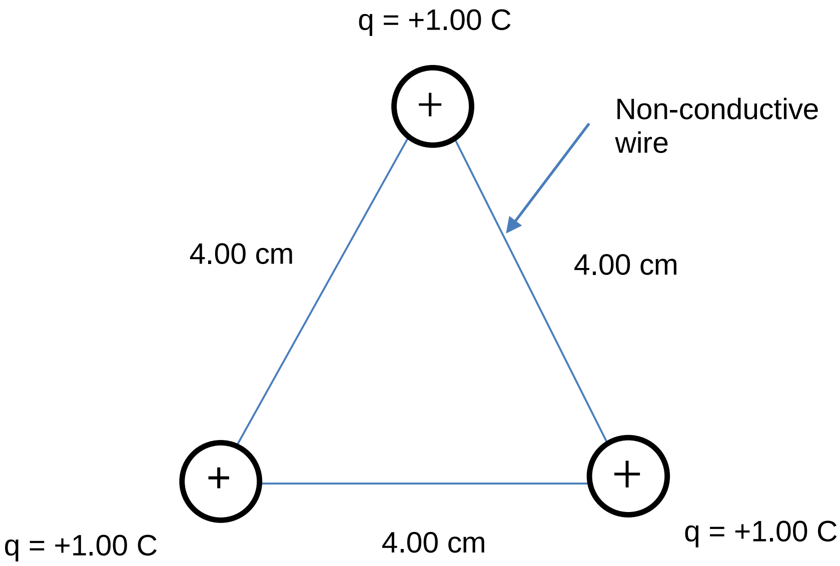
Question 3 **(6 marks)**

As shown in the diagram below three small, electrically charged spheres are joined by non-conductive wire. The distance between the centre of each sphere is 4.00 cm and the charge of each sphere is 1.00 C. You may ignore gravitational force in this question.



(a) Calculate the tension in the non-conductive wire. (4 marks)

Description	Marks
Force between two charged spheres $F_q = \frac{1}{4\pi\varepsilon_o} \times \frac{q_1 q_2}{r^2}$ $= \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{1 \times 1}{0.04^2}$	1
$F_q = 5.62 \times 10^{12} N$	1
The tension in the wire between two spheres directly opposes the force applied by the two spheres. They act in equal and opposite directions on a charge. Therefore $T = F_q$. A similar explanation would also be suitable.	1-2
Total	**4**

(b) If one the spheres had a charge of +2.00 C instead of +1.00 C would the spheres begin to move? Circle your answer and provide an explanation below. (2 marks)

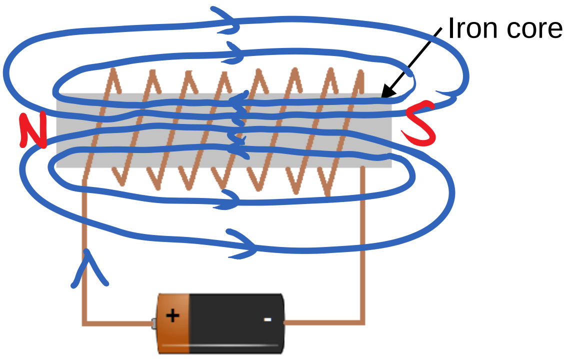
They will move They will not move

Explanation

Description	Marks
They won’t move	1
Although the force between the charges will increase the tension in the non-conductive wires will increase to oppose it. The net force on the each charge will continue to be zero and the wires won’t move.	1
Total	**2**

Question 4 **(6 marks)**

The diagram below shows an electromagnet powered by a DC battery.



(a) On the diagram

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

ii. draw the magnetic field produced by the electromagnet. (2 marks)

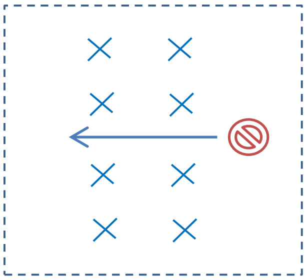
iii. indicate the effective north and south poles of the electromagnet. (1 mark)

(b) Explain why adding an iron core increases the strength of an electromagnet. (2 marks)

Description	Marks
The magnetic field applied by the coil aligns the causes the domains of the iron core to align with the field of the coil. This magnetises the iron core and which adds to the magnetic field produced by the coil.	1-2
Total	**2**

Question 5 **(4 marks)**

A beta particle (e^-) enters a magnetic field which is perpendicular to its velocity and experiences a force of 1.08×10^{-13} N upwards. It moves at 2.10×10^{6} m s^{-1} to the left as indicated.



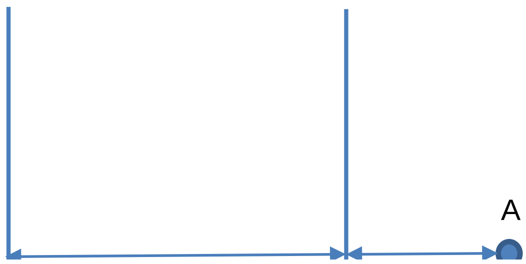
(a) Indicate the direction of the magnetic field by sketching at least 5 field lines within the hatched box on the diagram. (1 mark)

(b) Calculate the magnitude of the magnetic flux density perpendicular to the motion of the beta particle. Give you answer in mT. (3 marks)

Description	Marks
$F = qvB$ $B = \frac{F}{qv} = \frac{1.08\times10^{-13}}{1.60\times10^{-19}\times2.10\times10^{6}}$	1
$B = 0.321$	1
$B = 321\ mT$	1
Total	**3**

Question 6 **(4 marks)**

Two long, parallel wires are carry current in the direction shown. If the magnetic flux density at A is $3.20\mu T$, and the current in Wire 1 (I_1) is 7.00 A, calculate the current in Wire 2 (I_2).

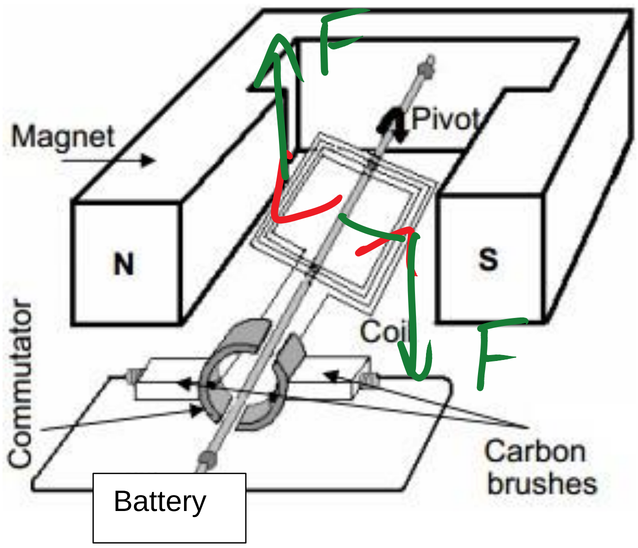


Description	Marks
As the flux due to both wires acts in the same direction at A $B_T = B_1 + B_2$ $B_T = \frac{\mu_0}{2\pi} \times \frac{I}{r_1} + \frac{\mu_0}{2\pi} \times \frac{I}{r_2}$ $3.20 \times 10^{-6} = 2 \times 10^{-7} \times \frac{7}{2.5} + 2 \times 10^{-7} \times \frac{I_2}{0.5}$ $3.20 \times 10^{-6} = 5.60 \times 10^{-7} + 2 \times 10^{-7} \times \frac{I_2}{0.5}$ $2 \times 10^{-7} \times \frac{I_2}{0.5} = 2.64 \times 10^{-6}$ $I_2 = \frac{0.5}{2\times10^{-7}} 2.64 \times 10^{-6}$	1-3
$I = 6.60\ A$	1
Total	**4**

Question 7 **(13 marks)**

The diagram shows a small DC motor connected via a commutator and carbon brushes to a DC battery. The direction of rotation is clockwise as shown. A uniform magnetic field exists between the magnetic poles and the maximum torque produced by the coil is 3.00 N m clockwise. The coil has a length (*l*) of 8.00 cm and width (w) of 3.50 cm and 150 turns of wire. The coil draws a current of 2.85 A from the battery.

i



(a) Indicate the direction of current in the length of the coil next to the north pole by placing an arrow on the diagram. (1 mark)

(b) Explain why DC motors have a commutator and brush arrangement. (3 marks)

Description	Marks
The brush and commutator arrangement allows current to flow from the power source, though the brush, into the commutator and through the coil while the coil rotates.	1
Having the two halves of the commutator (split rings) allows the current in the coil to reverse every half turn.	1
The reversal of current changes the direction of electromagnetic force applied to a side of the coil which allows torque to be applied in one direction.	1
Total	**3**

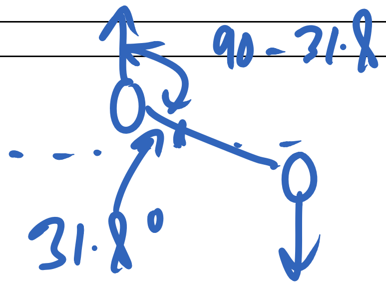
(c) Calculate the magnetic flux density of the magnet. (3 marks)

Description	Marks
$T_{max} = INBA$ $B = \frac{T_{max}}{INA}$ $B = \frac{3}{2.85\times150\times(0.8\times0.35)}$	1-2
$B = 2.51\ T$	1
Total	3

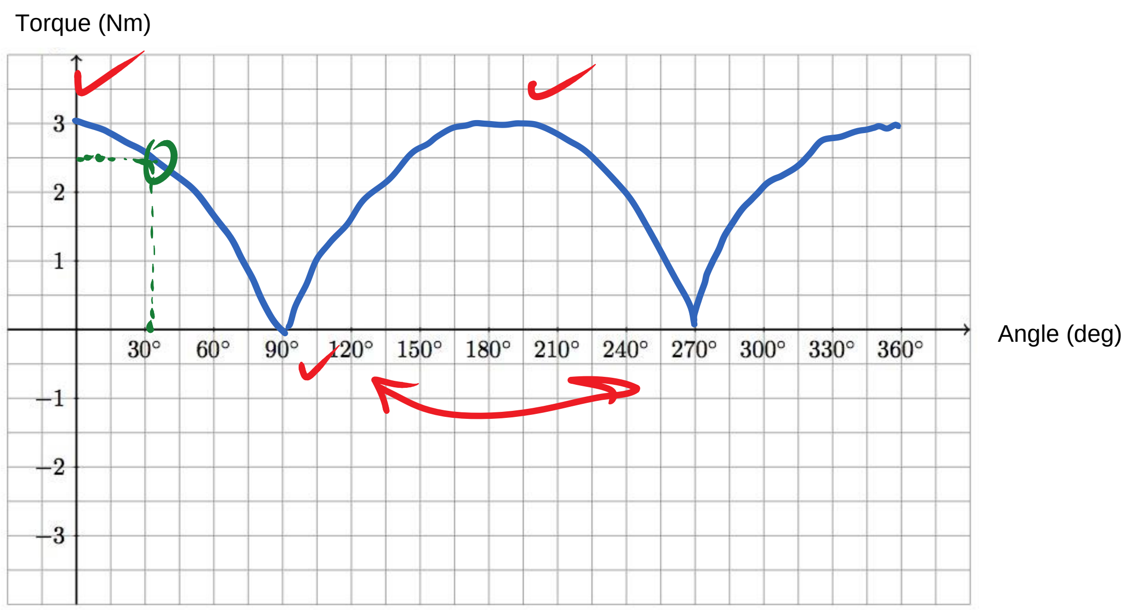
$\tau = 2rF$

(d) Calculate the rotation angle of the coil from the horizontal if the torque produced by the motor is 85.0 % of the maximum torque. (3 marks)

Description	Marks
$T = 0.85 \times T_{max} = T_{max} \times \cos\theta$ $\cos\theta = 0.85$ $\theta = \cos^{-1}(0.85)$	1-2
$\theta = 31.8^{o}$	1
Total	3

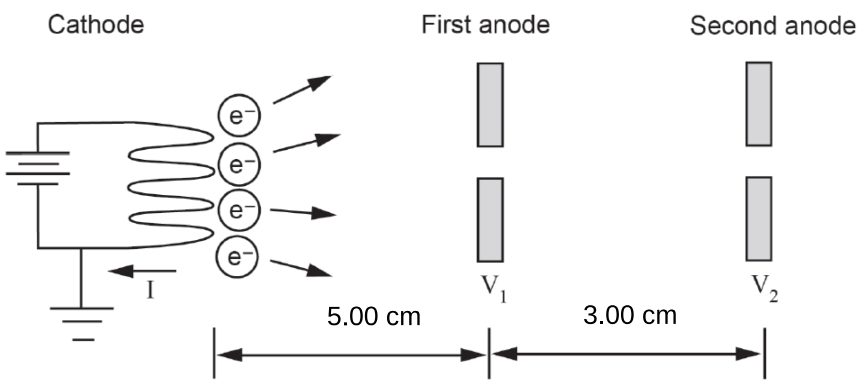


(e) On the graph paper below sketch the variation of torque produced by the coil when it rotates through one turn (0 to 360°) from being horizontal in the magnetic field. (3 marks)



Question 8 **(6 marks)**

An electron gun is a very important component of many devices, including particle accelerators, electron microscopes and cathode-ray tubes. A schematic diagram of an electron gun is shown below. The voltage at the cathode is zero.



Assume the initial velocity of a thermal electron as it is emitted by the cathode is zero. The anode voltages are V_1= 1500 V and V_2 = 4500 V and the distances between the cathode and anodes are as shown above.

(a) Calculate the velocity in m s^{-1} of the thermal electrons as they pass through the first anode. (3 marks)

Description	Marks
Work done on the electron by the first anode $W = qV$ $= 1.60 \times 10^{-19} \times 1500$ $= 2.40 \times 10^{-16}\ J$	1
$W = \Delta E_k$ $2.40 \times 10^{-16} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$ $v = \sqrt{\frac{2 \times 2.40 \times 10^{-16}}{9.11 \times 10^{-31}}}$ $v = 2.30 \times 10^{7}\ m\ s^{-1}$	1-2
Total	**3**

(b) Calculate the electrical work done by the electric field in moving one electron from the first anode to the second anode. (3 marks)

Description	Marks
$\Delta V = V_2 - V_1$ $\Delta V = 4500 - 1500$ $= 3000\ V$	1
$W = q\Delta V$ $= 1.6 \times 10^{-19} \times 3000$	1
$W = 4.80 \times 10^{-16}\ J$	1
Total	**3**

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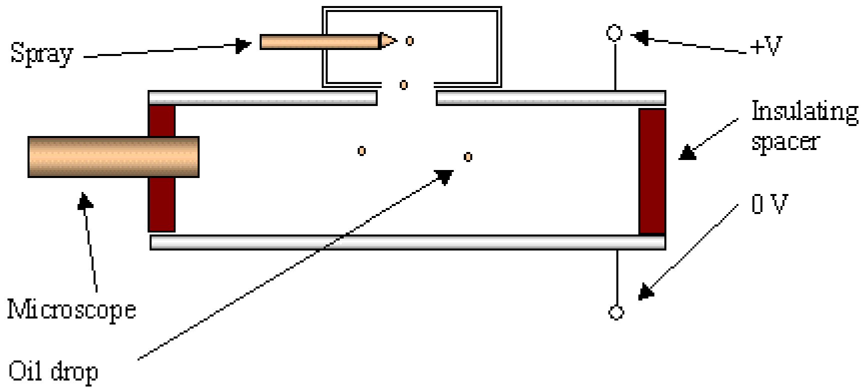
Question 9 **(5 marks)**

The Miliken oil drop experiment involved introducing charged oil drops into a space between two charged horizontal plates as shown below. He observed the oil drops using a microscope and noticed that some of the oil drops were held stationary by the electric field working against the force of gravity.



(a) If the potential difference between the plates is 7.00 kV and the plate separation is 40.0 mm, calculate electric field strength between the plates. (2 marks)

Description	Marks
$E = \frac{V}{d} = \frac{7000}{0.04}$	1
$E = 1.75 \times 10^5\ V\ m^{-1}$	1
Total	**2**

(b) If the mass of a stationary oil drop is 530 mg, calculate the charge on the oil drop. (3 marks)

Description	Marks
Gravitational force equals electric force $F_e = F_g$ $= 530 \times 10^{-6} \times 9.80$ $= 5.194 \times 10^{-3}\ N$	1
Force from electric field $F_e = qE$ $q = \frac{F_e}{E}$ $= \frac{5.194\times10^{-3}}{1.75\times10^5}$	1
$q = 3.00 \times 10^{-8} C$	1
Total	**3**