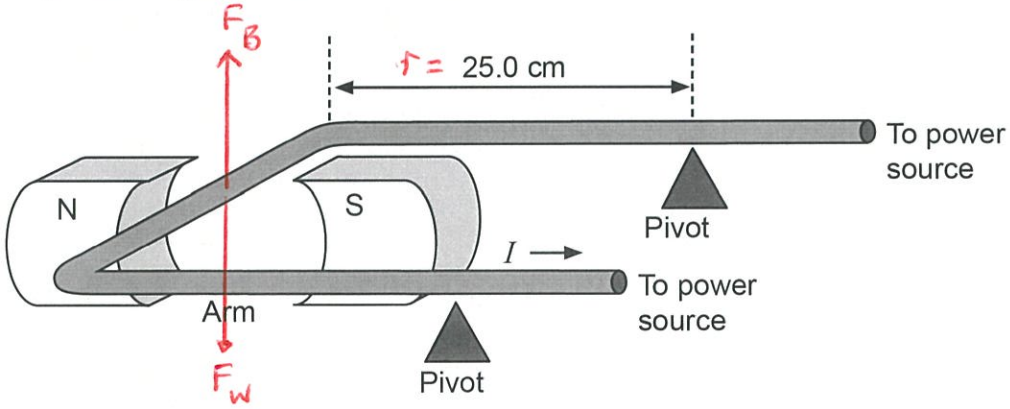
**YEAR 12 PHYSICS**
**ASSIGNMENT 4 - ELECTROMAGNETISM**

Name: SOLUTIONS Mark: ___/53

1. A wire carrying a current of 1.68 A has $8.75 \times 10^{-2}$ m of its length passed through a $4.44 \times 10^{-2}$ T magnetic field at right angles to it as shown below. The circuit is part of an apparatus that is able to measure the torque produced by the current passing through the magnetic field.




Given that the arm has a length of 25.0 cm from the wire in the field to the pivot point, calculate the torque produced. Include direction with your answer. (4 marks)

$M = F_B \uparrow$

$= IlB \uparrow$ (since $F_B = IlB$) (1)

$= (1.68)(8.75 \times 10^{-2})(4.44 \times 10^{-2})(0.250)$ (1)

$= 1.63 \times 10^{-3}$ Nm

Answer $1.63 \times 10^{-3}$ Nm (1)

Direction clockwise (up) (1)

2. (a) Draw an arrow indicating the direction of the magnetic field at point P due to the magnet shown. (2 marks)



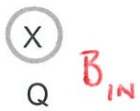
Field - horizontal line (1)
Direction - to the right (1)

(b) Describe the effect on a positively-charged particle travelling into the page at P. (2 marks)

- Experiences a force. (1)
- Down the page. (1)

3. (a) Draw an arrow indicating the direction of the magnetic field at point P due to the current-carrying wire Q as shown. (2 marks)

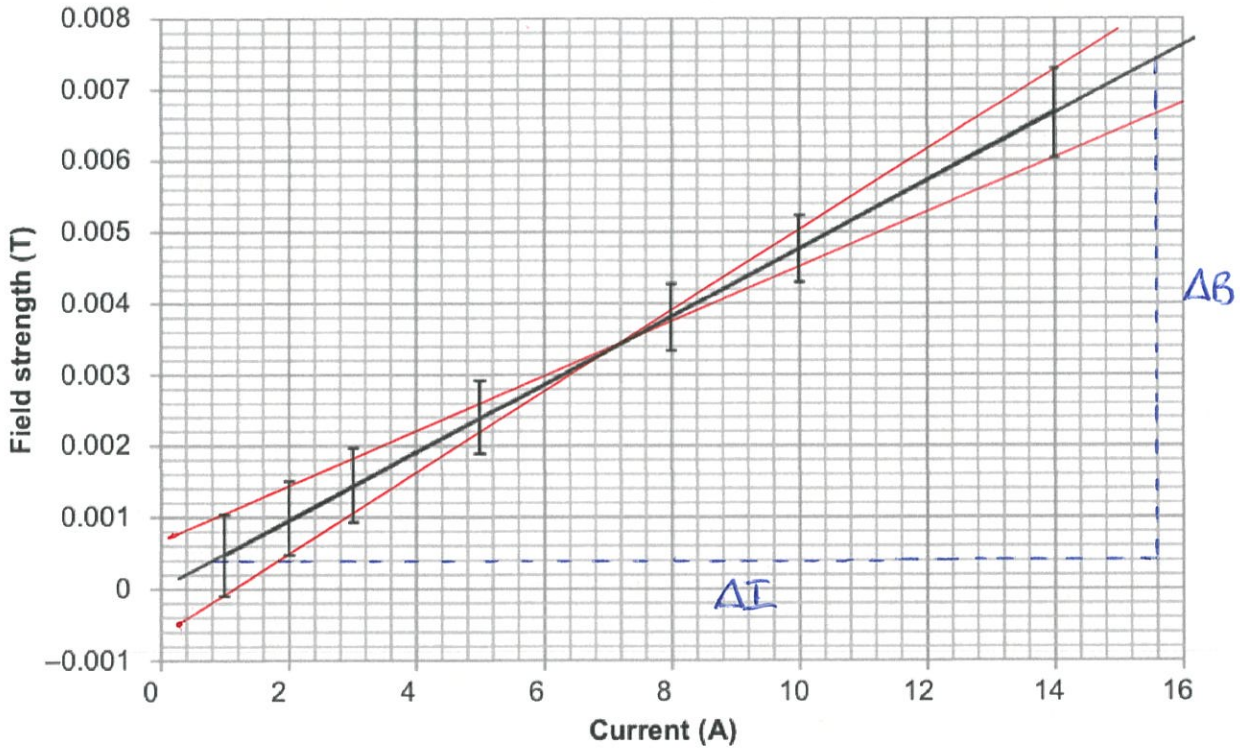
Vertical line (1)
Arrow up (1)


(b) Describe the effect on a positively-charged particle travelling into the page at P due to the current-carrying wire. (2 marks)

- Experiences a force. (1)
- Towards Q (to the right). (1)

4. The magnetic constant $\mu_0$ is the magnetic permeability of a vacuum. An iron alloy would have a different permeability $\mu_a$. To determine its permeability, a large block of the iron alloy had an insulated current-carrying wire pass through its middle. A measure of the magnetic field strength 1.00 m from the wire was made as the current was varied as shown on the graph below.




Use $B = \frac{\mu I}{2\pi r}$ to determine a gradient for the graph above and hence the magnetic constant $\mu$ (where $\mu = \mu_0\mu_a$). (3 marks)

2 appropriate points

gradient = $\frac{(0.0072 - 0.0004)}{(15.6 - 0.18)}$

$= 4.59 \times 10^{-4}\ TA^{-1}$ (1)

[Accept $4.54 - 5.01 \times 10^{-4}\ TA^{-1}$]

gradient = $\frac{\Delta B}{\Delta I} = \frac{\mu}{2\pi r}$ (1)

$\Rightarrow \mu = 2\pi r(\text{gradient})$

$= 2\pi(1.00)(4.59 \times 10^{-4})$

$= 2.89 \times 10^{-3}\ TA^{-1}$

$\mu =$ $2.89 \times 10^{-3}$ (1) (no units required)

[Accept $2.85 - 3.15 \times 10^{-3}\ TA^{-1}$]

(b) Use the gradient and the vertical error bars in the graph on page 14 to comment on the uncertainty of your answer to part (a). Express your answer in the appropriate significant figures. (4 marks)

Max gradient $= \dfrac{(0.0073 - (-0.0001))}{(14.0 - 1.0)}$

$= 5.69 \times 10^{-4}\ TA^{-1}$ (1)

Min gradient $= \dfrac{(0.0061 - 0.0011)}{(14.0 - 1.0)}$

$= 3.85 \times 10^{-4}\ TA^{-1}$ (1)

Gradient uncertainty $= \dfrac{(5.69 - 3.85) \times 10^{-4}}{2}$

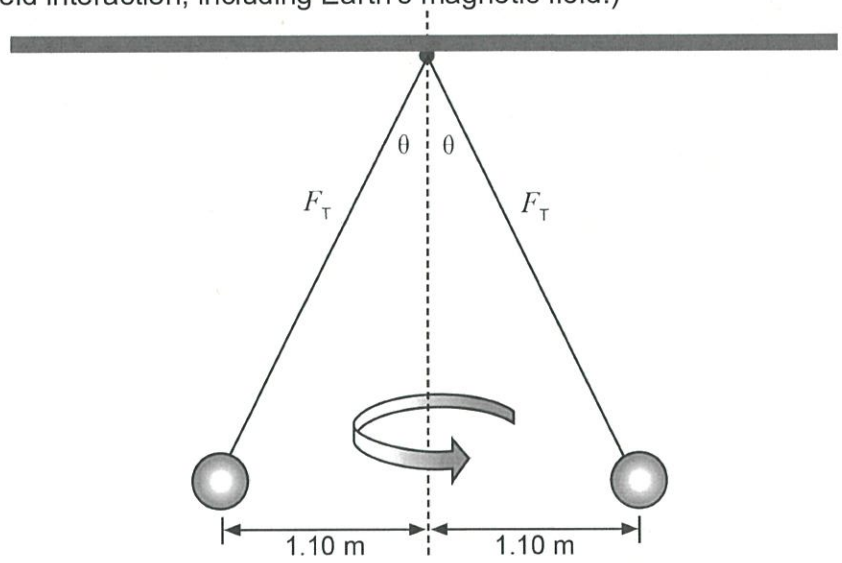
$= 0.920 \times 10^{-4}\ TA^{-1}$

$\mu$ uncertainty $= 2\pi (0.920 \times 10^{-4})$

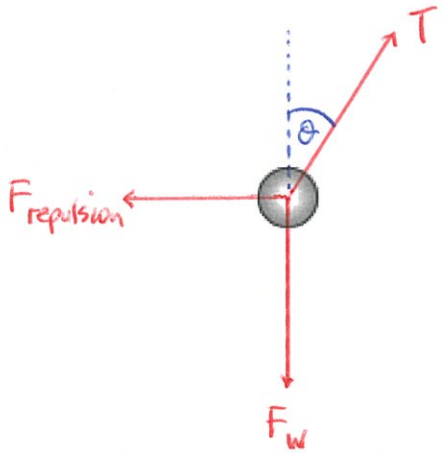
$= 5.78 \times 10^{-4}\ TA^{-1}$ (1)

Answer $2.89 \times 10^{-3}$ ± $0.58 \times 10^{-3}$ (1) (no units required)

5. Two identical, electrically-charged spherical balls tied to the ends of cords of negligible mass revolve freely in a horizontal plane as shown in the diagram below. The electric charge on each ball is $7.00 \times 10^{-6}$ C. The radius of the circle of motion is 1.10 m. The period ($T$) of revolution is 2.50 s and the mass of each ball is 0.200 kg. (Ignore the interference by any magnetic field interaction, including Earth's magnetic field.)




(a) On the ball below, complete a labelled, free body diagram of the force(s) acting on one of the balls. (3 marks)




3 forces shown (1)
At least 2 labelled correctly (1)
Does not include extra forces (1

(b) Show by calculation that the magnitude of the velocity of each ball is 2.76 $ms^{-1}$. (1 mark)

$$v = \frac{2\pi r}{T}$$
$$= \frac{2\pi(1.10)}{2.50}$$
$$= 2.76\ ms^{-1} \quad (1)$$

(c) Determine the angle (θ) and the tension ($F_T$) of one of the cords. (6 marks)

HORIZONTALLY: $\Sigma F_h = F_c$

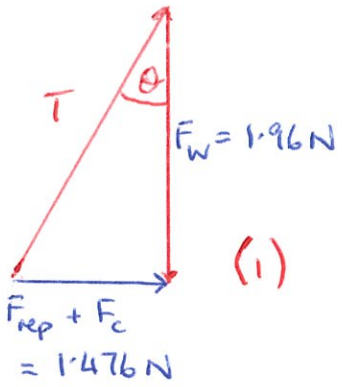
$\Rightarrow T\sin\theta - F_{repulsion} = F_c$

$\Rightarrow T\sin\theta = F_c + F_{repulsion}$ (1)

$= \frac{mv^2}{r} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{r^2}$

$= \frac{(0.200)(2.76)^2}{(1.10)} + \frac{1}{4\pi(8.85\times10^{-12})}\cdot\frac{(7.00\times10^{-6})^2}{(2.20)^2}$ (1)

$= 1.476\ N$ (1)




(1)

$\tan\theta = \frac{1.476}{1.96}$ $\cos\theta = \frac{1.96}{T}$

$\Rightarrow \theta = 37.0^\circ$ (1) $\Rightarrow T = \frac{1.96}{\cos 37.0^\circ}$

$= 2.45\ N$ (1)

This can also be solved using vertical and horizontal components.

Answer 2.45 N at an angle of 37.0° to the vertical

(d) In completing the calculations for part (c), why it is reasonable to consider the gravitational attraction between the two spheres to be negligible? Use a formula to support your answer. (3 marks)

$F_g = \frac{GM_1M_2}{r^2}$

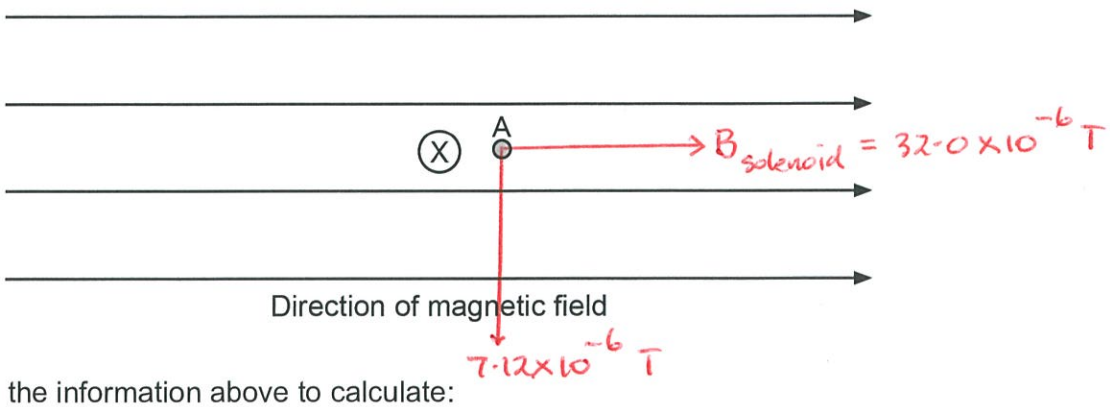
$= \frac{(6.67\times10^{-11})(0.200)(0.200)}{(2.20)^2}$

$= 5.51\times10^{-13}\ N$ (1)

From (c): $F_{rep} = 9.10\times10^{-2}\ N$ (1)

∴ Gravitational attraction is negligible by comparison. (1)

6. An experiment was conducted to determine the effect of an external magnetic field on a current-carrying conductor. A DC solenoid was used to produce a constant magnetic field of 32.0 μT. A conductor carrying a direct current of 285 mA was introduced to the magnetic field. The conductor was fixed in place and carries the current directly into the page. Point A is 8.00 mm from the centre of the conductor, along a line parallel to the constant magnetic field as shown below.




(a) Use the information above to calculate:

(i) the magnitude of the magnetic field at point A due to the current in the conductor. (2 marks)

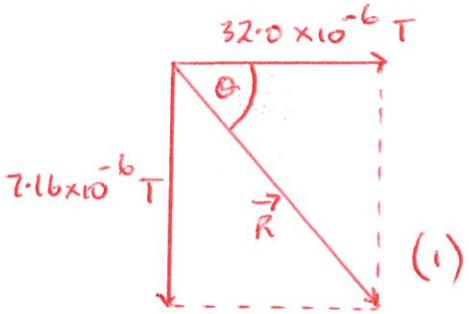
$$B = \frac{\mu_0 I}{2\pi r} \quad (1)$$

$$= \frac{(4\pi \times 10^{-7})(0.285)}{2\pi (8.00 \times 10^{-3})}$$

$$= 7.12 \times 10^{-6} \text{ T}$$

Answer magnitude $7.12 \times 10^{-6}$ T (1)

(ii) the magnitude and direction of the resultant magnetic field at point A. If you were unable to obtain an answer to part (a) (i), use $6.00 \times 10^{-6}$ T. Include a diagram in your answer. (3 marks)




(1)

$$\vec{R} = \sqrt{(32.0 \times 10^{-6})^2 + (7.12 \times 10^{-6})^2}$$

$$= 3.28 \times 10^{-5} \text{ T}$$

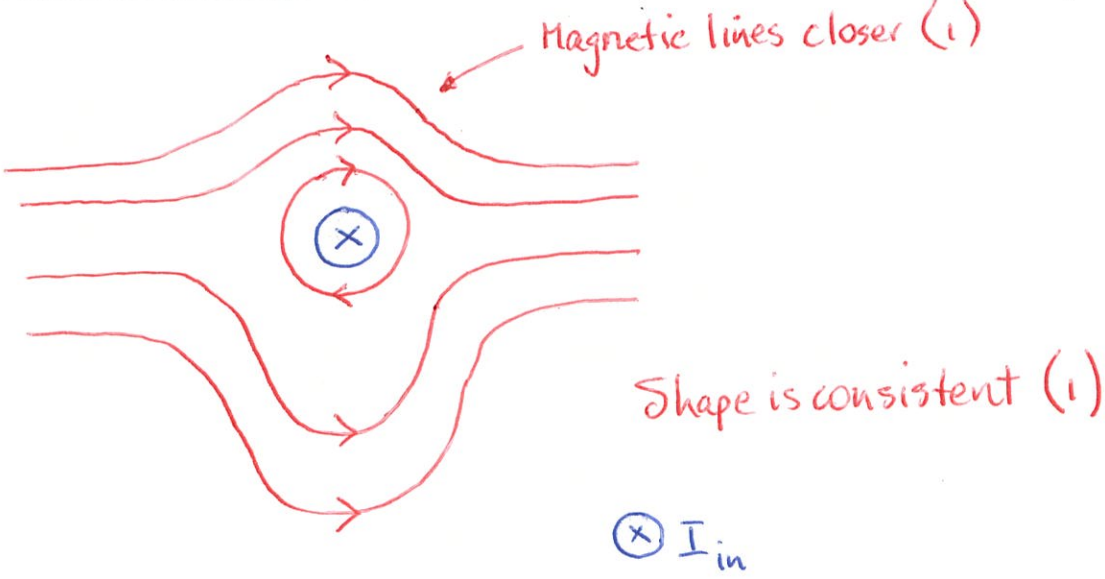
$$\tan\theta = \frac{7.12 \times 10^{-6}}{32.0 \times 10^{-6}}$$

$$\rightarrow \quad \theta = 12.5^\circ$$

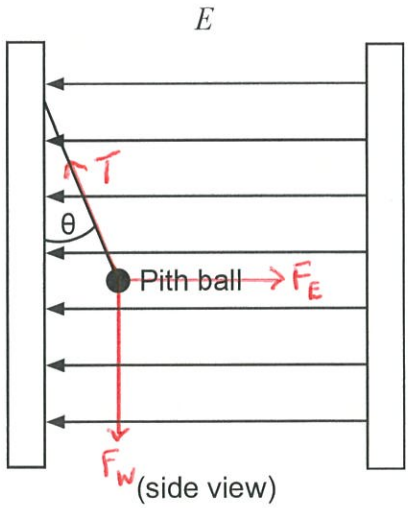
Answer magnitude $3.28 \times 10^{-5}$ T (1)

Direction 12.5° below the horizontal to the right (1)

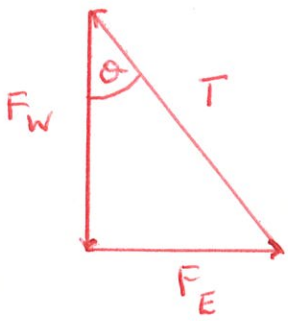
(b) Sketch the resultant magnetic field around the conductor. (2 marks)




7. A pith ball is a very small, lightweight object that readily picks up electric charge. A pith ball with a mass of $75.0 \times 10^{-6}$ kg is suspended by a string attached to a charged plate. The pith ball has an excess of $2.00 \times 10^{12}$ electrons on it and the electric field strength between the charged plates is 95.0 $NC^{-1}$.




(a) In the space below, draw a vector diagram of the forces acting on the pith ball. (3 marks)




Correct forces (1)
Closed right triangle (1)
Correct labels (1)

(b) Calculate the angle between the string and the charged plate. (5 marks)

$$F_E = Eq$$
$$= (95.0)(2.00 \times 10^{12})(1.60 \times 10^{-19}) \quad (1)$$
$$= 3.04 \times 10^{-5}\ N \quad (1)$$

$$F_W = mg$$
$$= (75.0 \times 10^{-6})(9.80)$$
$$= 7.35 \times 10^{-4}\ N \quad (1)$$

$$\tan\theta = \frac{F_E}{F_W} \quad (1)$$
$$= \frac{3.04 \times 10^{-5}}{7.35 \times 10^{-4}}$$
$$\Rightarrow \underline{\theta = 2.37^\circ} \quad (1)$$