Stage 3 Physics: Motion and Forces in Electric and Magnetic Fields

UNIT TEST

Name: **Suggested Answers** (40 marks)

1. When drawing field lines around point charges, they are drawn such that the lines are closer together near the point charge but further apart as you move away.

   a. Explain what this tells us about the fields around point charges. (1 mark)

   The closer you are to the point charge, the stronger the field so the lines are closer together.

   In parallel plates however, the lines are drawn parallel and the same distance apart.

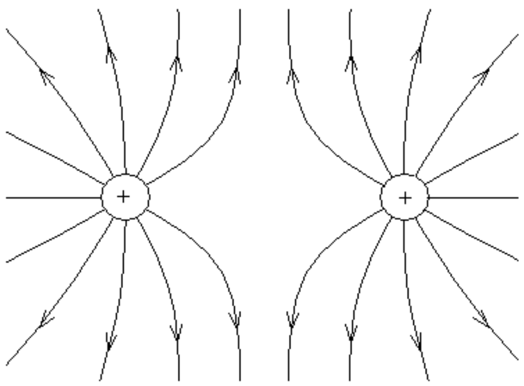
   b. Why is this different to point charges? (1 mark)

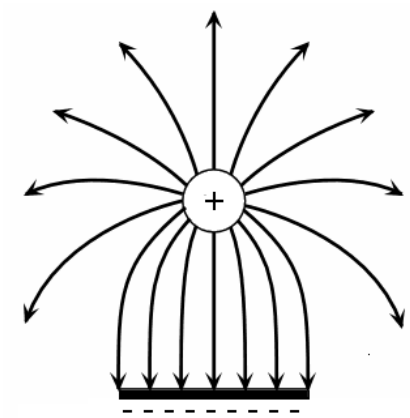
   The field between parallel plates is uniform throughout so the lines show the that there is no change in the strength and direction of the field.

2. Draw the electric field lines for the following two situations. (4 marks)

   a. Two positively charged point charges.

   b. A positive point charge above a negatively charged plate.





3. A pith ball (small foam ball) has been given a charge of -8.45×10^{-2} μC and is placed within an electric field. The pith ball experiences a force of 4.25×10^{-4} N north.

   a. Calculate the magnitude of the field at that point. (2 marks)

$$\mathbf{E = \frac{F}{q} = \frac{4.25\times10^{-4}}{-8.45\times10^{-8}}}$$

$$\mathbf{E = -5.03 \times 10^{3}\ N\ C^{-1}}$$

   b. What is the direction of the force? Explain your answer. (2 marks)

   The direction will be South.

   Field direction is the way a positively charged particle would move. Negative charges move in the opposite direction to the field so as the field is north, the charge will move south.

4. In an experiment, two parallel plates are set up in a vacuum. The plates are 2.50 cm apart and connected to opposite terminals of a 240 V power supply

a. Determine the magnitude of the electric field between the plates. (2 marks)

$$\mathbf{E = \frac{V}{d} = \frac{240}{0.025}}$$

E = 9600

$E = 9.60 \times 10^{3}$ V m^{-1}

b. Calculate the force the electric field exerts on an electron within the field. (2 marks)

F = Eq

$= 9600 \times 1.6 \times 10^{-19}$

$F = 1.54 \times 10^{-15}$ N

c. Calculate the lost in potential energy for an electron as it leaves the negative plate and hits the positive plate. (2 marks)

Work = energy = F x s

$= 1.54 \times 10^{-15} \times 0.025$

$= 3.85 \times 10^{-17}$ J

OR

Work = energy = Vq

$= 240 \times 1.6 \times 10^{-19}$

$= 3.85 \times 10^{-17}$ J

d. Calculate the maximum speed of the electron. (2 marks)

All the potential energy is converted to kinetic energy

$E_k = \frac{1}{2} mv^2$

$3.85 \times 10^{-17} = 0.5 \times 9.11 \times 10^{-31} \times v^2$

$$\mathbf{v = \sqrt{\left(\frac{3.85\text{x}10^{-17}}{(0.5\text{x}9.11\text{x}10^{-31})}\right)}}$$

$v = 9.19 \times 10^{6}$ m s^{-1}

e. If the plates were moved closer, how would it affect:

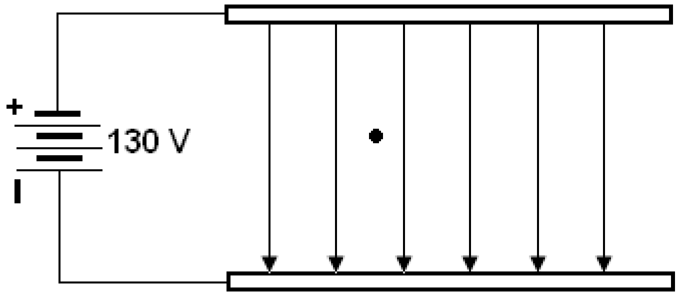
(i) the electric field strength between the plates? Explain. (2 marks)

No effect.
Power supply not changed so charge on plates not altered, so field lines are the same.

(ii) the potential difference? Explain. (2 marks)

Must decrease.
V = Ed, field is constant so if ‘d’ decreases, V must decrease.

5. A charged particle of mass 3.80×10^{-6} g is suspended between two plates as shown. The plates are 5.45 mm apart.



a. Determine the strength of the electric field between them. (2 marks)

$$E = \frac{V}{d} = \frac{130}{5.45 \times 10^{-3}} = 23853$$

$$E = 2.39 \times 10^{4}\ \mathrm{V\ m^{-1}}$$

b. Calculate the charge on the particle. (3 marks)

since suspended, mg = Eq

$$3.80 \times 10^{-9} \times 9.8 = 2.39 \times 10^{4} \times q$$

$$q = \frac{3.80 \times 10^{-9} \times 9.8}{2.39 \times 10^{4}}$$

$$q = 1.56 \times 10^{-12}\ \mathrm{C}$$

c. The charge is due to a number of excess electrons on the particle. Calculate the number of excess electrons. (1 mark)

$$\text{excess electrons} = \frac{1.56 \times 10^{-12}}{1.6 \times 10^{-19}}$$

$$= 9.76 \times 10^{6}\ \text{electrons}$$

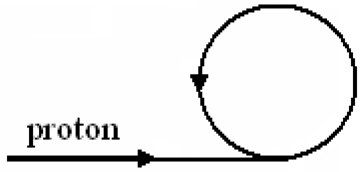
6. Calculate the force on an electron which is moving horizontally with a constant velocity of 8.25×10^{7} m s^{-1} south when it enters a uniform magnetic field of 5.5×10^{-3} T east. (2 marks)

$$F = Bvq$$

$$= 5.5 \times 10^{-3} \times 8.25 \times 10^{7} \times 1.6 \times 10^{-19}$$

$$F = 7.26 \times 10^{-14}\ \mathrm{N}$$

7. A proton experiences a force of 2.11 x 10^{-14} N when it enters a magnetic field as shown in the diagram. The velocity of the proton is 1.50 x 10^{6} ms^{-1}.



a. Describe the direction of the magnetic field. (1 mark)

into the page

b. Calculate the strength of the magnetic field that is acting on the proton. (2 marks)

$$B = \frac{F}{qv} = \frac{2.11 \times 10^{-14}}{(1.6 \times 10^{-19} \times 1.50 \times 10^{6})}$$

B = 8.80 x 10^{-2} T

c. What is the diameter of the path followed by the proton? (3 marks)

$$F_e = F_c$$

$$Bvq = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB} = \frac{1.67 \times 10^{-27} \times 1.50 \times 10^{-6}}{1.6 \times 10^{-19} \times 8.80 \times 10^{-2}}$$

r = 0.1779 m

diameter = 2 x r
= 2 x 0.1779
diameter = 0.356 m

d. Calculate the frequency of the path of the proton. (2 marks)

$$T = \frac{2\pi r}{v} = \frac{2 \times \pi \times 0.1779}{1.50 \times 10^{6}}$$

T = 7.45 x 10^{-7} s

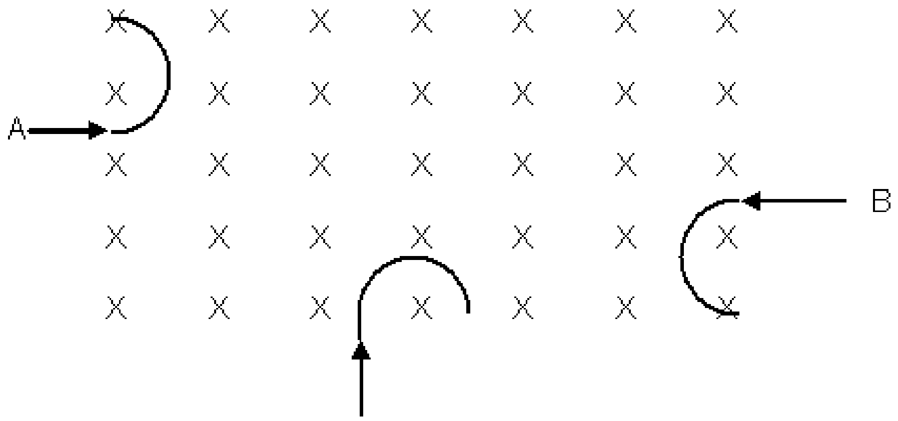
$$f = \frac{1}{T} = \frac{1}{7.45 \times 10^{-7}}$$

f = 1.23 x 10^{6} Hz

8. The diagram below shows a uniform magnetic field with three particles A, B and C having masses and charges as shown in the table below. They each enter the magnetic field with the same velocity, v. Complete the diagram to show the paths of particles A, B and C.

(3 marks)

Particle	Relative charge	Relative mass
A	1 +	m
B	2 +	2m
C	1 -	m



For all particles

$F_e = F_c$

$r = \dfrac{mv}{Bq}$

A and C same radius but different direction

B: $r_B = \dfrac{2mv}{B2q}$ 2's cancel so same r as A and C

Students may have different diagrams to above but the key idea is that the radius for each is the same