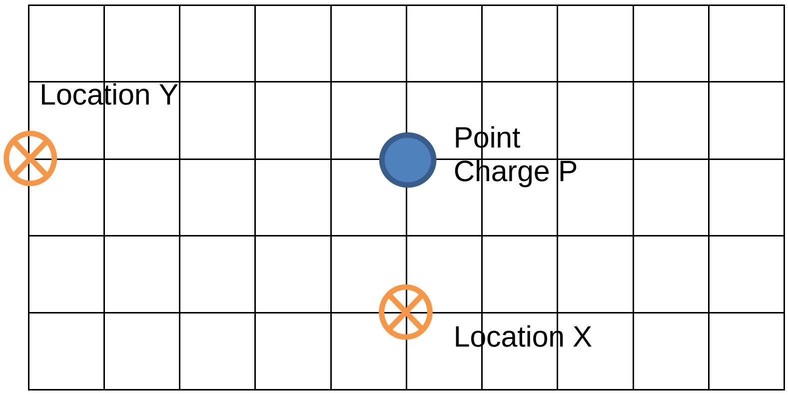
Year 12 Physics – Stage 3
Motion & Forces in Electromagnetic Fields
Practice Test

Time allowed: 50 minutes
Total marks available: 50
Use appropriate significant figures for accuracy

Student Name: Answer Key

1. A large positive point charge P is fixed in the position shown on the diagram below.



a) The electric field strength due to P at location X is **E** (down). In relative terms determine the electric field strength at location Y.

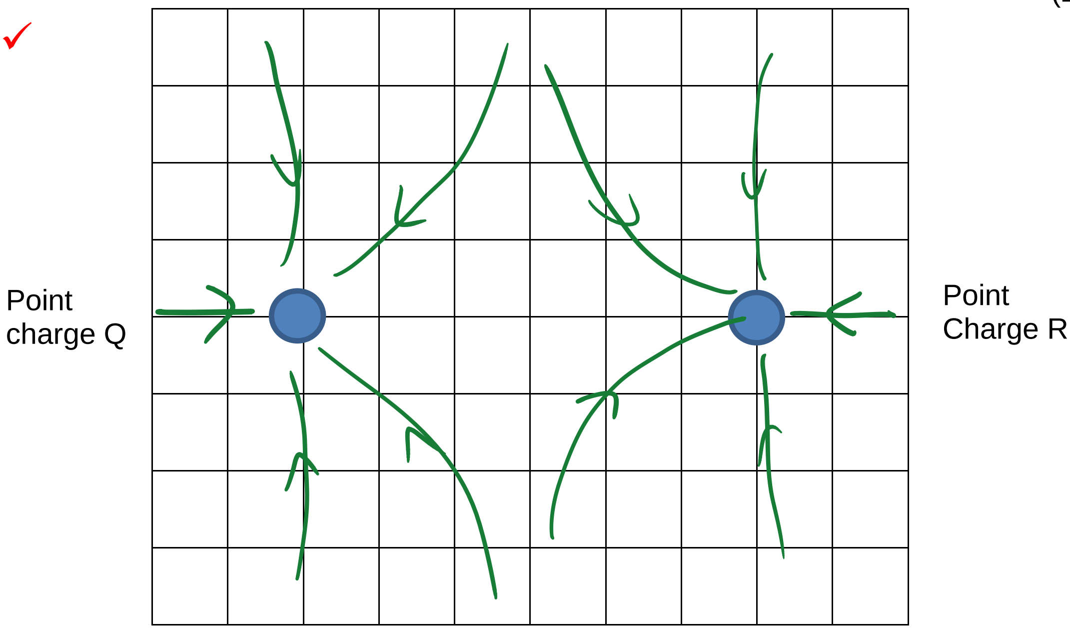
(3)

Inverse square law
P to X = 2 squares P to Y = 5 squares ✓
$The\ field\ strength\ at\ Y = \frac{2^2}{5^2} E = 0.16\ E$ ✓ left ✓

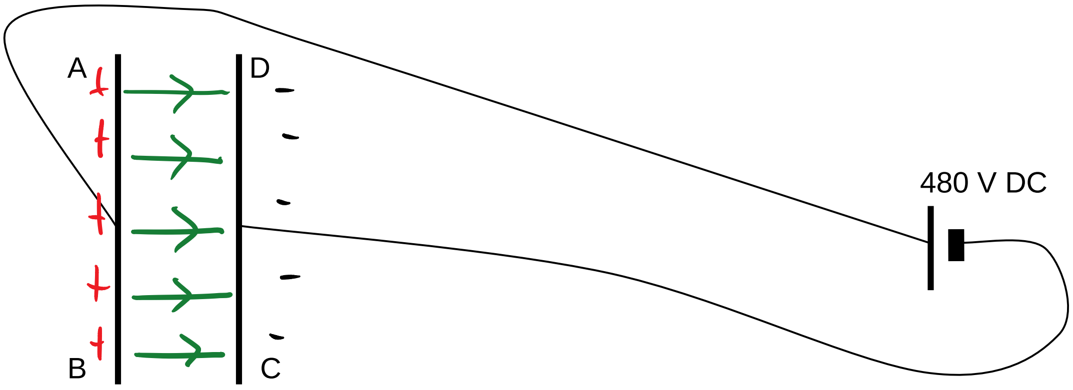
b) The diagram below shows equal negative point charges Q and R which are fixed in position. Draw at least 5 field lines from each charge to show the resultant electric field.

(2)

Direction ✓
Shape ✓



2. Two parallel plates, AB and CD, have a high voltage (potential difference) across them as shown below.



a. Sketch a uniform electric field pattern that exists between plates AB and CD. (2)

Equally spaced parallel ✓ direction as shown ✓

b. Calculate the electric field strength if the battery has a voltage of 480 V DC and the plate separation is 3.50 mm. (2)

The field strength $E = \frac{V}{d} = \frac{480}{0.0035}$ ✓ = 1.37×10^5 V m^{-1} ✓

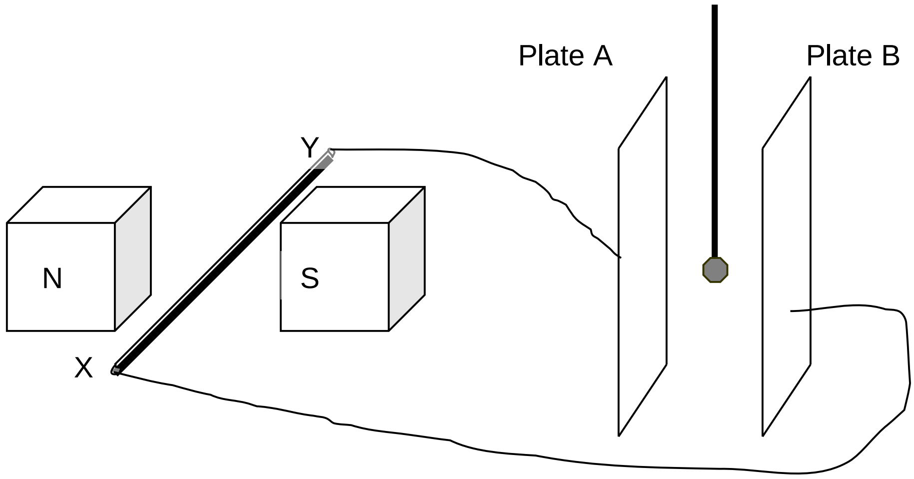
c. Calculate the force experienced by a charged metal flake of mass 4.65×10^{-3} kg and charge 9.30 μC when placed in this uniform field. (2)

The field strength $E = \frac{F}{q} = \frac{F}{9.30 \times 10^{-6}}$ = 1.37×10^5 ✓

F = 1.28 N ✓

(no direction required as charge not stated positive/negative)

3. A length of copper rod XY is held in a strong magnetic field and is connected to two vertical metal plates A and B. A light negatively charged sphere made of conducting material is suspended between the plates on an insulated thread and can swing freely.



a. If the rod XY is moved rapidly up,

State the direction of the induced current along the rod XY: towards Y (1)

b. State the direction of force exerted on the charged sphere. (Circle the best response) (1)

Into page   Out of page   Left ✓   Right   Up   Down

c. In a separate experiment the sphere is swung to touch plate B - state the direction of any force acting on rod XY by circling a response from below.

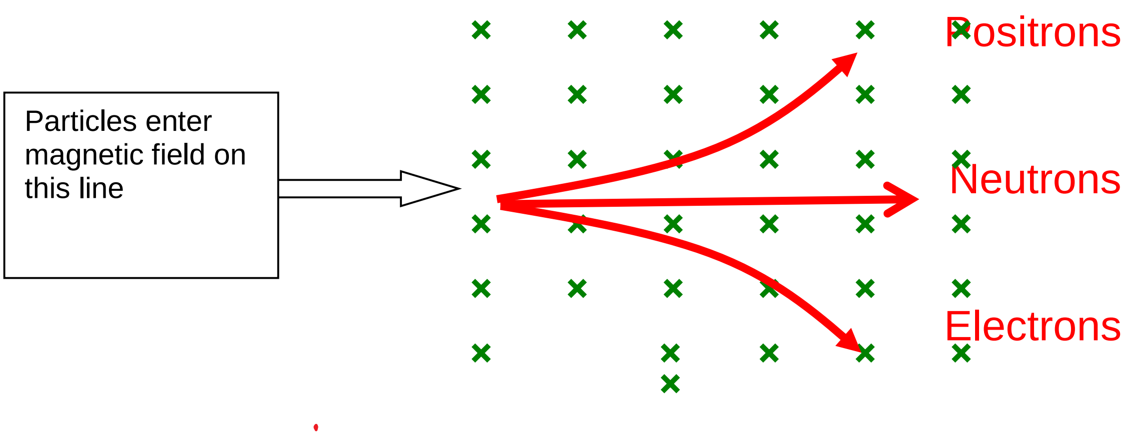
(1)

Into page   Out of page   Left   Right   Up ✓   Down   No Force

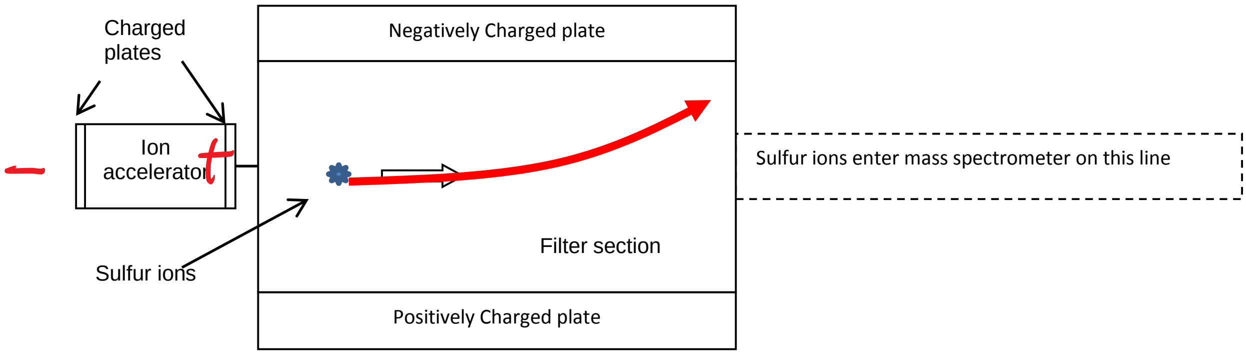
4. A source of radiation which emits positrons, electrons and neutrons is placed so the particles pass into a cloud chamber which has a magnetic field directed into of the page as shown in the diagram below. The particles travel at the same speed.

On the diagram draw and label the approximate paths followed by each of the particles. (3)

Subtract a mark if radii are different



5. A Velocity Filter (Velocity Selector) is a device used to govern the speed of charged particles entering a mass spectrometer. In a certain mass spectrometer Sulfur ions (S^{2-}) are accelerated from rest through an electric field established by charged parallel plates before entering the filter section. Mass of Sulfur ion = 5.32×10^{-26} kg



a. Indicate, on the diagram, the polarity of the charged plates in the **ion accelerator**.

(1)

b. Calculate the potential difference between the charged plates in the **Ion accelerator** that will give the Sulfur ions a **maximum** velocity of 3.30×10^5 m s^{-1}

(3)

$W = \Delta KE = q.V$ concept ✓

$$\frac{1}{2}mv^2 = q.V$$

$$\frac{1}{2}5.32 \times 10^{-26} \times (3.30 \times 10^5)^2 = 3.20 \times 10^{-19}.V$$ ✓

V = 9.05×10^3 V ✓

c. Indicate the direction of the magnetic field within the **filter section** required such that the direction of the magnetic and electric forces experienced by the Sulfur ions act in opposite directions.

(2)

Out of page = dots ✓ placed in correct location ✓

d. Derive an expression for the speed of ions that will pass through the filter in a straight line. The expression you derive must consider the relationship between the Magnetic and Electric fields.

(2)

$$The\ field\ strength\ E = \frac{F}{q}\ so\ F_{electric} = E.q$$

$F_{magnetic}$ = q.v.B

F (magnetic) = F (electric) q.v.B = E.q ✓

so $V = \frac{E}{B}$ ✓

e. The filter is required to select Sulfur ions with a velocity of 2.80×10^5 m s^{-1} to enter the mass spectrometer. If the magnetic flux density within the filter chamber is set to 8.52 mT then calculate the electric field strength required between the two charged plates.

(2)

$$v = \frac{E}{B}$$

✓

$$E = v.B = 2.80 \times 10^5 \times 0.00852 = 2385.6\ N\ per\ C$$

$= 2.39 \times 10^3$ N C^{-1} ✓

f. Will more massive isotopes of ionised Sulfur be selected at the same speed? Explain

(2)

Yes according to equation v = E / B ✓ mass is not a factor ✓

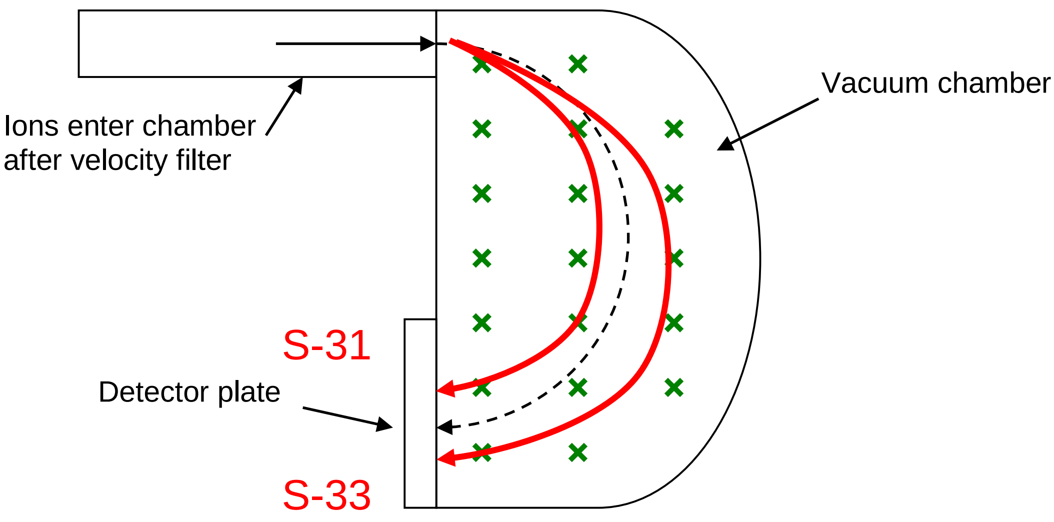
g. Explain, with reference to the diagram, the path taken by Sulfur ions moving with a velocity of 2.90×10^5 m s^{-1} within the filter section. You must explain why.

(2)

v here is faster than selection velocity

$F\ (\text{magnetic}) = qvB$ so this force is affected by speed and increases✓ Shows arrow curving up on the diagram. ✓

6. The Sulfur ions (S^{2-}) from the previous question enter the vacuum chamber of a mass spectrometer at a speed of 2.80×10^5 m s^{-1}. They are acted on by a magnetic field such that they follow a semi-circular path. The path for Sulfur-32 is shown.



(a) Indicate the direction of the magnetic field in the vacuum chamber that will achieve the semi-circular path shown.

(1)

Into page

(b) Derive an expression for the radius of the circular path followed by the ions in terms of mass, charge, speed and flux density.

(3)

F (magnetic) = F (centripetal)

so $qvB = \frac{mv^2}{r}$ ✓ re-arrange $r = \frac{mv}{qB}$

(c) Explain how the device is able to separate different isotopes of Sulfur from the standard isotope of Sulfur-32

(2)

Different isotopes have different masses and therefore according to equation radius is proportional to mass ✓ ✓

$r = \frac{mv}{qB}$

(d) Show clearly on the diagram where the isotopes Sulfur-31 and Sulfur-33 are likely to strike the detector plate and sketch their paths from the entry line.

(2)

(e) A Sulfur-32 ion of mass 5.32×10^{-26} kg needs to be deviated in a semi-circular path of diameter 40 cm. Calculate the value of the magnetic flux density in the **Vacuum Chamber** required to achieve this.

(3)

Identifies variable r = 0.20 m✓

$$B = \frac{mv}{qr} \qquad B = \frac{5.32 \times 10^{-26}\ 2.80 \times 10^{5}}{3.20 \times 10^{-19} \times 0.20} \checkmark$$

B =0.233 T ✓

(f) If a small amount of air leaks into the vacuum chamber, explain clearly how the circular path of the Sulfur ions is likely to be affected.

(2)

Velocity is reduced by collisions, so according to equation radius will decrease ✓ Path = spiral inwards✓

$$r = \frac{mv}{qB}$$

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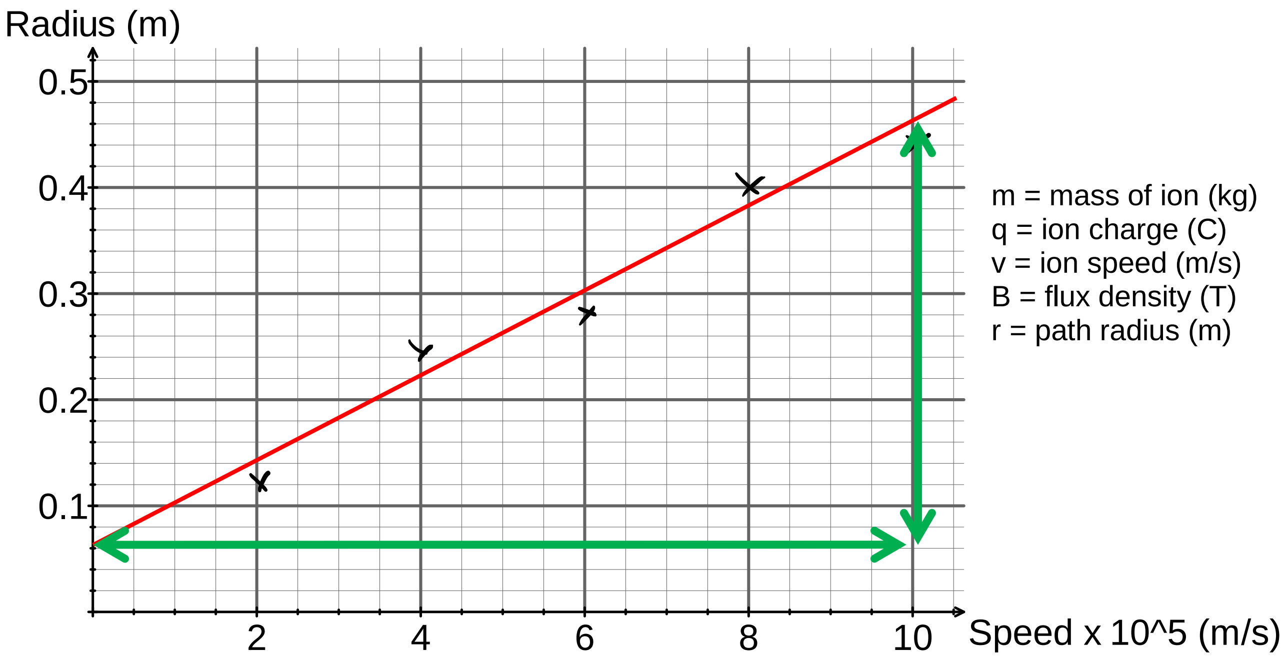
7.



In a mass spectrometer the magnetic force on a charged particle in motion causes it to deflect in a circular path. The graph relates to the path radius obtained when the ion velocity was varied from 2×10^5 m/s to 1×10^6 m/s . The magnetic flux density was fixed at 0.653 T. The charged particles were singly charged positive ions of sodium (Na^+).

The data follows a y = **a**.x + c format for the expression $r = \frac{m}{B.q} . v$ where **a** is the gradient.

a) Use equations on the formulae and constant sheet to derive the above expression (2)

F (magnetic) = F (centripetal) (repetition apologies PGA)

so $qvB = \frac{mv^2}{r}$ ✓ re-arrange $r = \frac{mv}{qB}$

b) From the graph, obtain a value for the gradient of the line of best fit. (2)

Identifies from the graph rise = 0.40 run = 10×10^5 ✓

$\text{gradient} = \frac{0.40}{10E5}$ = 4.00×10^{-7} s ✓

c) From the gradient of the line of best fit obtained, determine the mass of the sodium ion (Na^+) (2)

$\text{gradient} = \frac{m}{B.q}$ = 4.00×10^{-7} s ✓

m = $4.00 \times 10^{-7} \times 0.653 \times 1.60 \times 10^{-19}$

m = 4.18×10^{-26} Kg