- *Thus, in order for the particle to suffer **NO DEFLECTION** and so exit the device at **Y** :*

MAGNETIC FORCE UP = ELECTRIC FORCE DOWN

$$BQv = EQ$$

From which :

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

(N C-1) (m s-1) (T)

POINTS TO NOTE

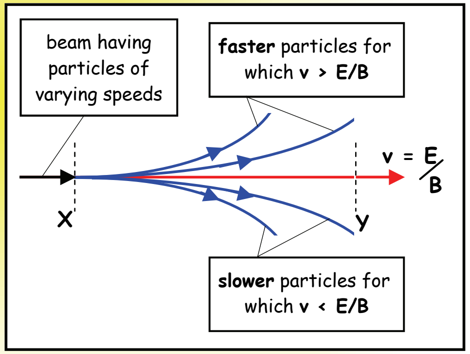
- *By controlling **E** and **B**, **ONLY PARTICLES OF VELOCITY, v =E/B** are allowed through.*

- *The **velocity (v)** of a charged particle may be determined by measuring **E** and **B**.*

- *If a charged particle beam containing particles of **varying speeds** enters the crossed-fields region :*

  *F_B = **BQv** will be **greater** for **faster** particles and **smaller** for **slower** particles.*

  *F_E = **EQ** is the **same** for particles of different speed.*



*So, **FASTER** particles are deflected **UPWARDS** because - $F_B > F_E$*

***SLOWER** particles are deflected **DOWNWARDS** because - $F_B < F_E$*

THE MASS SPECTROMETER

- ***Mass spectrometers** are used to accurately measure the mass of charged particles and hence identify them. Their actual design is dependent on the kind of particle which is being identified, but all mass spectrometers use Combined **electric** and **magnetic** fields to control the motion of the particles under investigation. Some are designed to analyse biological specimens (large molecules) while others are geared to the **isotopic analysis of atoms**.*

*The diagram below shows the **Bainbridge mass spectrometer** which can be used for isotopic analysis.*

*A fine beam of **positively** charged particles (ions) is directed in a vacuum through a velocity selector. The beam passes through a region in which there is an **electric field** of strength **E** as well as a **magnetic field** of flux density **B_1 at right angles** to the electric field. As we have already seen, particles having velocity **$v = E/B_1$** will pass through undeflected. This velocity can be adjusted by controlling the size of **E** and **B_1**.*

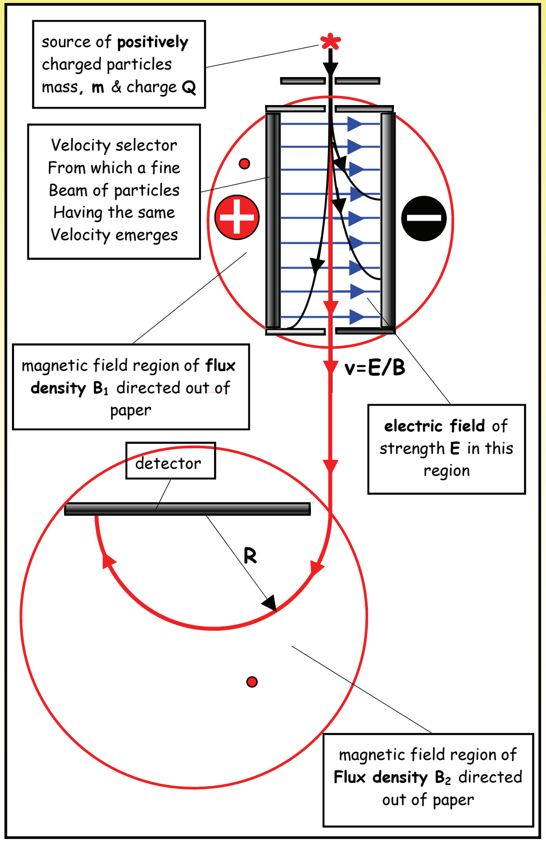
*These particles then Enter a uniform magnetic Field of flux density B2 and are then caused to move in a circular path of radius **R**.*

$$B_2Qv = \frac{mv^2}{R}$$

$$R = \frac{mv}{B_2Q}$$

From which :

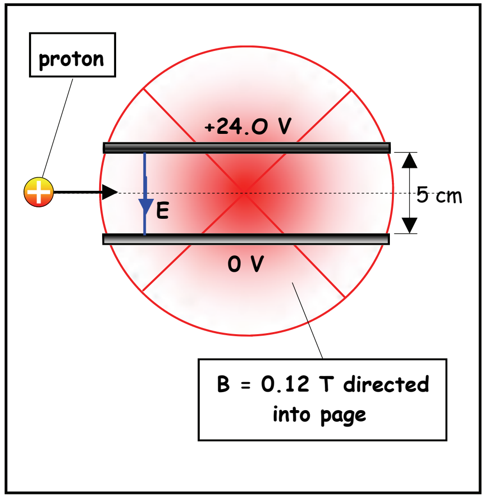
$$R = \frac{mE}{QB_2B_1}$$



*Thus by measuring **R**, the mass **m** can be determined.*

- **PRACTICE QUESTIONS (3)**

1 A proton enters a region of **crossed electric** and **magnetic** fields.
The parallel plates creating the electric field are **5.0 cm** apart with the top plate having a **+24.0 V** potential difference relative to the bottom plate. A magnetic field of flux density **0.12 T** is directed **into the page** in the same region.



Calculate the **speed** of the proton if it passes through this velocity selector without deflection.

2 (a) Calculate the magnitude of the **force** on an electron moving at **3.5×10^7 m s^{-1}** as it enters a uniform magnetic field region of flux density **6.5×10^{-3} T** at **right angles** to its path.

(b) Given that the electron has a mass of **9.11×10^{-31} kg,** calculate the **acceleration** of the electron and hence the **radius** of the path it follows in the field.

3 The diagram on page **11** shows a **Bainbridge** mass spectrometer. *12*

The charged particle beam consists of singly ionised neon atoms which are all moving with the **same** speed of **4.5×10^6 m s^{-1}** through a vacuum.

When the beam exits the **velocity selector,** it enters a uniform magnetic field region and follows a **circular** path of radius **0.115 m.**

(a) **Explain** why the particles follow a **circular path.**

(b) Which **rule** is used to predict the **direction of the magnetic force** which causes the particles to follow a circular path?

(c) Given that each neon ion has a mass of **3.32×10^{-26} kg,** calculate the magnitude of the **force** acting on each ion.

(d) Calculate the **flux density** of the magnetic field into which the ions enter after they exit the velocity selector.

(e) In this case, the velocity selector only allows ions having a speed of **4.5×10^6 m s^{-1}** to pass through **without deflection.**

(i) If the flux density of the magnetic field in the velocity selector is **2.0×10^{-2} T,** calculate the **strength** of the electric field in this region.

(ii) Use the value of the electric field strength obtained in **(i),** to calculate the **potential difference** between the parallel plates if they are **0.10 m** apart.

UNIT G485	Module 1	5.1.2	Magnetic Fields

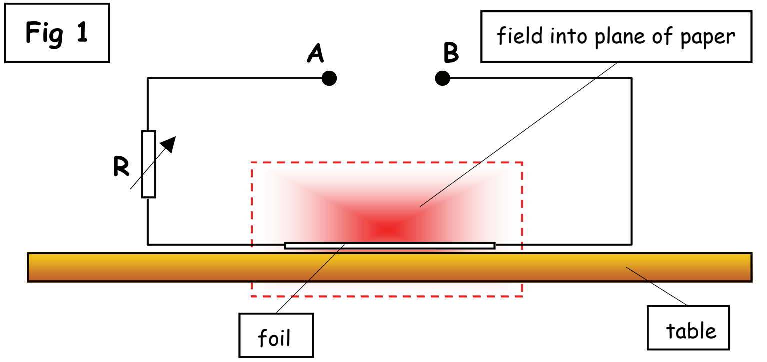
- HOMEWORK QUESTIONS

1 (a) **Explain** why a current-carrying conductor experiences a force when placed in an external magnetic field.

(b) **Define** the **tesla (T).**

(c) A thin aluminium foil of length $\mathbf{5.0 \times 10^{-2}\ m}$ and mass **0.2 g** rests on a horizontal table. A uniform magnetic field of flux density **0.32 T** is applied in the direction shown in **Fig 1.**

Fig 1



A battery is connected between **A** and **B** and the current is adjusted using the variable resistor **R.** The current in the foil is slowly increased from zero until the foil **just lifts** off the table.

(i) On **Fig 1.,** complete the circuit diagram with the symbol for a battery connected so that the foil tends to lift off the table.

(ii) Calculate, for the foil when it just lifts off the table :

1. The magnitude of the **force** on the foil

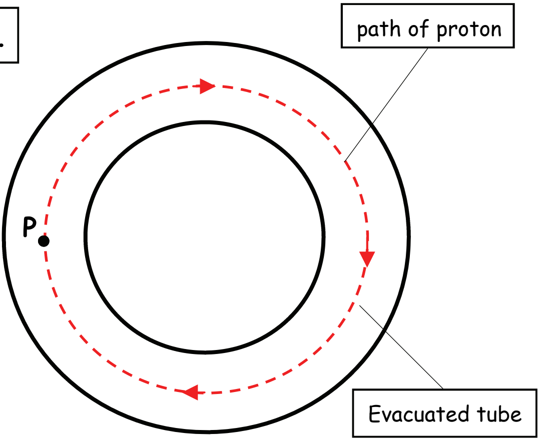
2. The **current** in the foil.

(OCR A2 Physics - Module 2824 - Specimen Paper)

2 (a) **Define magnetic flux density.** *13*

(b) **Fig 2.** shows an evacuated circular tube in which charged particles can be accelerated. A uniform magnetic field of flux density **B** acts in a direction **perpendicular to the plane of the tube.** Protons move with speed **v** along a **circular path** within the tube.

Fig 2.



(i) On **Fig 2.** draw an arrow at **P** to indicate the **direction** of the **force** on the protons for them to move in a circle within the tube.

(ii) **State** the **direction** of the magnetic field. **Explain** how you arrived at your answer.

(iii) Write down an algebraic expression for the **force F** on a proton in terms of the magnetic field at point **P.**

(iv) Calculate the value of the **flux density B** needed to contain protons of speed $\mathbf{1.5 \times 10^{7}\ m\ s^{-1}}$ within a tube of radius **60 m.**

(v) **State** and **explain** what action must be taken to contain protons, injected at **twice the speed (2v)** within the tube.

(OCR A2 Physics - Module 2824 - June 2005)

3 This question is about the electron beam inside a television tube.

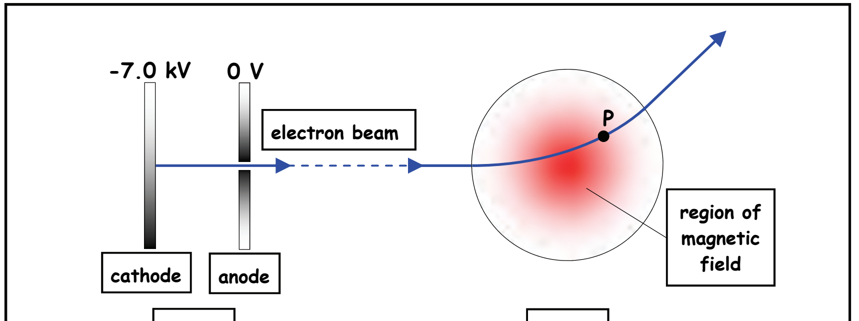


Fig 3. Fig 4.

(a) **Fig 3.** shows a section through a simplified model of an electron gun in an evacuated TV tube.

(i) On **Fig 3.** draw **electric field lines** to represent the field between the **cathode** and the **anode.**

(ii) The electrons emitted at **negligible speed** from the **cathode** are accelerated through a p.d. of **7.0 kV.** Show that the speed of the electrons at the anode is about **5.0 x 10^{7} m s^{-1}**.

(b) Some electrons pass through a small hole in the anode. They enter a region of **uniform magnetic field** as shown by the circled area in **Fig 4.** They follow a circular arc in this region before continuing to the TV screen.

(i) **Draw an arrow** through the point labelled **P** to show the **direction of the force on the electrons** at this point.

(ii) **State the direction of the magnetic field** in the circled area. **Explain** how you arrived at your answer.

(iii) Calculate the **radius** of the arc of the path of the electron beam when the value of the magnetic flux density is **3.0 x 10^{-3} T.**

(c) The region of the uniform magnetic field is created by the electric current in an arrangement of coils. Suggest how the end of the electron beam is swept **up and down** the TV screen.

(OCR A2 Physics - Module 1 - January 2007)

4 A nitrogen atom is initially stationary at point **P** in **Fig 5.**, **midway** between two large, horizontal, parallel plates in an evacuated chamber. The nitrogen atom becomes charged. There is an electric field between the plates. **Ignore** any effects of gravity. *14*

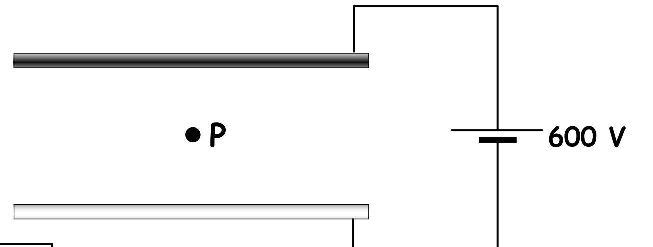


Fig 5.

(a) The direction of the electric force on the nitrogen ion is **vertically downwards. State, with a reason,** the **sign** of the charge on the ion.

(b) The voltage between the plates is **600 V.** At the instant that the ion, having a charge **1.6 x 10^{-19} C** and mass **2.3 x 10^{-26} kg,** reaches the lower plate, show that :

(i) The **kinetic energy** of the ion is **4.8 x 10^{-17} J.**

(ii) The **speed** of the ion is **6.5 x 10^{4} m s^{-1}**.

(c) The electric field strength between the plates is **4.0 x 10^{4} N C^{-1}**. Calculate the **separation** of the plates.

(d) The ion passes through a hole in the lower plate at a speed of **6.5 x 10^{4} m s^{-1}**. It enters a region of uniform magnetic field of flux density **0.17 T** at **right angles** to the plane of **Fig 6.**

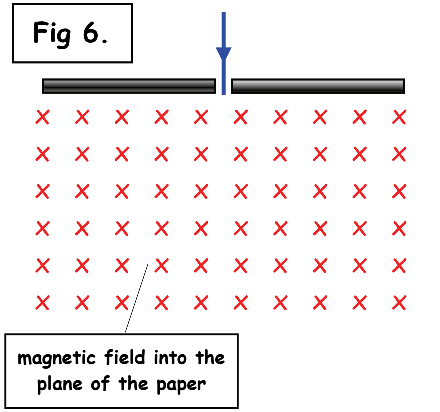


Fig 6.

(i) **Sketch on Fig 6.** the semicircular path taken by the ion.

(ii) Calculate how far from the hole the ion will collide with the plate. Use data from **(b).**

(OCR A2 Physics - Module 2824 - June 2006)