Section	Group	Name	Signature
Grade			
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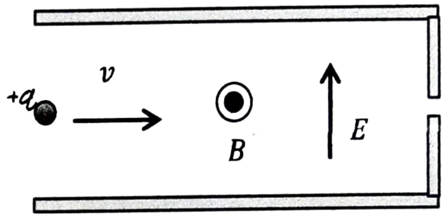
After this activity you should know: *• Be able to do problems which have both magnetic and electric fields • Understand how cross electric and magnetic fields are used in a velocity selector. • Understand how a mass spectrometer works.*

A velocity selector is a device that only lets charges with a particular velocity through.



1. The positive charge $+q$ enters from the left with a speed v. The magnetic field B and electric field E are directed as shown. Neglect gravity.

   a. What is the direction of the magnetic force on the positive charge (in/out/left/right/top/bottom/zero)?

   ~~Down~~ ~~Zero~~ Down

   b. What is the direction of the electric force on the positive charge (in/out/left/right/top/bottom/zero)?

   UP

   c. In what direction will the charge be deflected if it is moving very fast? *Hint: only one of the forces depend on teh speed of the charge. Think about which force will dominate when the charge is moving very fast.*

   Down

   d. In what direction will the charge be deflected if it is moving very slowly?

   UP

   e. There is only one speed where the charges will not be deflected. Find this speed in terms of E, B and/or q. Show work. *Neglect gravity.*

   $\cancel{q}\vec{v}\times\vec{B} = E\cancel{q}$ $\quad v = \dfrac{E}{B\sin(\theta)}$

   f. Which answers (a thru e) changes if the charge was negative instead of positive. Which answers do not change?

   A B C D E

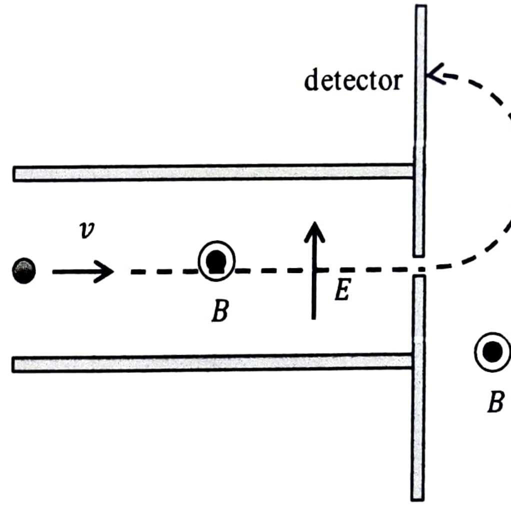
   g. Now assume the electric field is directed into the page, opposite the direction of $\vec{B}$. Will the velocity selector still work?

   No

J.J. Thomson used cross electric and magnetic fields in his discovery of the electron in 1897. He showed that the charges in the a cathode ray tube consisted of particles with a very low mass to charge ratio by measuring their deflection in an electric field.

2. A mass spectrometer is used to determine the mass of the ions in a sample. Once the mass of the ions are known one can determine what molecular composition of the sample. The Behrend chemistry department has several mass spectrometers.

   A new singly charged ion *(the sign of the charge is unknown but we know it is either +e or −e)* enters a velocity selector as shown with crossed electric and magnetic fields of magnitude *E* and *B*. Only ions with the selected speed then leave through the right hole and enter a region with the same magnetic field *B* but no electric field. The magnetic force then causes the charges to move in a semi-circular path of radius r as shown. By measuring r one can determine the mass of the ions.



   a. Is the ion positive or negative?

   Negative

   b. Determine the mass of the ion in terms of e, B, E and/or r. Show work. *Note: your answer should not contain the speed v.*

$$m\frac{v^2}{r} = q\,vB$$

$$= \frac{qBr}{v}$$

$$v = \frac{E}{B\,\cancel{\sin(\theta)}=1}$$

$$m = \frac{qr}{E}$$

   c. What happens to the radius if a singly charged ion with twice the mass goes through the spectrometer?

- 8 times as large
- 4 times as large
- twice as large
- a factor of $\sqrt{2}$ as large
- unchanged
- a factor of $1/\sqrt{2}$ as large
- 1/2 as large
- 1/4 as large
- 1/8 as large

   d. What happens to the radius if the magnetic field is doubled both inside and outside the velocity selector?

- 8 times as large
- 4 times as large
- twice as large
- a factor of $\sqrt{2}$ as large
- unchanged
- a factor of $1/\sqrt{2}$ as large
- 1/2 as large
- 1/4 as large
- 1/8 as large