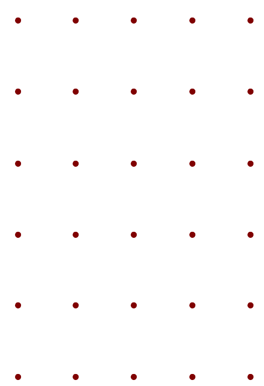
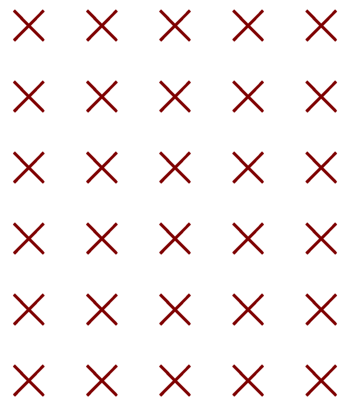
How We Show a Magnetic Field into and Out of the Page.

Many times we need to use three dimensions to describe a problem but this page (or screen) is 2-dimensional. We therefore define symbols to represent what a magnetic field into or out of the page looks like.

Field out of the page



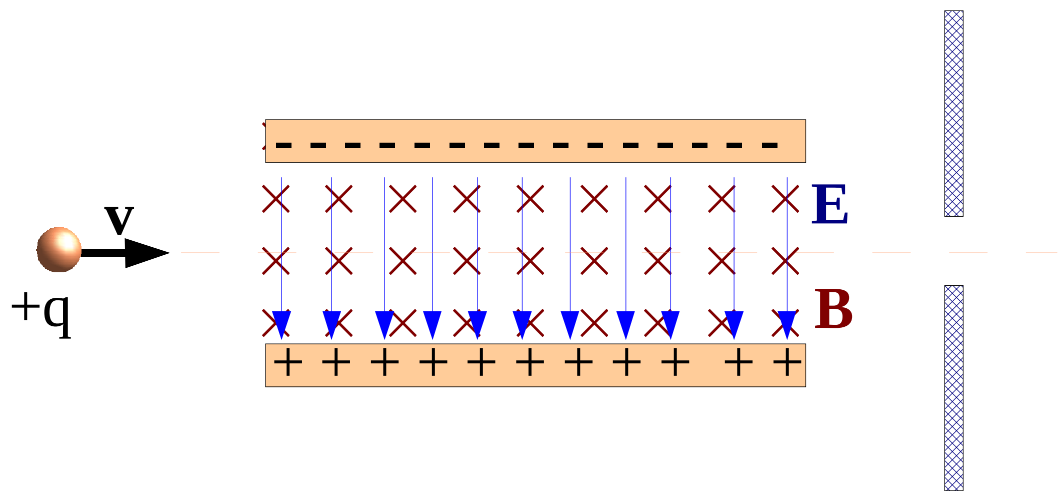
Field into the page

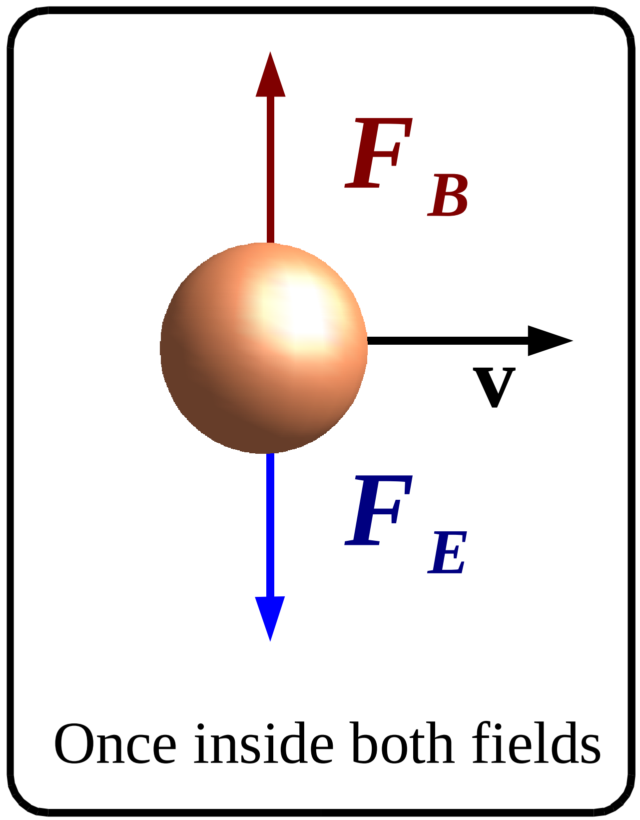


Think of the field as being an arrow. If it is coming toward you, you see the point and if it is going away from you, you see the feathers at the end.

Applications of a Magnetic Force on Charged Particles

The magnetic field, combined with an electric field, can be used to select charged particles of a given velocity from a stream of particles. How?





Velocity Selector

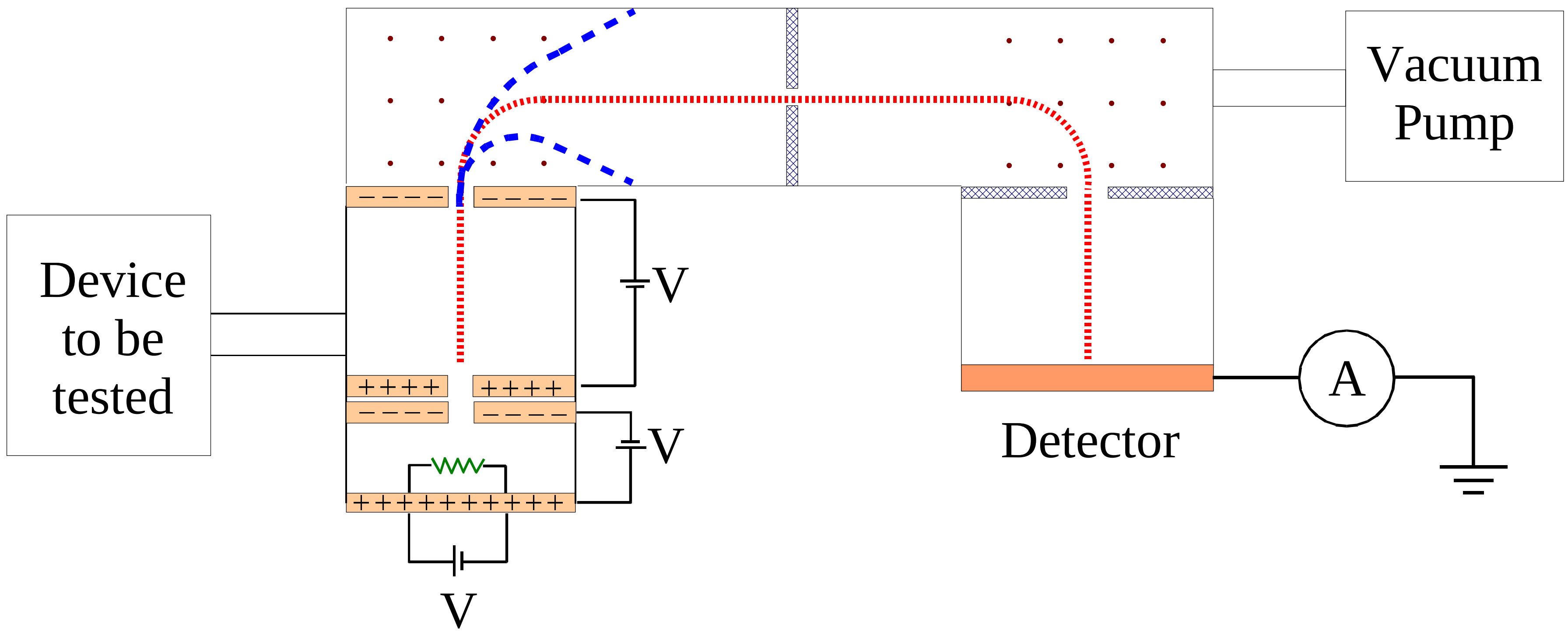
The magnetic force is a function of the incoming particles velocity. The electric force is not. Let's look at the magnitude of both forces.

$$F_E = qE \qquad F_B = qvB\sin\theta = qvB(\text{if } \theta \text{ is 90 deg})$$

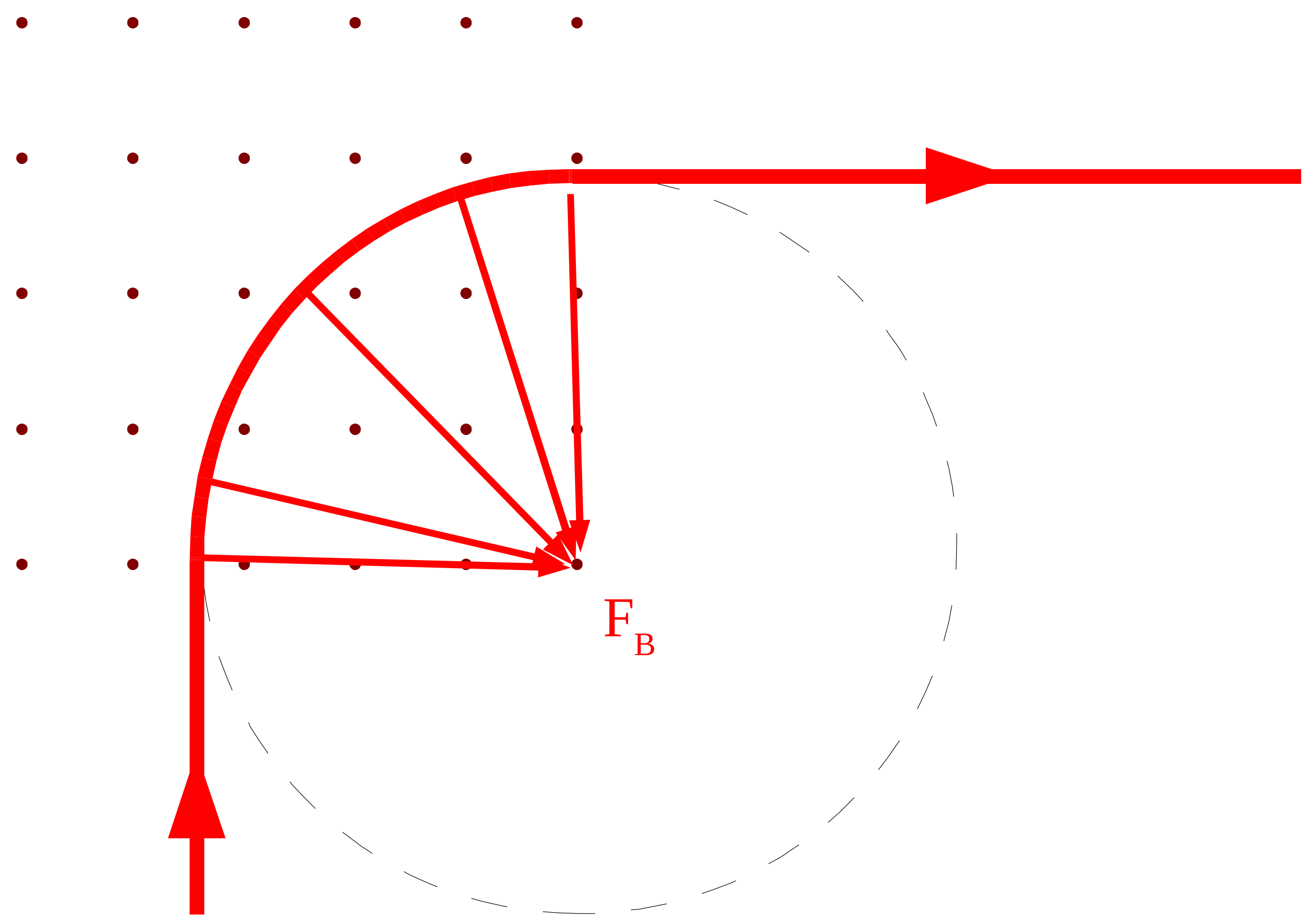
In order to balance: $F_E = F_B$

$$qvB = qE \quad \Rightarrow \quad v = \frac{E}{B}$$

Helium Leak Detector



Magnetic Force is Normal to the Curve and Directed Inward Everywhere



Magnetic Force and Centripetal Force

$$F_B = qVB\sin\theta$$

Let's send the particle into the magnetic field with a velocity perpendicular to the field

so $\sin\theta = \sin 90^o = 1$

$$F_B = qVB$$

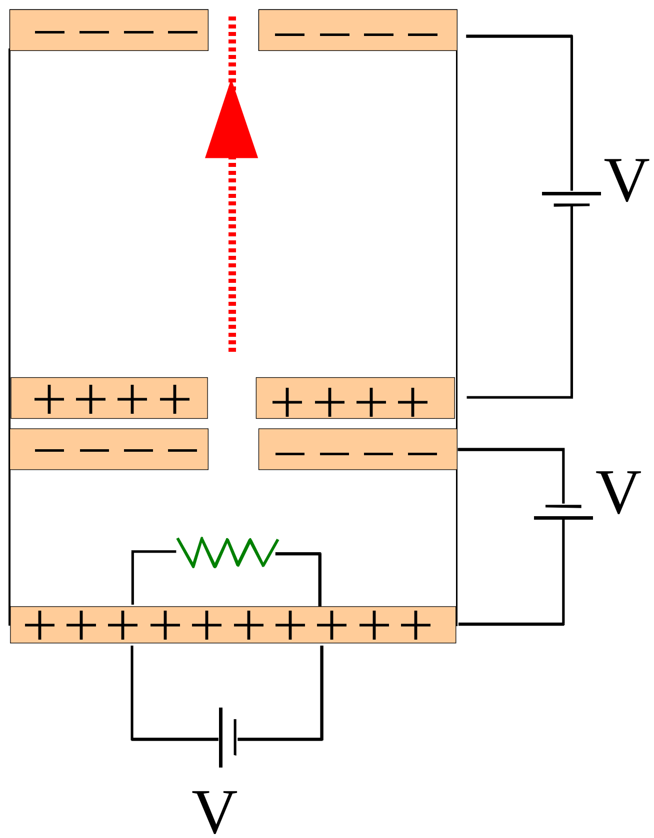
Now, we also know

$F_C = \frac{mv^2}{r}$ so: $\frac{mv^2}{r} = qvB$

or

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

Uniform Acceleration Before **B** Field



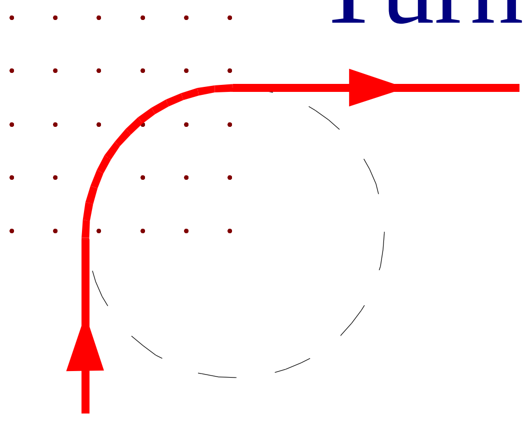
Now look at v.
Before the particle enters the magnetic field, it is accelerated by a uniform ***E*** field.
Using conservation of energy,

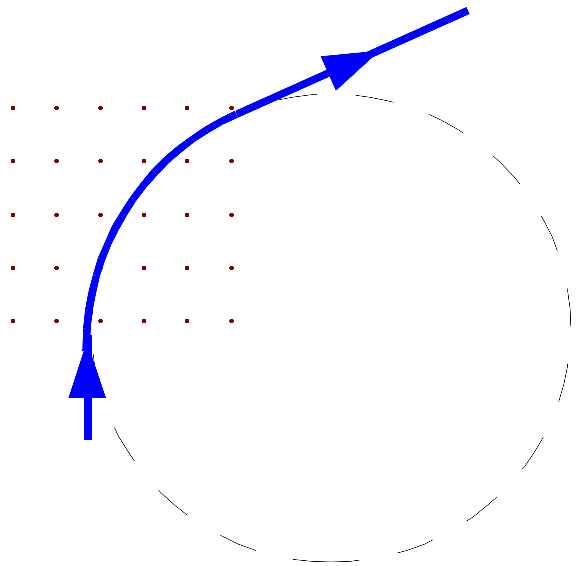
$$\frac{1}{2} m v^2 = q V$$

therefore,

$$v = \sqrt{\frac{2 q V}{m}}$$

Only One Mass Makes the Correct Turn in the Magnetic Field





From before: $\frac{m\,v}{r} = q\,B$ and $v = \sqrt{\frac{2\,q\,V}{m}}$

so: $m\sqrt{\frac{2\,q\,V}{m}}\frac{1}{r} = q\,B$

Now square every term.

$m^2\frac{2\,q\,V}{m}\frac{1}{r^2} = q^2 B^2$ (cancel terms) $\Rightarrow$ $m\,2\,V\frac{1}{r^2} = q\,B^2$

Finally, $m = \frac{q\,r^2}{2\,V}B^2$

A larger mass would make a more shallow turn in the field and not make it through the slit ½ way down the tube between the source and the detector.

A Current in a Wire also Feels a Magnetic Force

Recall $F_B = q V B \sin\theta$

If we multiply the LHS by $\frac{\Delta t}{\Delta t}(1)$

$$F_B = \frac{q}{\Delta t} V \Delta t B \sin\theta$$

but $\frac{q}{\Delta t} = I$

and recall velocity $= \frac{\Delta x}{\Delta t}$

so: $\Delta x = v \Delta t$ or $L = v \Delta t$

(L is the length of the wire in the field)

Finally: $F_B = I L B \sin\theta$