A moving charge in a magnetic field

- basically like an electric current
- the charge experiences a force due to the non-zero component of the field that is perpendicular to its velocity
- + particle => direction of conventional current
  - particle => direction is opposite the conventional current
- use right hand rule to determine direction

Calculation of the force:

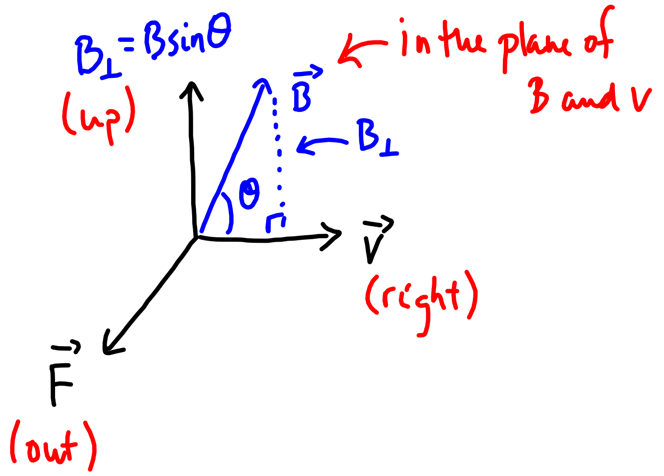
$$F = BIL\sin\theta$$

$$F = B\left(\frac{q}{\Delta t}\right)L\sin\theta$$

$$F = Bq\left(\frac{L}{\Delta t}\right)\sin\theta \qquad v = \frac{L}{\Delta t}$$

$$F = qvB\sin\theta$$

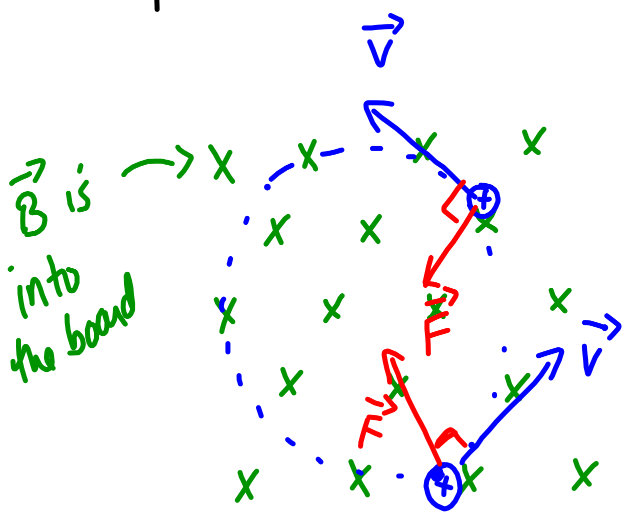
The force is at right angles to the velocity and the field



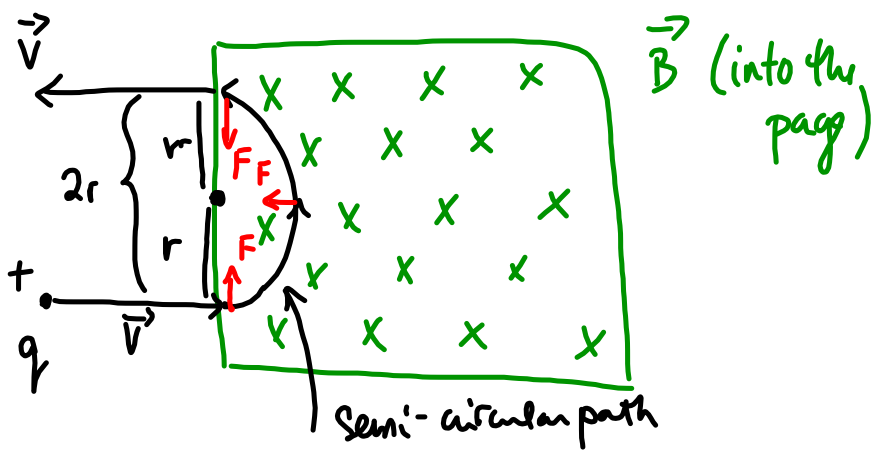
The effect of the force acting on the moving charge

- an unbalanced force acts on the charge (i.e. there is a net force)
- according to Newton's second law, the particle will accelerate in the direction of the net force.

- the particle's direction changes
- the unbalanced force must also change direction since it is at right angles to the velocity.
- the unbalanced force is a centripetal force and the particle travels a circular path.



A charged particle moving at right angles to a magnetic field moves around a circle.



A force which is at right angles to velocity is a centripetal force:

from TOPIC 2: $F = \frac{mv^2}{r}$ from TOPIC 6: $F = qvB$

(for charged particle moving perpendicular to $\vec{B}$)

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

rearranging to solve for r: $r = \frac{mv^2}{qvB}$

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

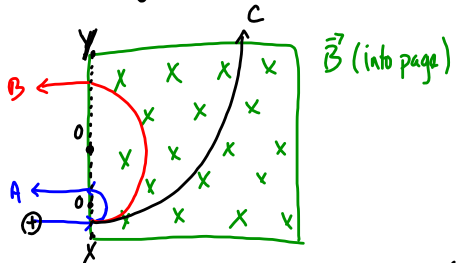
$\frac{m}{q}$ is the mass to charge ratio of the particle.

mv is momentum of the particle (related to kinetic energy)
(recall: $p = \sqrt{2mE}$)

The radius of the particle's circular path is directly proportional the velocity of the particle

The radius of the particle's circular path is directly proportional to the mass to charge ration

The radius of the particle's circular path is inversely proportional to the magnetic field strength.



A has the smallest velocity
C has the largest velocity

The centre of the curved path lies on XY

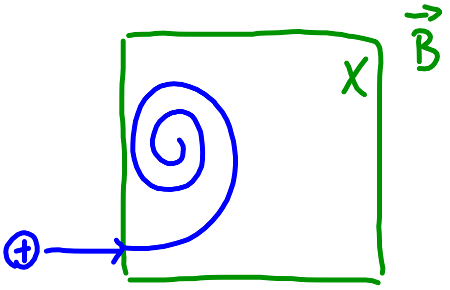
Changing the charge will change the direction of deflection

Changing the direction of the magnetic field changes the direction of the deflection.

changing both and there is no change
(as long as B, v, q, m stay the same)

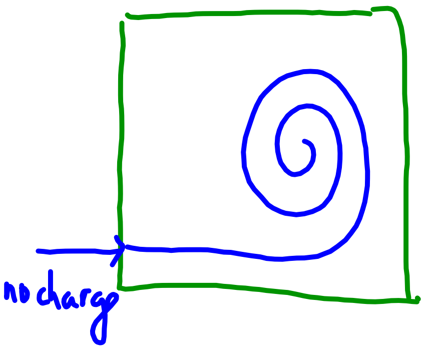
If the mass is greater and the speed stays the same, then the radius will be greater.

Interpreting Particle Paths



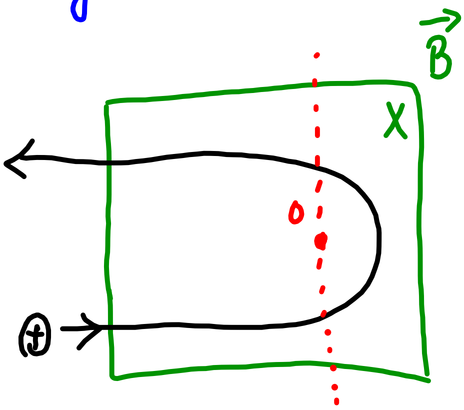
A positive particle enters the field and slows down ($r \propto v$)

path shows that the particle spirals inwards.



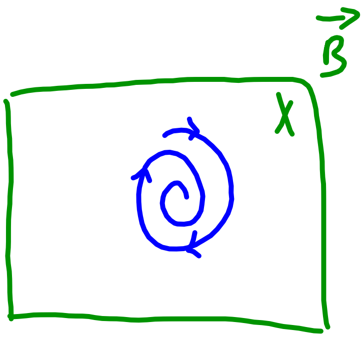
An uncharged particle gains a positive charge and slows down

the path is no curved initially (no charge)



Why is this impossible?

The centre of the curved path is not on the "edge" of the field.



A negative particle is created with high velocity inside the field and is slowing down

The particle was created in the field since no path leads into field.

The particle is neg (curves the way)

slows down ⇒ r gets smaller.

Recall: $F_c = F_{mag}$

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

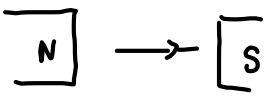
$$r = \frac{mv^2}{qvB}$$

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

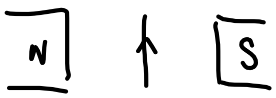
mass to charge ratio

Example

Determine the force per unit length acting on the wire carrying a current of 1.5A in a magnetic field of 4.0×10^{-2} T in each of the situations:



$\rightsquigarrow$ $F = 0 \quad (I \parallel B)$

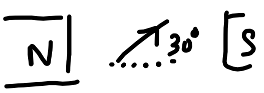


$\rightsquigarrow$ $F = BIL\sin\theta$ $\quad (F = B_{\perp}IL)$

$F = (4.0\times10^{-2}\,T)(1.5A)(1m)\sin 90^\circ$

$F = 6.0\times10^{-2}\,N$

$\vec{F} = 6.0\times10^{-2}\,N$ (into page)



$F = BIL\sin\theta$

$F = (4.0\times10^{-2}\,T)(1.5A)(1m)\sin 30^\circ$

$F = 3.0\times10^{-2}\,N$

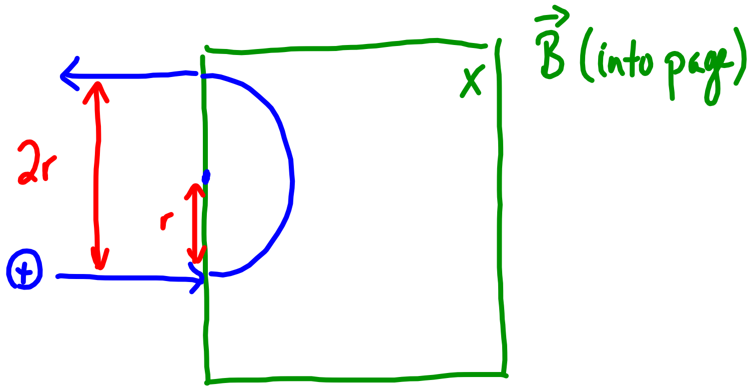
$\vec{F} = 3.0\times10^{-2}\,N$ (into page)

Example

A proton travelling at $5.0\times10^{6}\,ms^{-1}$ enters at right angles into the region of a magnetic field of strength 2.5T. Draw the path that the proton will follow and determine the radius of the curved path in the field.

$m = 1.7\times10^{-27}\,kg$

$q = 1.6\times10^{-19}\,C$



$F_{mag} = F_c$

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

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

$r = \frac{(1.7\times10^{-27}\,kg)(5.0\times10^{6}\,ms^{-1})}{(1.6\times10^{-19}\,C)(2.5\,T)}$

$r = 0.021\ m$

$(2.1\,cm)$