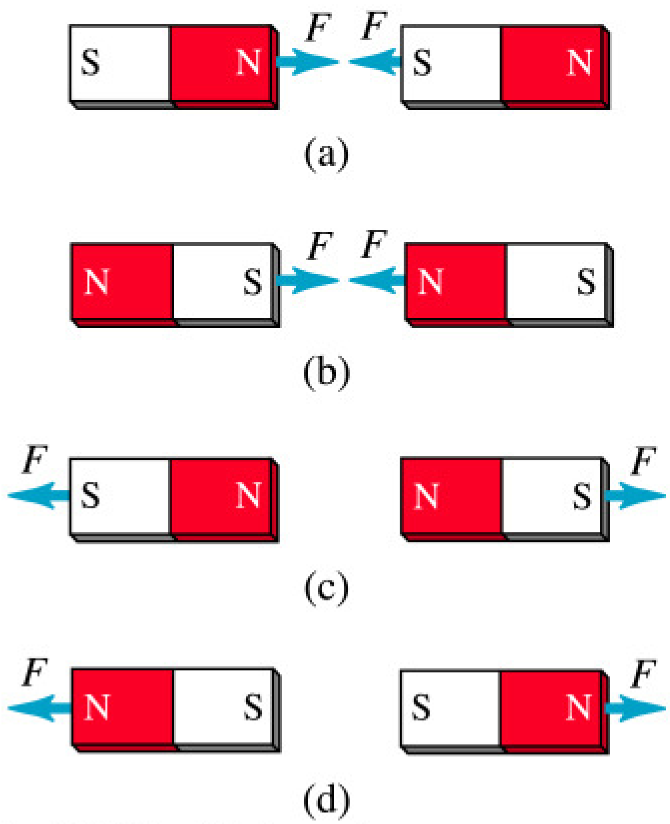
Magnetic Fields and Forces

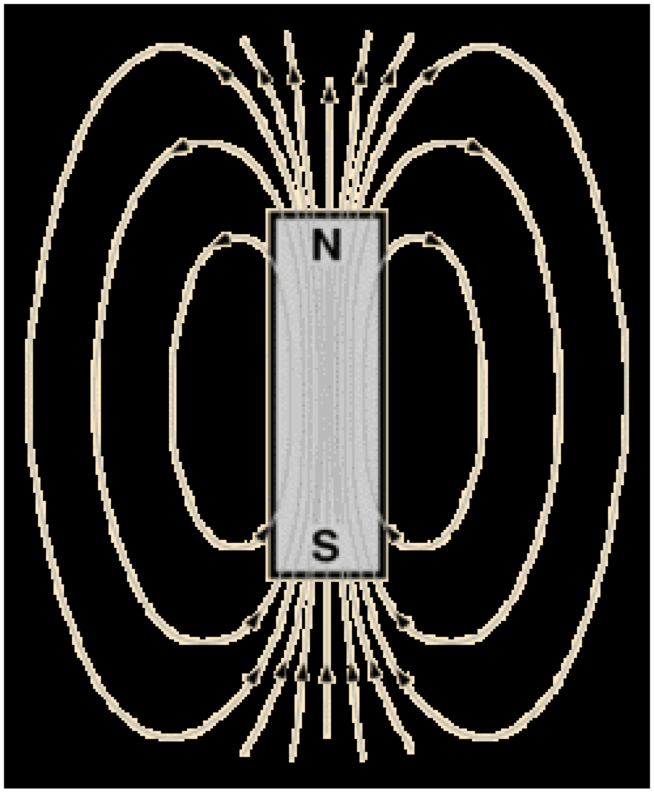
Honors Physics

Facts about Magnetism



- Magnets have 2 poles (north and south)
- Like poles repel
- Unlike poles attract
- Magnets create a MAGNETIC FIELD around them

Magnetic Field

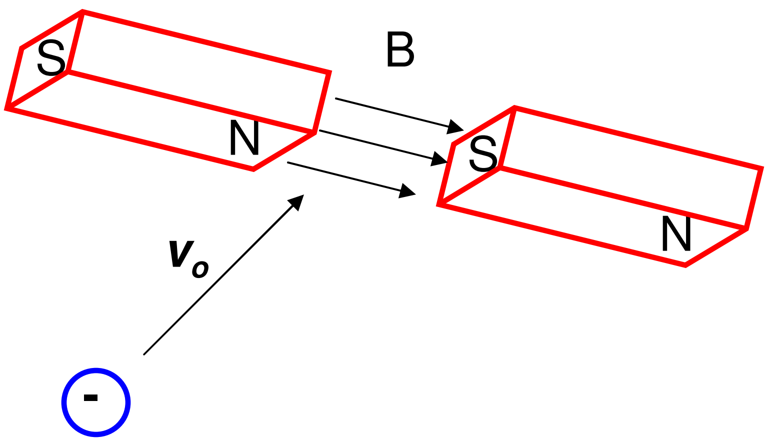


A bar magnet has a magnetic field around it. This field is 3D in nature and often represented by lines LEAVING north and ENTERING south

To define a magnetic field you need to understand the MAGNITUDE and DIRECTION

We sometimes call the magnetic field a B-Field as the letter “B” is the SYMBOL for a magnetic field with the TESLA (T) as the unit.

Magnetic Force on a moving charge



If a MOVING CHARGE moves into a magnetic field it will experience a MAGNETIC FORCE. This deflection is 3D in nature.

$$\vec{F}_B = q\vec{v} \otimes \vec{B}$$

$$F_B = qvB\sin\theta$$

The conditions for the force are:

- Must have a magnetic field present
- Charge must be moving
- Charge must be positive or negative
- Charge must be moving **PERPENDICULAR** to the field.

Magnetic Force

$$\vec{F}_B = q\vec{v} \otimes \vec{B}$$

Magnetic force is a CROSS PRODUCT!

A cross product is one where the vectors involved MUST be perpendicular.

$$F_B = qvB\sin\theta$$

A proton moving east experiences a force of 8.80 x 10^{-19} N upward due to the Earth's magnetic field. At this location, the field has a magnitude of 5.50 x10^{-5} N to the north. Find the speed of the particle.

$$F_B = qvB\sin\theta$$

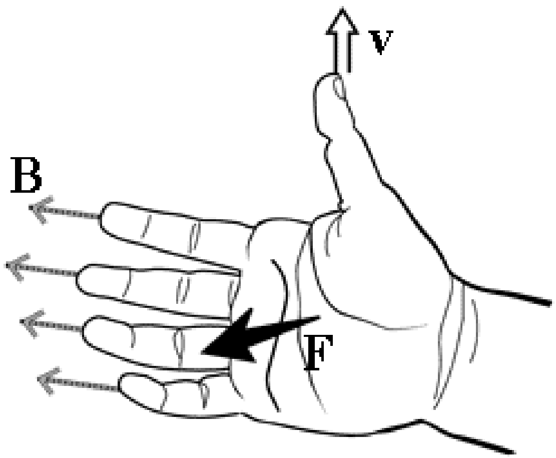
$$8.50x10^{-19} = (1.6x10^{-19})(v)(5.50x10^{-5})\sin 90^\circ$$

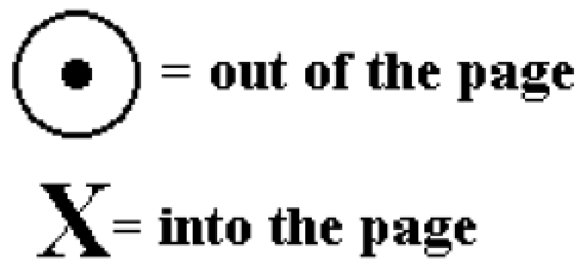
$v =$ **100,000 m/s**

Direction of the magnetic force?

Right Hand Rule

To determine the DIRECTION of the force on a **POSITIVE** charge we use a special technique that helps us understand the 3D/perpendicular nature of magnetic fields.





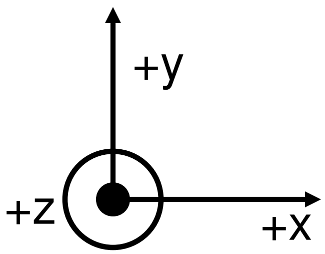
Basically you hold your right hand flat with your thumb perpendicular to the rest of your fingers

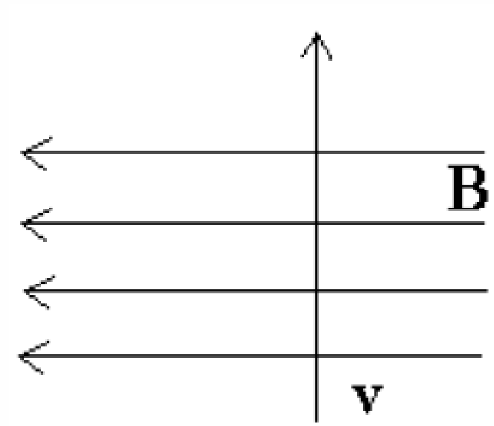
- The Fingers = Direction B-Field
- The Thumb = Direction of velocity
- The Palm = Direction of the Force

For **NEGATIVE** charges use left hand!

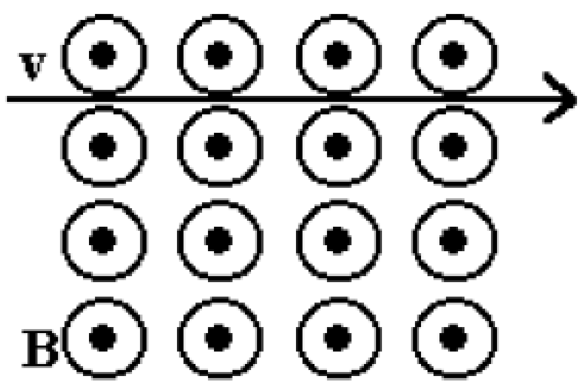
Example

Determine the direction of the unknown variable for a proton moving in the field using the coordinate axis given

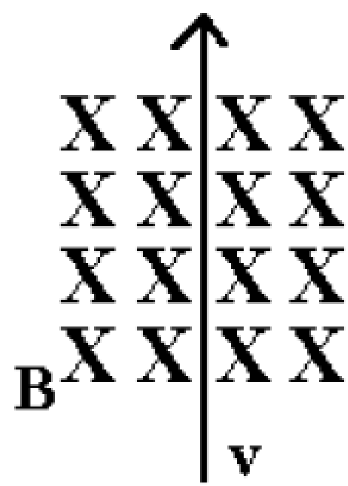




B = -x
v = +y
F = **+z**



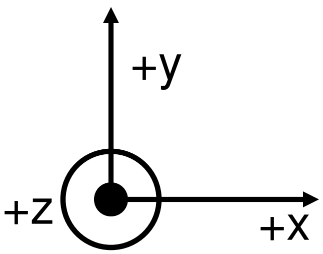
B =+Z
v = +x
F = **-y**

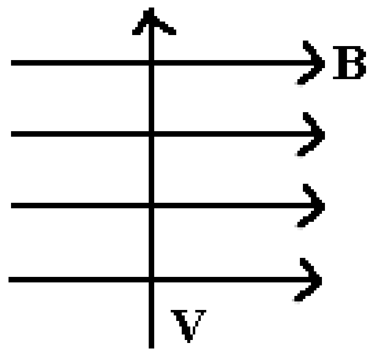


B = -z
v = +y
F = **-x**

Example

Determine the direction of the unknown variable for an electron using the coordinate axis given.

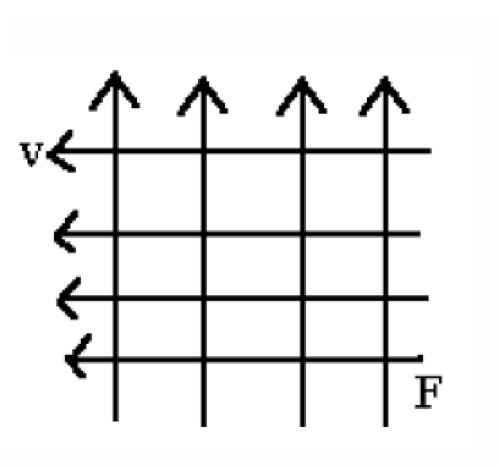




B = +x

v = +y

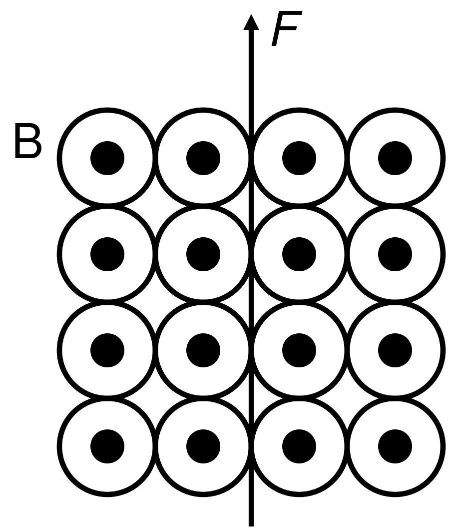
F = **+z**



B = **-z**

v = - x

F = +y



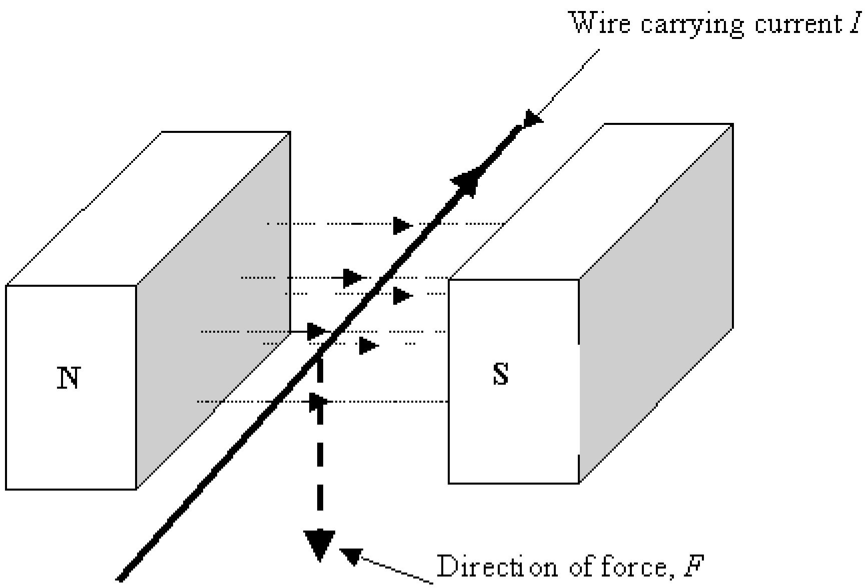
B = +z

v = **+x**

F = +y

Charges moving in a wire

Up to this point we have focused our attention on PARTICLES or CHARGES only. The charges could be moving together in a wire. Thus, if the wire had a CURRENT (moving charges), it too will experience a force when placed in a magnetic field.



You simply used the RIGHT HAND ONLY and the thumb will represent the direction of the CURRENT instead of the velocity.

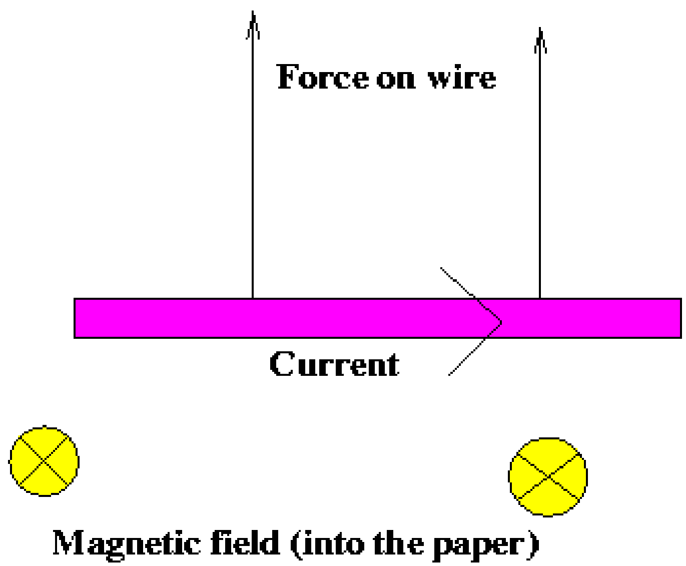
Charges moving in a wire

$$F_B = qvB\sin\theta \times \frac{t}{t}$$

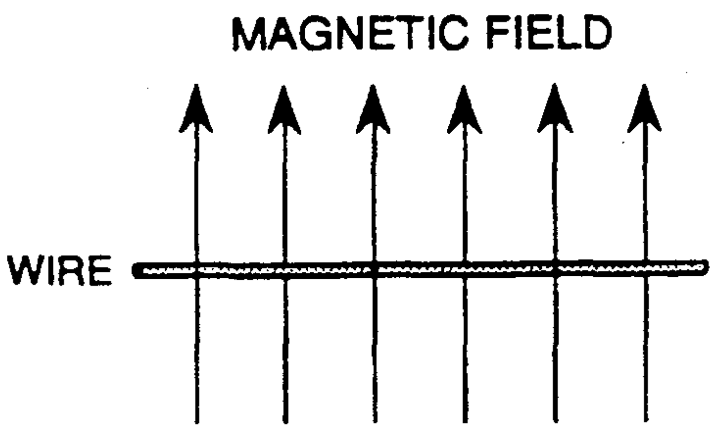
$$F_B = (\frac{q}{t})(vt)B\sin\theta$$

$$F_B = ILB\sin\theta$$

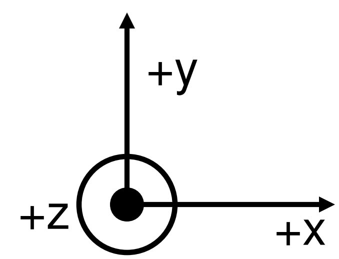
At this point it is VERY important that you understand that the MAGNETIC FIELD is being produced by some **EXTERNAL AGENT**



Example



A 36-m length wire carries a current of 22A running from right to left. Calculate the magnitude and direction of the magnetic force acting on the wire if it is placed in a magnetic field with a magnitude of 0.50 x10^{-4} T and directed up the page.



$$F_B = ILB\sin\theta$$

$$F_B = (22)(36)(0.50x10^{-4})\sin 90$$

$$F_B =$$ **400 N**

B = +y

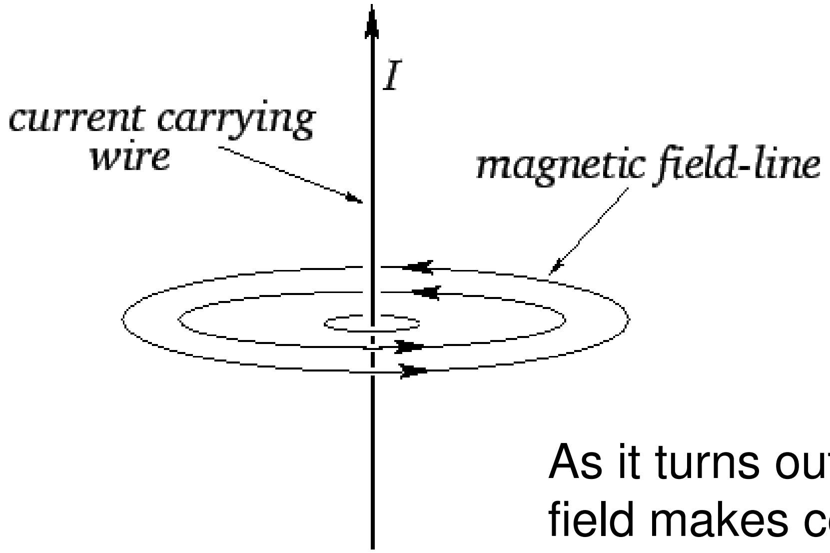
I = -x

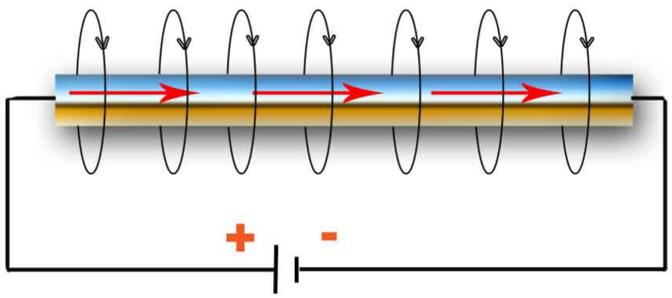
F = **-z, into the page**

WHY does the wire move?

The real question is WHY does the wire move? It is easy to say the EXTERNAL field moved it. But how can an external magnetic field FORCE the wire to move in a certain direction?

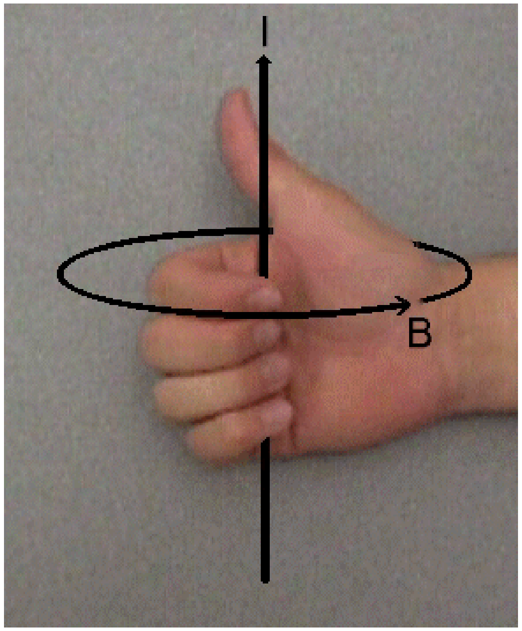
THE WIRE ITSELF MUST BE MAGNETIC!!! In other words the wire has its own INTERNAL MAGNETIC FIELD that is attracted or repulsed by the EXTERNAL FIELD.



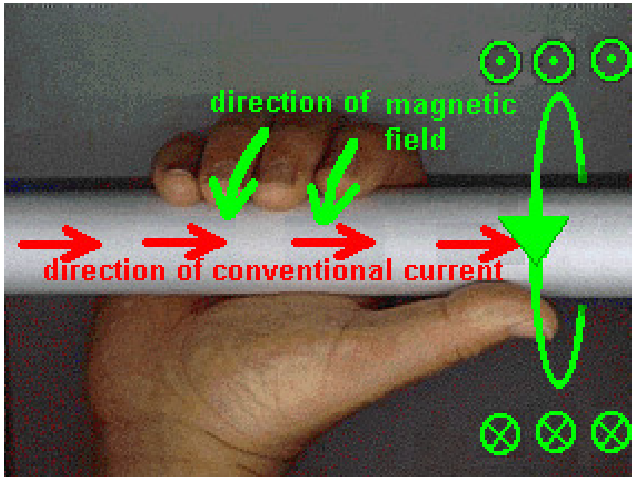


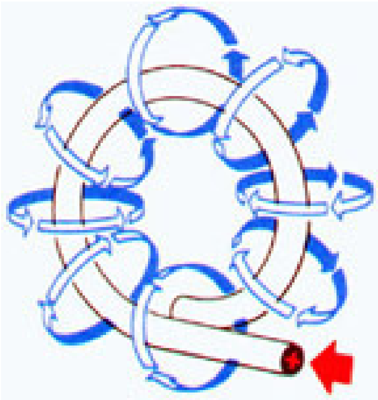
As it turns out, the wire's OWN internal magnetic field makes concentric circles round the wire.

A current carrying wire's INTERNAL magnetic field



To figure out the DIRECTION of this INTERNAL field you use the right hand rule. You point your thumb in the direction of the current then CURL your fingers. Your fingers will point in the direction of the magnetic field





The MAGNITUDE of the internal field

The magnetic field, B, is directly proportional to the current, I, and inversely proportional to the circumference.

$$B \alpha I \qquad B \alpha \frac{1}{2\pi r}$$

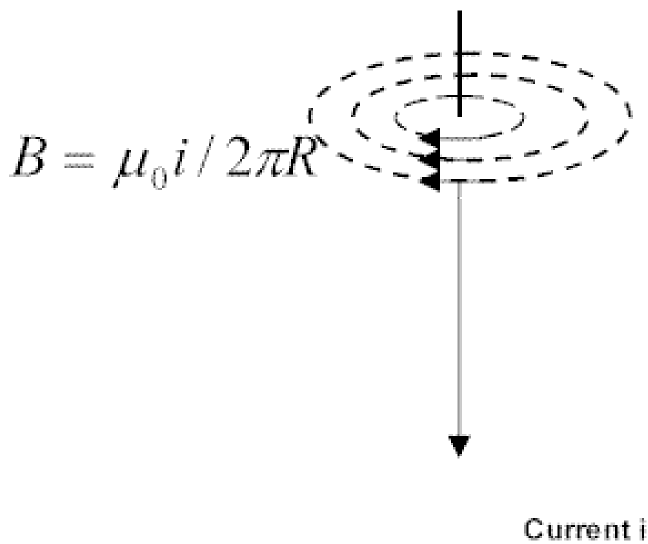
$$B \alpha \frac{I}{2\pi r}$$

μ_o = constant of proportionality

μ_o = vacuum permeability constant

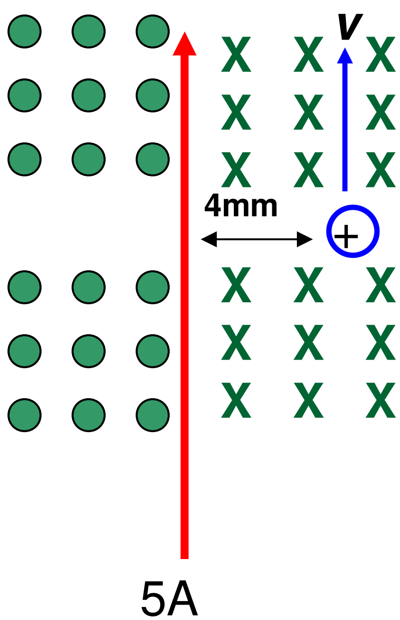
$$\mu_o = 4\pi x 10^{-7} (1.26 x 10^{-6}) \frac{Tm}{A}$$

$$B_{\text{internal}} = \frac{\mu_o I}{2\pi r}$$



Example

A long, straight wires carries a current of 5.00 A. At one instant, a proton, 4 mm from the wire travels at 1500 m/s parallel to the wire and in the same direction as the current. Find the **magnitude** and **direction** of the magnetic force acting on the proton due to the field caused by the current carrying wire.



B = +z

v = +y

F = **-x**

$$F_B = qvB_{EX} \qquad B_{IN} = \frac{\mu_o I}{2\pi r}$$

$$B_{IN} = \frac{(1.26x10^{-6})(5)}{2(3.14)(0.004)} =$$ **2.5 x 10^{-4} T**

$$F_B = (1.6x10^{-19})(1500)(B_{wire}) =$$

6.0 x 10^{-20} N