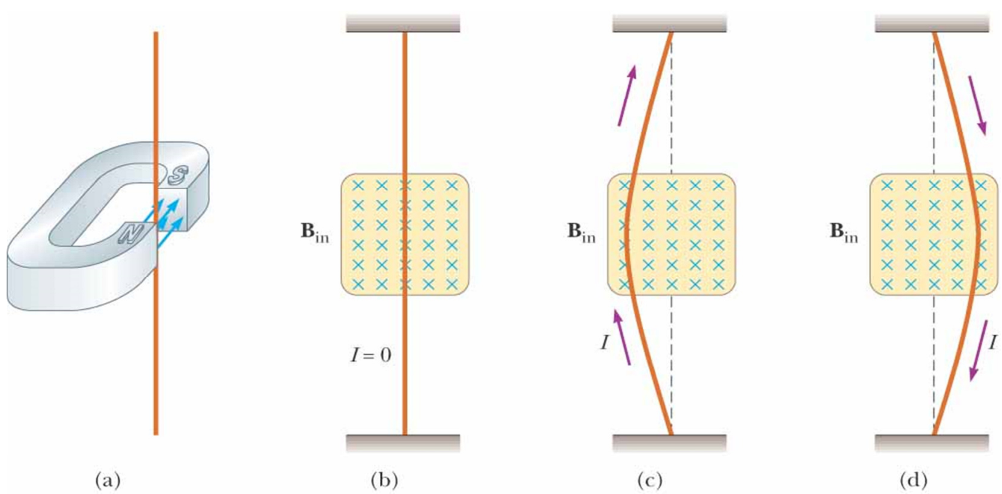
29.2 Magnetic Force acting on a current-carrying conductor

If a magnetic force is exerted on a single charged particle when the particle moves through a magnetic field, it should not surprise you that a current-carrying wire also experiences a force when placed in a magnetic field.

The current is a collection of many charged particles in motion; hence, the resultant force exerted by the field on the wire is the vector sum of the individual forces exerted on all the charged particles making up the current.

The force exerted on the particles is transmitted to the wire when the particles collide with the atoms making up the wire.



We have learned that a charged particle is affected by a magnetic force when it is placed in magnetic field, called eq. (29.1)

$$\vec{F}_B = q\ \vec{\mathrm{v}} \mathrm{x} \vec{\mathrm{B}} = \mathrm{q}|\vec{\mathrm{v}}||\vec{\mathrm{B}}|\ \sin\theta$$

So, for N charged particle that moves in wire of length *l* and cross section A (see figure below) the magnetic force can be written as,

$$\vec{F}_B = Nq\ \vec{v} \mathrm{x} \vec{B}$$

Or,

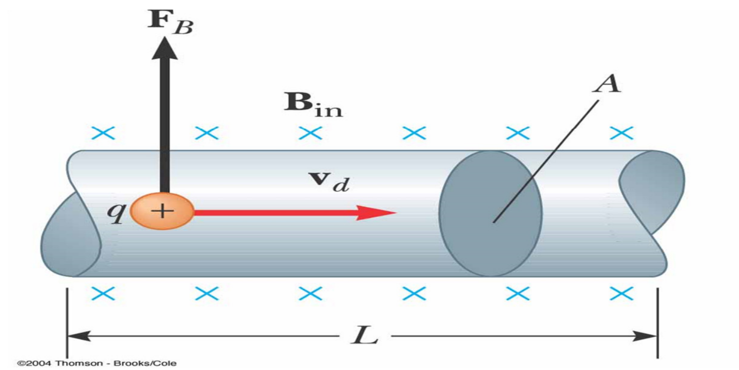
$$\vec{F}_B = n.A.l\ q\ \vec{v} \mathrm{x} \vec{B}$$

But, we know that $I = nqv_dA$.

Then,

$$\boxed{\vec{F}_B = I\ \vec{l} \mathrm{x} \vec{B}}$$

This equation represents the magnetic force exerting on a wire of length *l* and carrying current I.

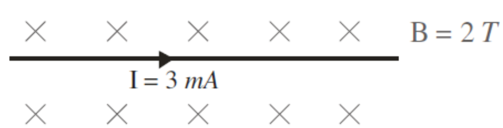


Examples:

1- A straight wire 10 m long carries a current of 50A placed in a perpendicular uniform magnetic field. If the force per unit length on this wire is 4 N/m, what is the magnitude of the magnetic field.

2- A conductor 3 m long carries a current of 5A is placed in a region parallel to a uniform magnetic field of 2 T. What is the magnetic force acting on the conductor?

3- If the magnetic force acting on the wire equals 9 *mN*, the length (L) is:



4- When a proton moves with a speed of 4 × 106 m/s through a magnetic field of 1.7 T, it experiences a magnetic force of 9.4 × 10-13N. The angle between the proton's velocity and the magnetic field is: