October 8th

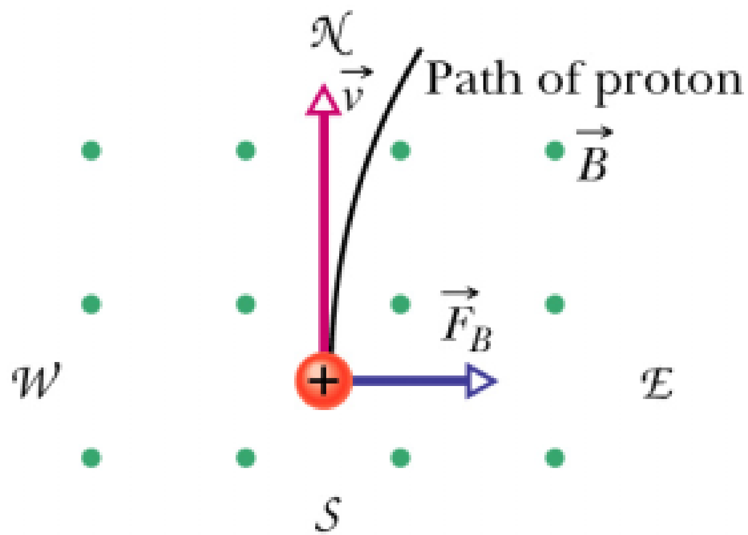
Magnetic Fields - Chapter 29

Review

- Force due to a magnetic field is $\vec{F}_B = q\vec{v} \times \vec{B}$

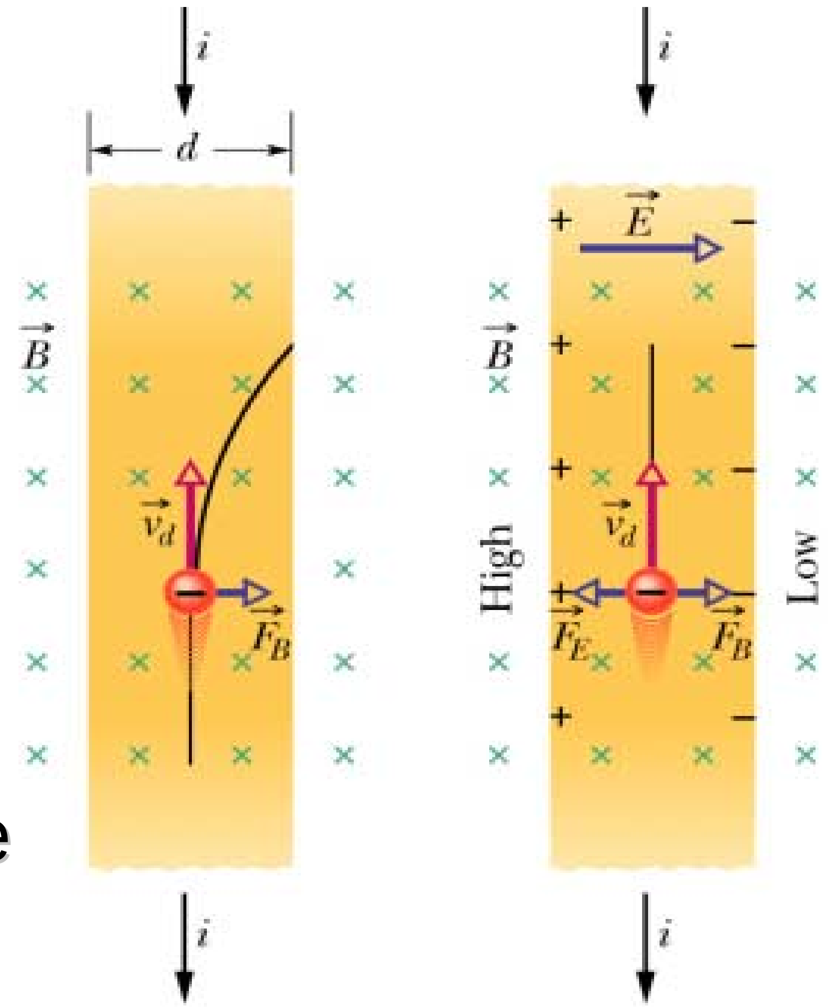
- Charged particles moving with $v \perp$ to a B field move in a circular path with radius r

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



Hall Effect

- Electrons moving in a wire (= current) can be deflected by a *B* field called the Hall effect
- Creates a Hall potential difference, *V*, across the wire
- Instead of an individual electron let's consider the current through the wire



What is F_B on a current?

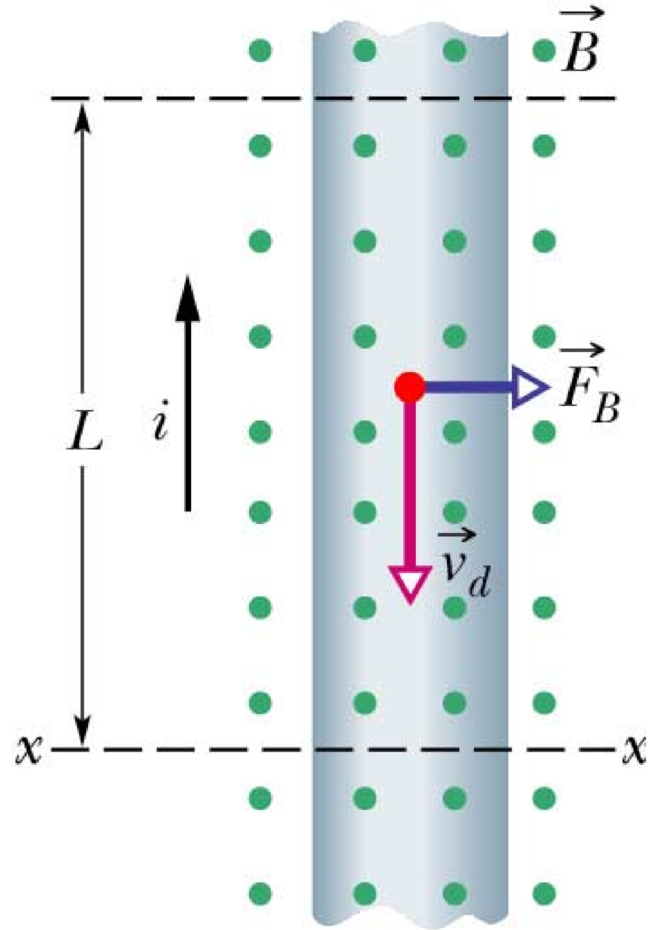
$$\vec{F}_B = q\vec{v} \times \vec{B}$$

- Want to replace q with i

$$i = \frac{dq}{dt} \quad \text{so} \quad q = it$$

- Relate time t to length of wire L and drift velocity v_d

$$v_d = \frac{L}{t} \quad \text{so} \quad t = \frac{L}{v_d}$$



Magnetic Fields (Fig. 29-17)

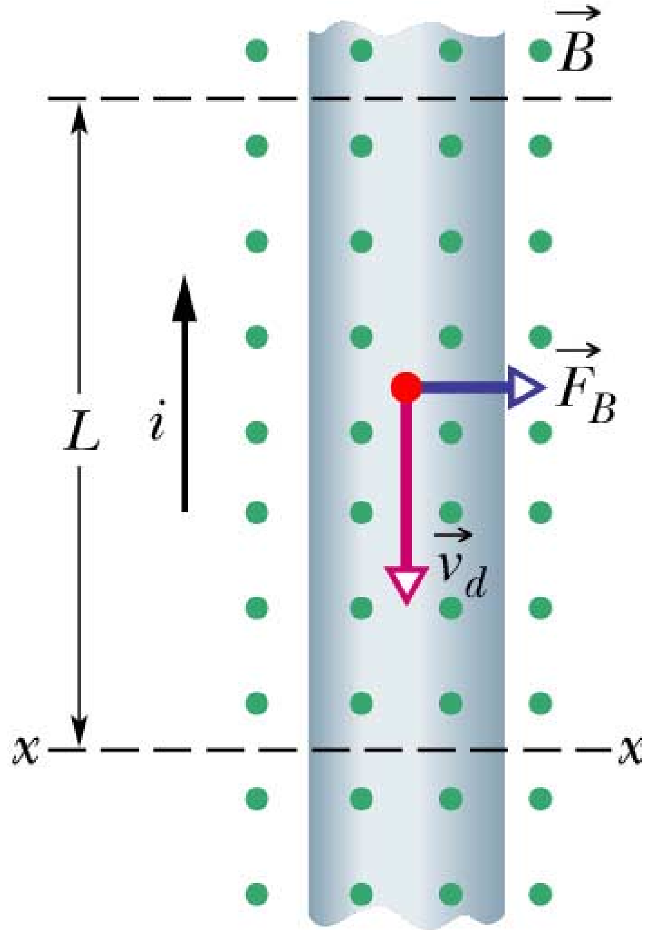
- Charge is $q = \frac{iL}{v_d}$

- Substitute this for q in

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

- Velocity is drift velocity, v_d

$$F_B = qv_d B \sin\phi = \frac{iLv_d}{v_d} B \sin\phi$$

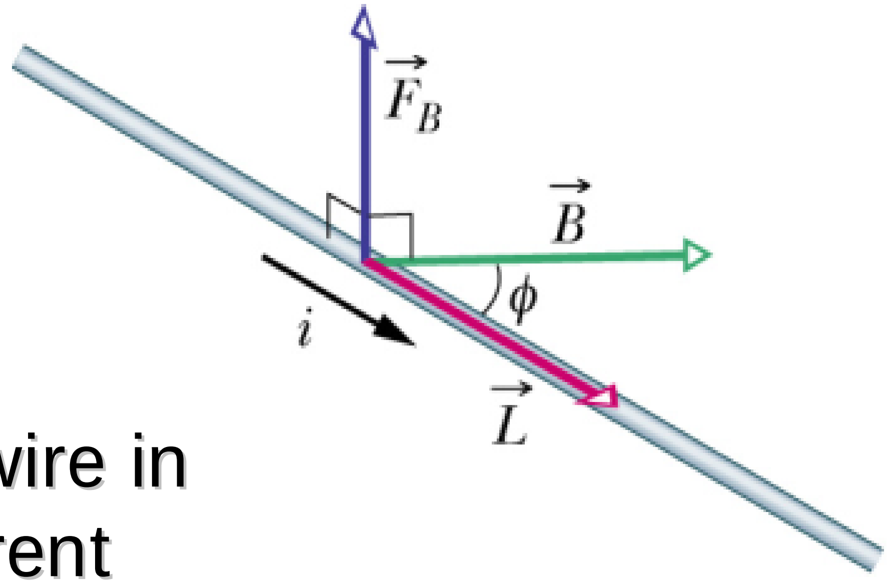


Magnetic Fields (Fig. 29-18)

$$F_B = iLB\sin\phi$$

- Force on a current is

$$\vec{F}_B = i\vec{L}\times\vec{B}$$

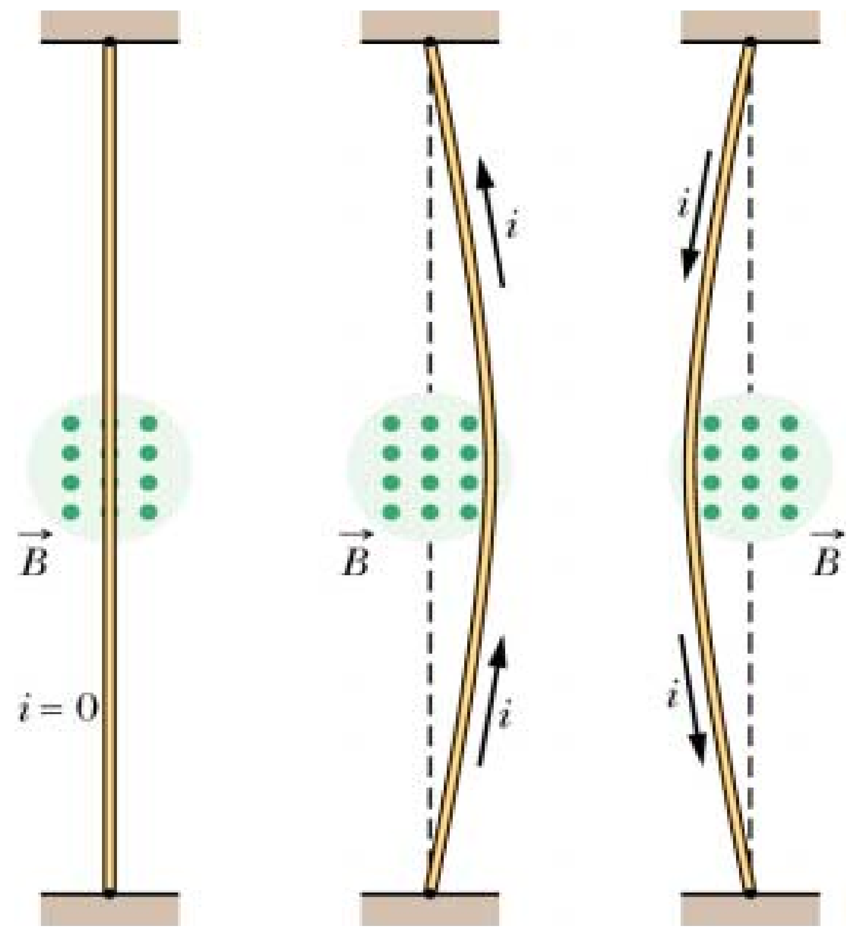


- Vector L points along wire in the direction of the current

- Force on a single charge is $\vec{F}_B = q\vec{v}\times\vec{B}$

Magnetic Fields (Fig. 29-16)

- Hall effect - *B* field exerts force on electrons moving in wire
- Electrons cannot escape wire so force is transmitted to wire itself
- Change either direction of current or *B* field, reverses force on wire



Checkpoint #5

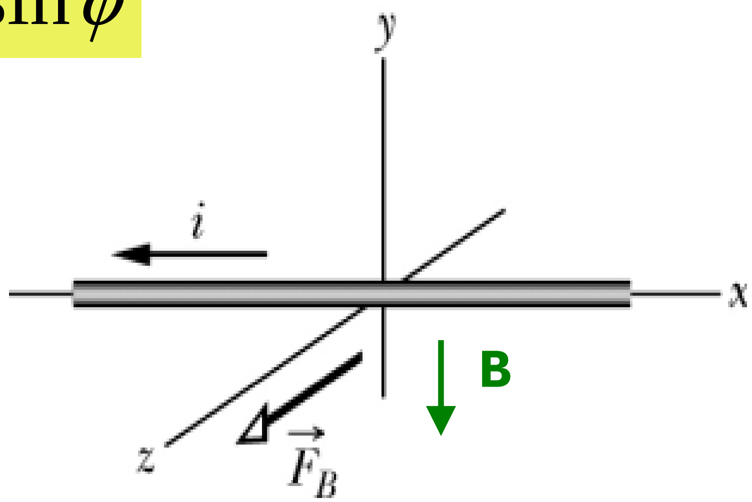
- What is the direction of the *B* field so F_B is maximum?

$$\vec{F}_B = i\vec{L} \times \vec{B} = iLB\sin\phi$$

- Where's the maximum?

$$\sin\phi = 1, \quad \phi = 90$$

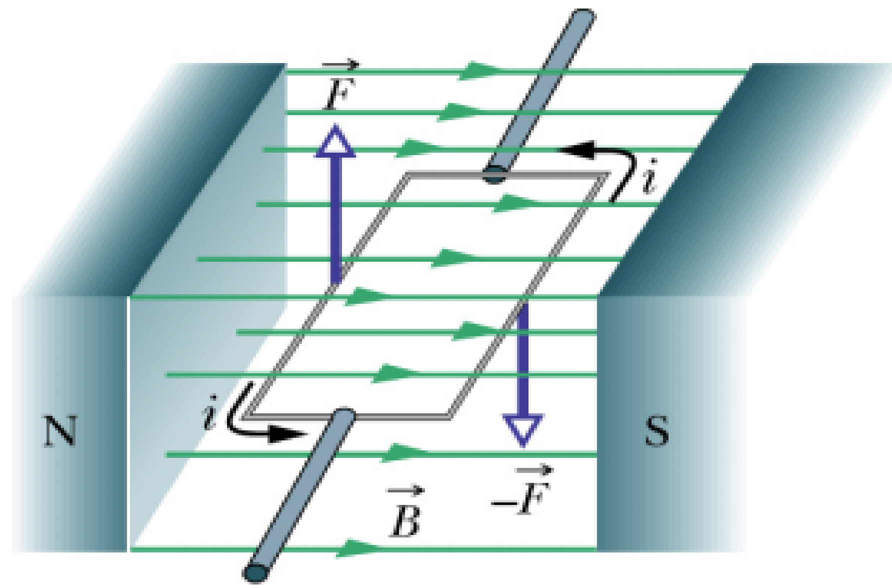
- What's the direction of *B* ?
  Use right-hand rule



B points in -y

Magnetic Fields (Fig. 29-20)

- What happens if we put a loop of wire carrying a current in a *B* field ?



- F_B on opposite sides of the loop produce a torque on the loop causing it to rotate.

Electric motor – a commutator reverses the direction of the current every half turn to that the torque is always in the same direction.

Magnetic Fields (Figs. 29-21c)

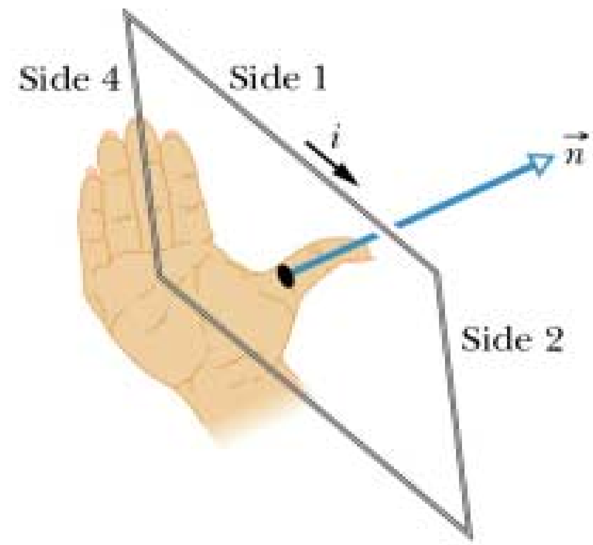
- Define normal *n* to plane using right-hand rule
- Torque tends to rotate loop to align *n* with *B* field
- Torque for single loop

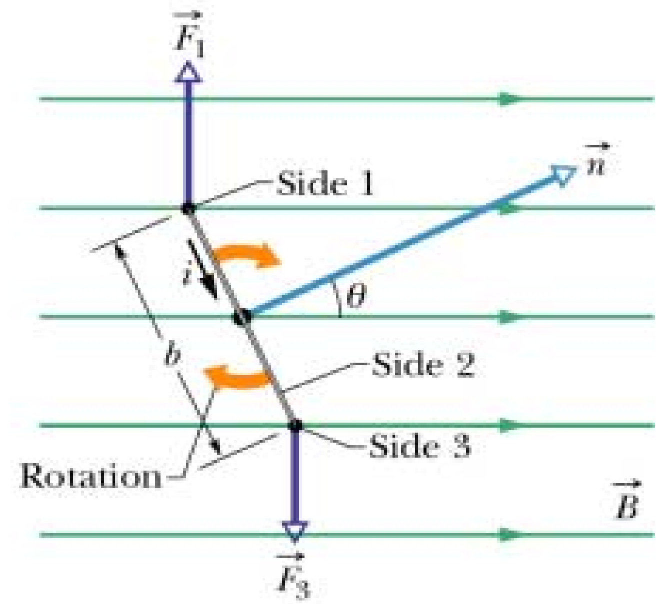
$$\tau = iAB\sin\theta$$

where A is the area of the loop and θ is between *n* and *B*

- Replace single loop with coil of *N* loops or turns

$$\tau = (NiA)B\sin\theta$$





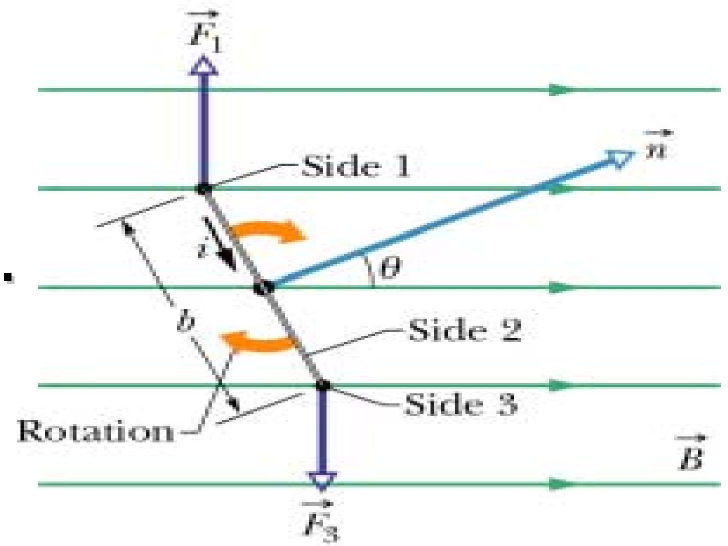
Magnetic Fields

- Define magnetic dipole moment $\mu = NiA$

$$\tau = (NiA)B\sin\theta = \mu B\sin\theta$$

- The direction of the magnetic dipole moment is the same as the normal vector to the plane.

$$\vec{\mu} = \vec{n}$$



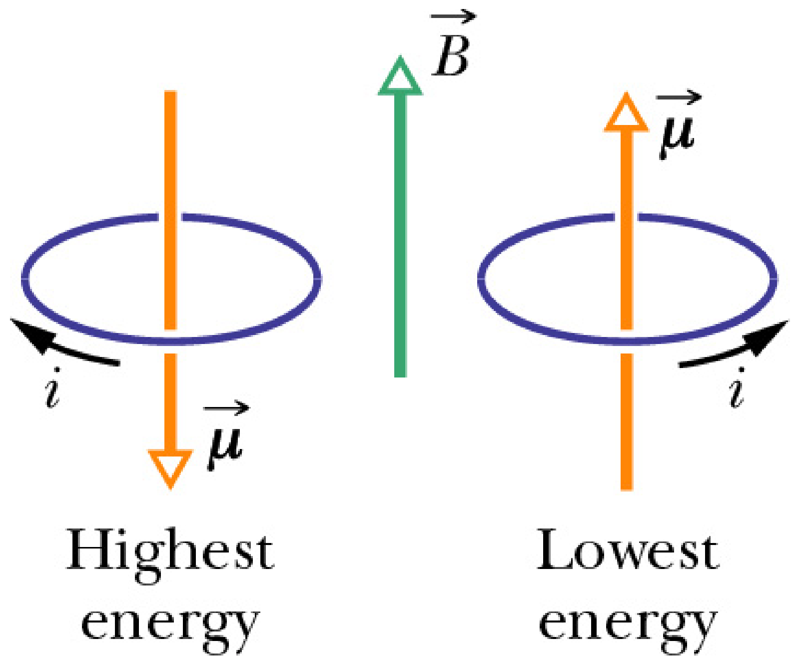
- The torque becomes

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

Magnetic Fields

- A magnetic dipole in a magnetic field has a magnetic potential energy, *U*
- Lowest energy when dipole moment lined up with *B* field
- Highest energy when dipole moment directed opposite *B* field

$$U = -\vec{\mu} \bullet \vec{B}$$



Magnetic Fields

- Magnetic dipole moment μ has

Torque

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

Potential Energy

$$U = -\vec{\mu} \bullet \vec{B}$$

- Remember electric dipole moment *p*

Torque

$$\vec{\tau} = \vec{p} \times \vec{E}$$

Potential Energy

$$U = -\vec{p} \bullet \vec{E}$$