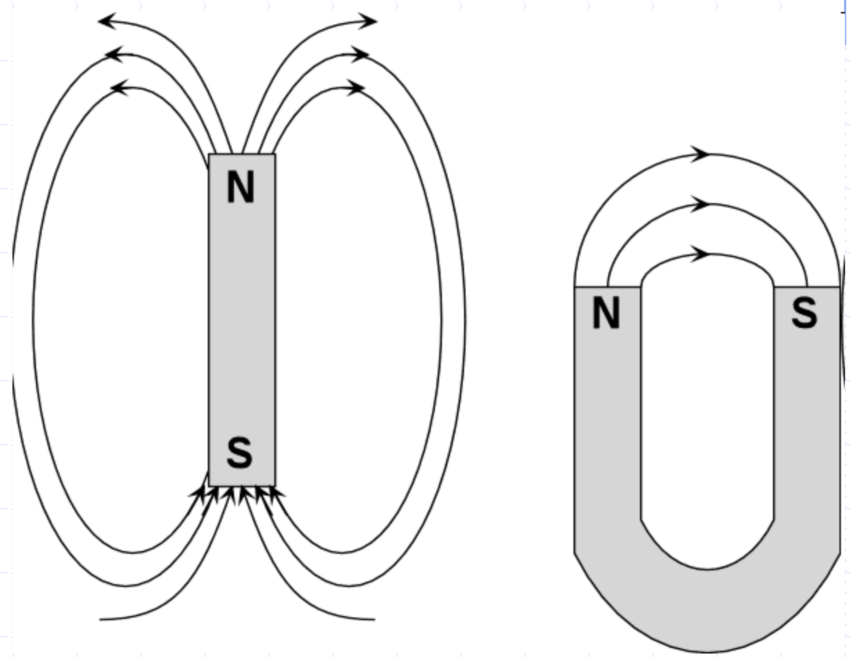
Chapter 21 Summary: Magnetic Forces and Magnetic Fields

Essential Concepts and Summary

Magnetic Fields

- Magnetic forces have property that like poles repel, unlike poles attract
- Unlike electric charges, nobody has isolated a magnetic monopole. Even smallest magnets are dipoles.
- Field lines go N-S
- SI Unit: Tesla



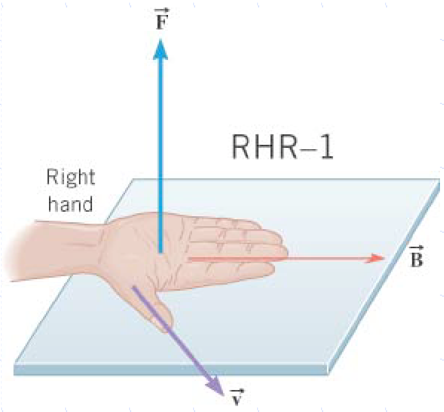
Magnetic Fields on Moving Charges

- 2 Conditions for Magnetic Force: charge must be moving and cannot be moving parallel to direction of magnetic field
- Right Hand Rule 1: palm=Force, thumb=velocity, fingers=magnetic field (particle is positive)
- RHR becomes LHR for negative particles

$$F = |q_0| B(v \sin\theta)$$

$$1T = \frac{1N \cdot 1s}{1C \cdot 1m}$$

$$1\ gauss = 10^{-4}\ T$$



Motion of Charged Particle in Magnetic Field

- While motion in electric field is in plane of field, motion in magnetic field is perpendicular to field
- Hence, b/c displacement is never in same direction as magnetic force, the *magnetic force cannot do work*
- Speed of particle does *not* change—only direction
- Magnetic force remains perpendicular to velocity and is directed toward the center of the circular path
- Convention: **x** means points into page, **.** means out of page

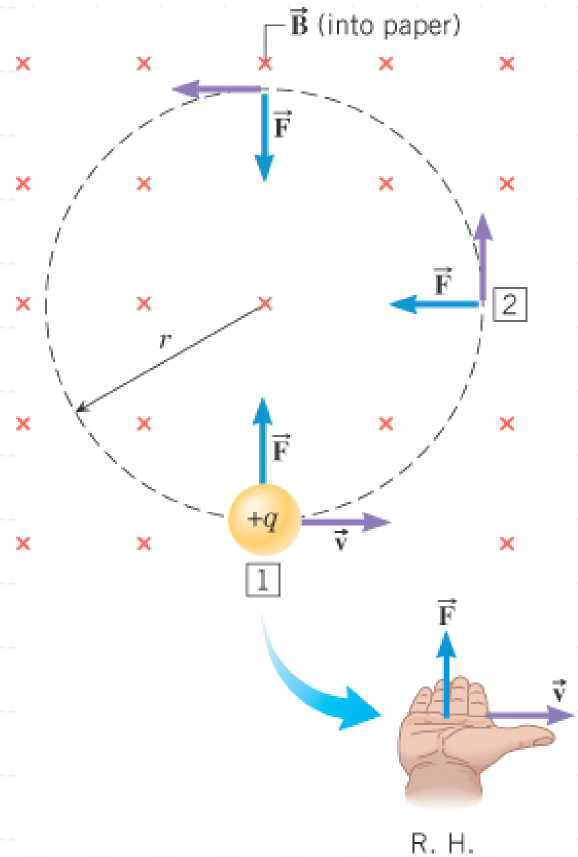
Charged Particle in Circular Trajectory

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

$$F = |q| vB \sin(90^\circ)$$

$$|q| vB \sin(90^\circ) = \frac{mv^2}{r}$$

$$r = \frac{mv}{|q| B}$$



Mass Spectrometer

- Identifies unknown molecules
- Atoms vaporized and ionized, leaving with net positive charge of +e.
- Accelerated through difference V, gaining speed v. Then enter magnetic field B
- The mass m can be expressed in terms of r, B, and v.

$$m = \left(\frac{er^2}{2V}\right)B^2$$

Force of Current in Magnetic Field

- RHR stays same, except v is replaced by I
- The magnetic force exerted on a series of charges, I, for time _t.
- As in case with single charge, force is greatest when current is perpendicular to magnetic field

$$F = qvB\sin\theta$$

$$F = \left(\frac{\mathrm{V}q}{\mathrm{V}t}\right)(v\mathrm{V}t)B\sin\theta$$

$$F = ILB\sin\theta$$

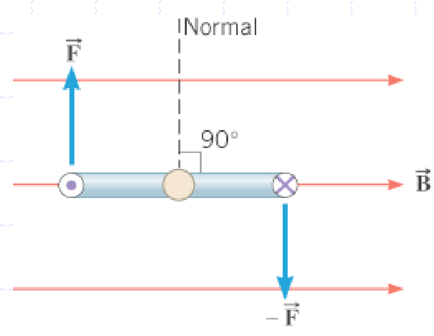
Torque on a Current-Carrying Coil

- When a loop is placed in a magnetic field, the loop tends to rotate such that its normal becomes aligned with the magnetic field.
- The quantity NIA is called the magnetic moment, and its unit is ampere x meter^2

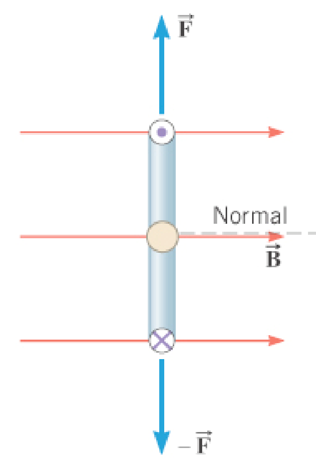
$$\tau = ILB\left(\frac{1}{2}w\sin(\phi)\right) + ILB\left(\frac{1}{2}w\sin(\phi)\right)$$

$$\tau = IAB\sin\phi$$

$$\tau = NIAB\sin(\phi)$$



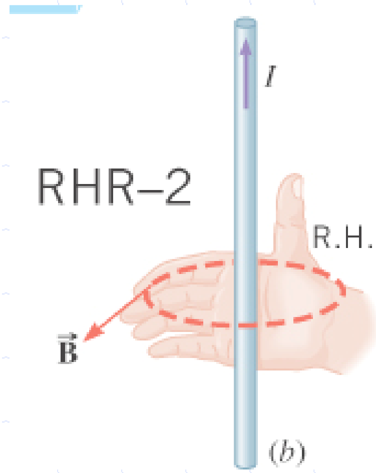
(a) Maximum torque

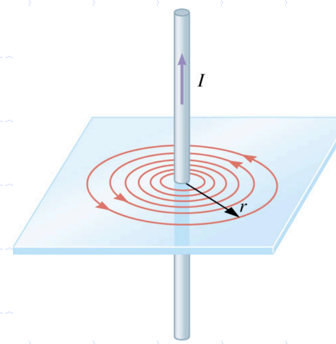


(b) Zero torque

Magnetic Field Produced by Currents

- Current-carrying wire produces a magnetic field of its own
- RHR No. 2: Curl the right hand into a half circle. The thumb is the conventional current I, the tip of the fingers are the magnetic field B.

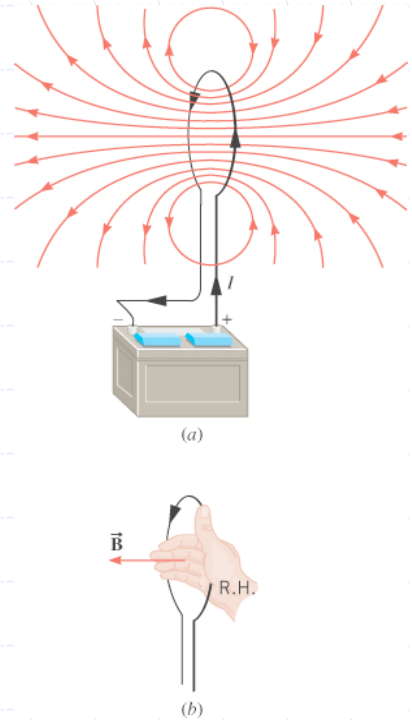




$$B = \frac{\mu_0 I}{2\pi r}$$

$$\mu_0 = 4\pi \cdot 10^{-7} \frac{T \cdot m}{A}$$

Magnetic Field Produced by Currents in Loops

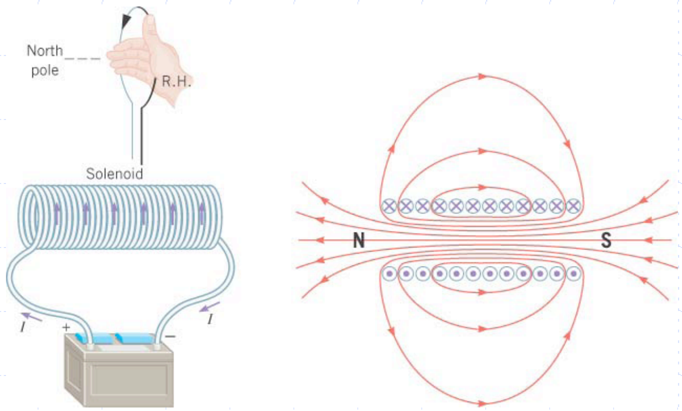


- Magnetic fields created by loops.
- If a circular loop with N loops, at center of loop the magnetic field is perpendicular to plane of loop.

$$B = N\frac{\mu_0 I}{2R}$$

Magnetic Field Produced by Currents--the Solenoid

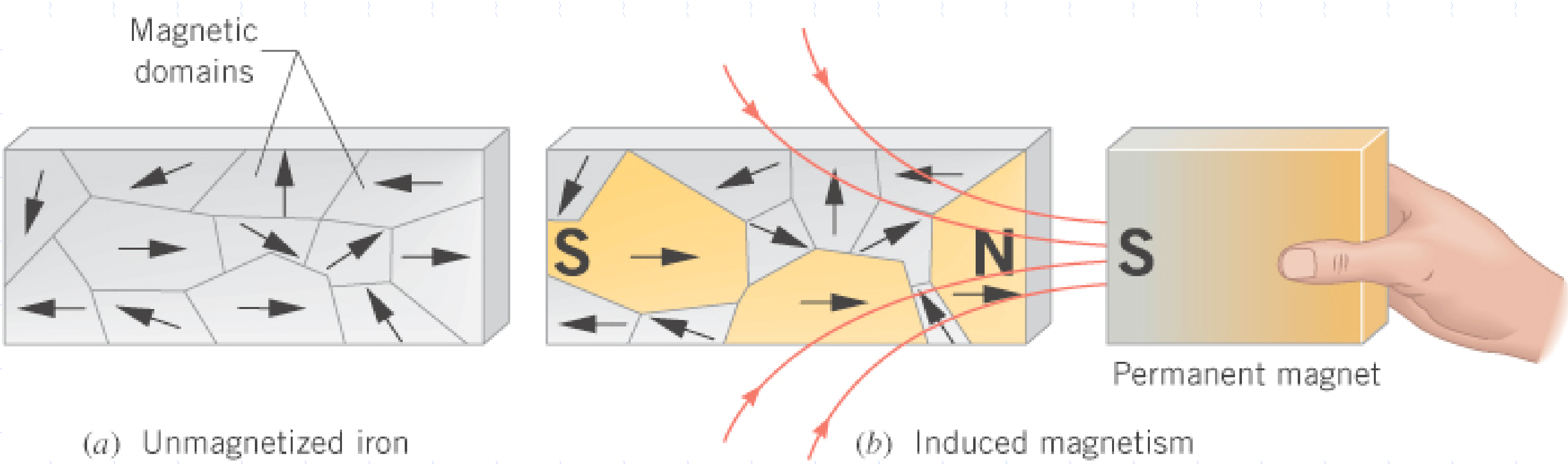
- Solenoid is long coil of wire in shape of helix.
- In essence, when the turns are tight enough and there are enough of them, the entire thing acts as single bar magnet



$$B = \mu_0 n I$$

Induced Magnetism

- Some metals are **ferromagnetic**, meaning their atoms behave like mini magnets, but on a grand scale they cancel out. When placed in external magnetic field, these can be lined up and the metal then becomes magnetized.



(a) Unmagnetized iron (b) Induced magnetism

Images:

- http://www.ncat.edu/~ylin/phys226/Ch21A.pdf
- http://physicslearning.colorado.edu/PiraHome/PhysicsDrawings.htm