Physics 1B
Electricity & Magnetism

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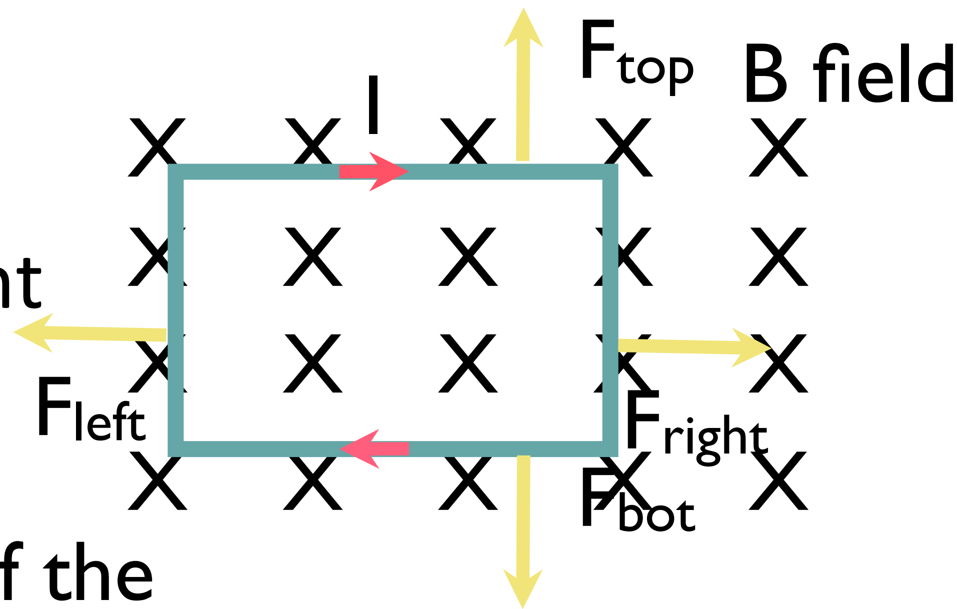
Outline of today

- Finish Chapter 22
  - Torque on a current loop
- Start with Chapter 23

Torque on a Current Loop

Let's say we have a rectangular loop of wire (of length b and width a) with a clockwise current immersed in a magnetic field.



What would be the direction of the magnetic force on this wire loop?

Use RHR1 on each section of the wire.

For the top section, the force would point upward.

For the bottom, the force would point downward.

For the left, the force would point to the left.

For the right, the force would point to the right.

Torque on a Current Loop

- The forces cancel out. So nothing will happen to the loop.

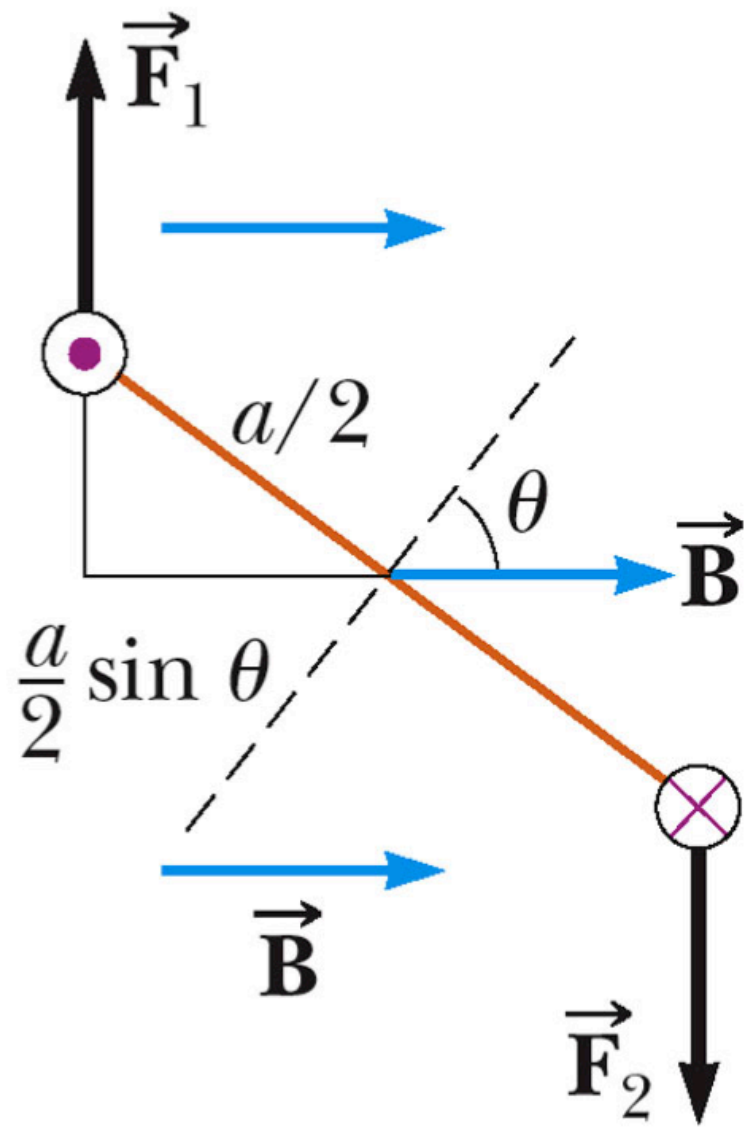
But, what if the wire loop was slightly tilted (θ) with respect to the magnetic field.

Now, we can create a torque due to these forces about a central axis.

The torque on the top section will be given by:

$$\tau_{top} = |\vec{r}||\vec{F}_{top}|\sin\theta$$

$$\tau_{top} = \frac{a}{2}F_{top}\sin\theta$$



Torque on a Current Loop

- The torque on the bottom section will be given by:

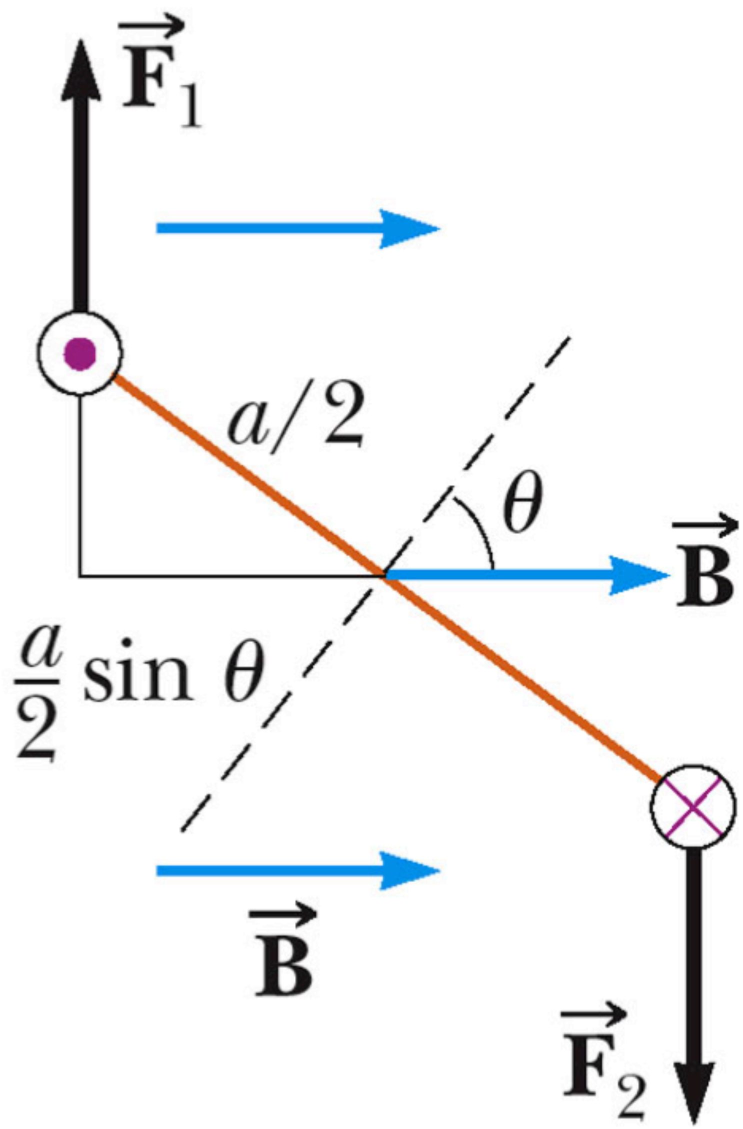
$$\tau_{bot} = |\vec{r}||\vec{F}_{bot}|\sin\theta$$

$$\tau_{bot} = \frac{a}{2} F_{bot} \sin\theta$$

The force on the top and bottom wire will have the same magnitude given by:

$$F_{top} = F_{bot} = IbB\sin 90^\circ = IbB$$

Also, by right hand rule, the torques will point in the same direction, such that the torque from the top and bottom add.



Torque on a Current Loop

To find the total torque on the current loop, merely add the torques:

$$\tau_{tot} = \tau_{top} + \tau_{bot}$$

$$\tau_{tot} = \frac{a}{2} F_{top} \sin\theta + \frac{a}{2} F_{bot} \sin\theta$$

$$\tau_{tot} = aF_{top} \sin\theta = a(IbB)\sin\theta$$

$$\tau_{tot} = IAB \sin\theta$$

where A is the area of the loop.

If we were to make N loops of this wire then our equation would become:

$$\tau_{tot} = NIAB \sin\theta$$

Magnetic Moment

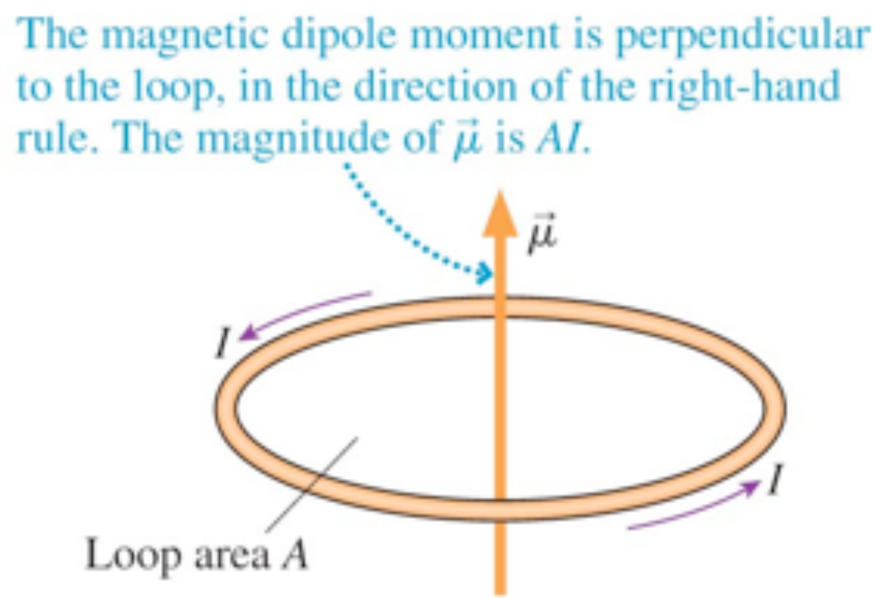
The first part of right side of the last equation (NIA) is completely dependent on properties of the loop.

Because of this we define the magnetic moment vector, μ , of the wire:

$$\mu = NIA$$

The magnetic moment vector points perpendicular to the plane of the loop(s), a normal so to speak.

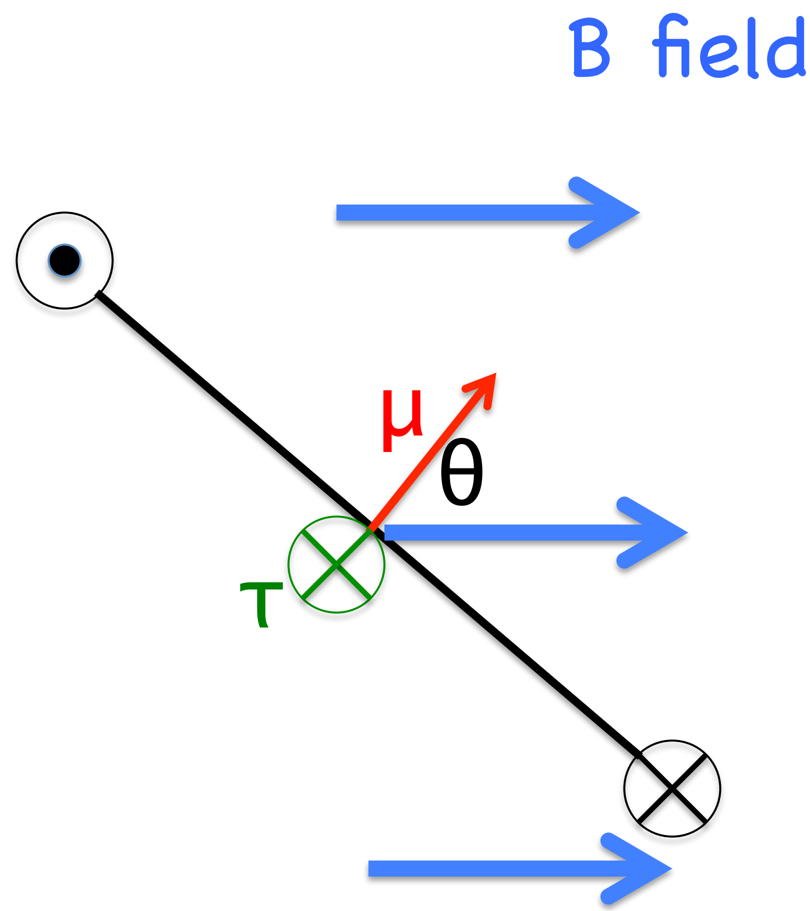
FIGURE 33.20 The magnetic dipole moment of a circular current loop.



Magnetic Moment

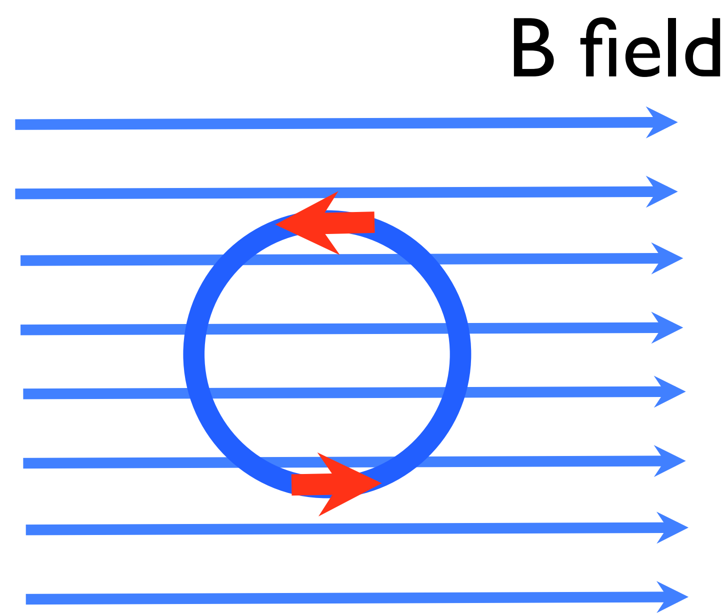
The angle θ will be between μ and B such that:

$$\tau = \vec{\mu} \times \vec{B} = |\vec{\mu}||\vec{B}|\sin\theta$$



Torque A Current Loop

- <u>Example</u>
- A circular coil of wire with average radius 5.00cm and exactly 30 turns lies in a vertical plane. It carries 5.00A of current, counterclockwise when viewed from above. The coil is in a uniform magnetic field directed to the right, with a magnitude of 1.20T. Find the magnetic moment and the torque on the coil. Which way does the coil tend to rotate?



<u>Answer</u>

First, you must define a coordinate system.

Here we must define the normal for the coil, we say that it is perpendicular to the coil (out of the board).

Torque A Current Loop

<u>Answer</u>

Use the magnetic moment equation:

$$\mu = NIA$$

The area is for the circular loop giving us:

$$\mu = NI\left(\pi r^2\right)$$

$$\mu = (30)(5\text{A})\pi(0.05\text{m})^2 = 1.18\ \text{A}\cdot\text{m}^2$$

Where the direction of this magnetic moment is the same as the direction of the normal of the coil.

For torque:

$$\tau = \vec{\mu}\times\vec{B} = |\vec{\mu}||\vec{B}|\sin\theta$$

$$\tau = \left(1.18\ \text{A}\cdot\text{m}^2\right)(1.20\text{T})\sin 90^\circ$$

$$\tau = 1.42\ \text{N}\cdot\text{m}$$

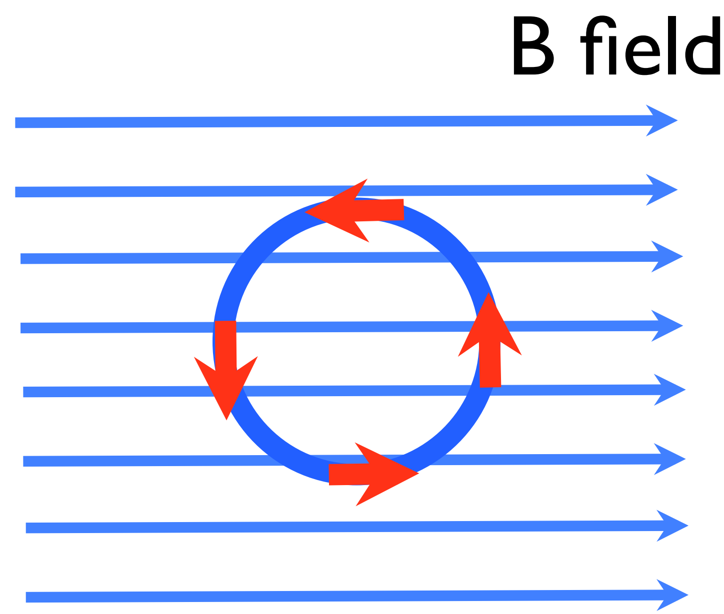
Torque A Current Loop

<u>Answer</u>

For direction, look at four separate points on the circular loop (top, left, bottom, and right parts):

Using RHR 1 on the top and bottom gives us:

Zero magnetic force (I and B are parallel in both instances).



Using RHR 1 on the left gives us:

A magnetic force that is out of board.

Using RHR 1 on the right gives us:

A magnetic force that is into the board.

So the coil will flip such that the right side goes into the board and the left side comes out of the board.

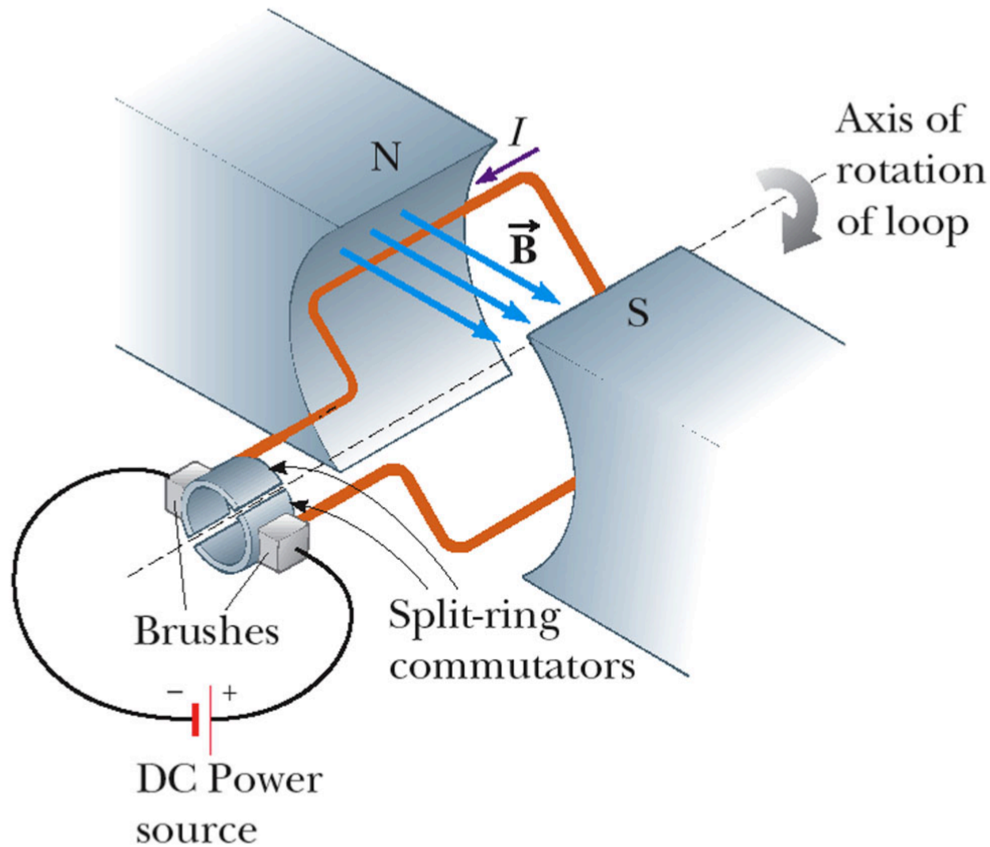
Electric Motor

An application of this concept is the electric motor.

An electric motor converts electrical energy to mechanical energy (specifically rotational kinetic energy).

A simple electric motor consists of a rigid current-carrying loop that rotates when placed in a magnetic field.

To provide continuous rotation in one direction, the current loop must periodically reverse, (AC current).



For Next Time (FNT)

Start reading Chapter 23

Finish working on the homework for Chapter 22