Lecture 4

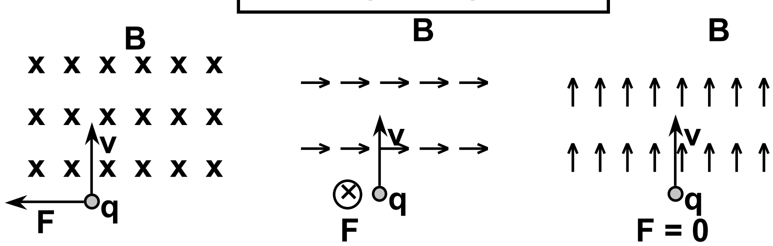
Physics 1502: Lecture 15
Today's Agenda

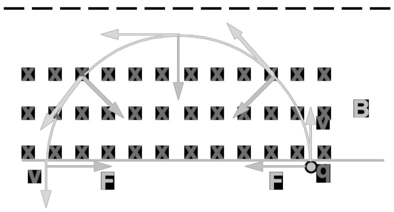
- Announcements:
  - Answers to midterm 1
- NO Homework due this week
- Magnetism

Magnetism

The Magnetic Force

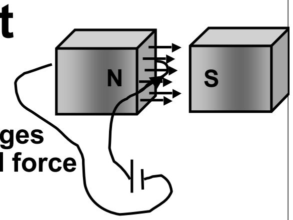
$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$





Lecture 4

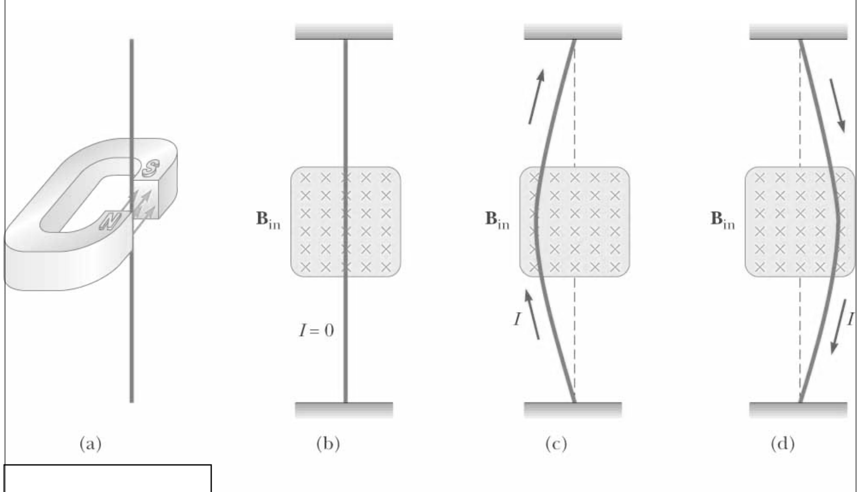
Magnetic Force on a Current



- Consider a current-carrying wire in the presence of a magnetic field B.
- There will be a force on each of the charges moving in the wire. What will be the total force dF on a length dl of the wire?
- Suppose current is made up of n charges/volume each carrying charge q and moving with velocity v through a wire of cross-section A.

- Force on each charge = $q\vec{v} \times \vec{B}$
- Total force = $d\vec{F} = n\,A\,dl\,q\vec{v} \times \vec{B}$
- Current = $I = \frac{dq}{dt} = \frac{n\,A\,v\,dt\,q}{dt} = n\,A\,v\,q$ $\Rightarrow$ $d\vec{F} = I d\vec{l} \times \vec{B}$

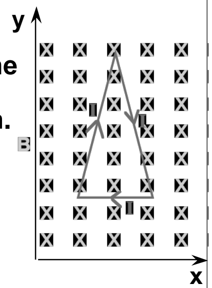
Simpler: For a straight length of wire L carrying a current I, the force on it is: $\vec{F} = I\vec{L} \times \vec{B}$



Lecture 15, ACT 1

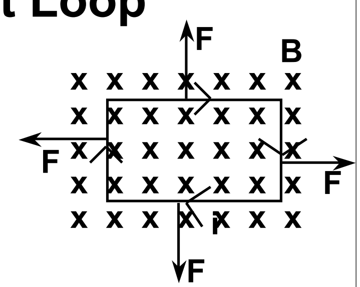
- A current I flows in a wire which is formed in the shape of an isosceles triangle as shown. A constant magnetic field exists in the -z direction.
  - What is F_y, net force on the wire in the y-direction?

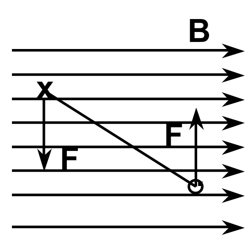
(a) $F_y < 0$ (b) $F_y = 0$ (c) $F_y > 0$



Magnetic Force on a Current Loop

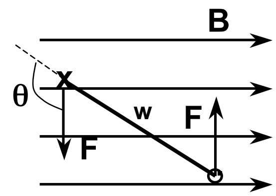
- Consider loop in magnetic field as on right: If field is ⊥ to plane of loop, the net force on loop is 0!
  - Force on top path cancels force on bottom path ($F = IBL$)
  - Force on right path cancels force on left path. ($F = IBL$)
- If plane of loop is not ⊥ to field, there will be a non-zero torque on the loop!





Calculation of Torque

- Suppose a square wire loop has width w (the side we see) and length L (into the screen). The torque is given by:

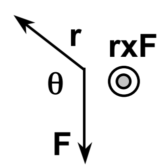


$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\Rightarrow \quad \tau = 2\left(\frac{W}{2} F \sin\theta\right)$$

$$F = I B L \Rightarrow \boxed{\tau = A I B \sin\theta}$$

since: A = wL = area of loop



- Note: if loop ⊥ B, sinθ = 0 ⇒ τ = 0

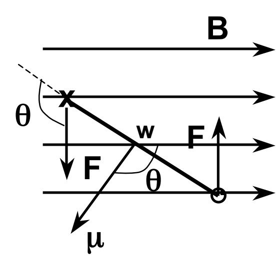
  maximum τ occurs when loop parallel to B

Magnetic Dipole Moment

- We can define the magnetic dipole moment of a current loop as follows:

magnitude: $\boxed{\mu = A I}$

direction: ⊥ to plane of the loop in the direction the thumb of right hand points if fingers curl in direction of current.

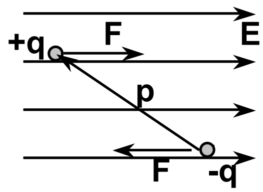


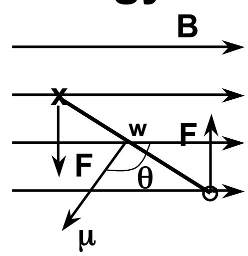
- Torque on loop can then be rewritten as:

$$\tau = A I B \sin\theta \quad \Rightarrow \quad \boxed{\vec{\tau} = \vec{\mu} \times \vec{B}}$$

- Note: if loop consists of N turns, μ = N A I

Electric Dipole Analogy





$\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{F} = q\vec{E}$

$\vec{p} = 2q\vec{a}$

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

$\vec{\tau} = \vec{r} \times \vec{F}$

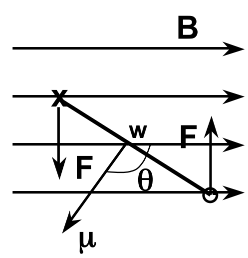
$\vec{F} = I\vec{L} \times \vec{B}$ (per turn)

$\mu = N A I$

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

Potential Energy of Dipole

- Work must be done to change the orientation of a dipole (current loop) in the presence of a magnetic field.
- Define a potential energy U (with zero at position of max torque) corresponding to this work.

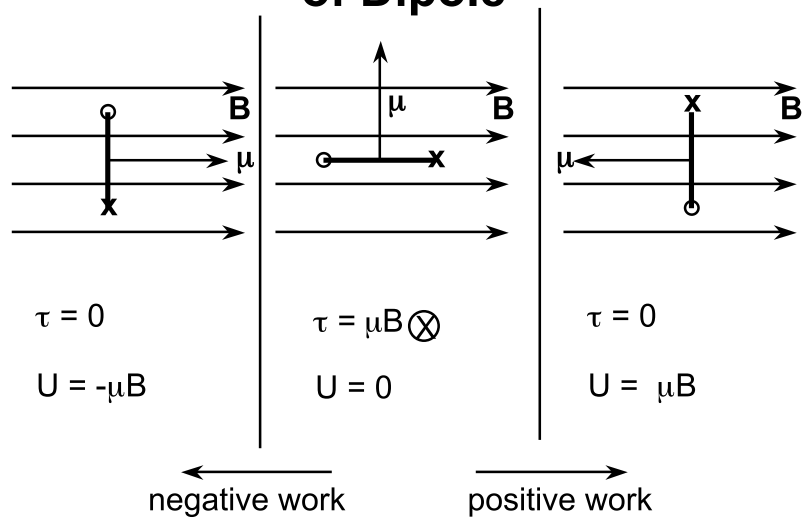


$$U = \int_{90^o}^{\theta} \tau \, d\tau \Rightarrow U = \int_{90^o}^{\theta} \mu B \sin\theta \, d\theta$$

$$U = \mu B \left[-\cos\theta\right]_{90^o}^{\theta} \Rightarrow U = -\mu B \cos\theta \Rightarrow \boxed{U = -\vec{\mu} \cdot \vec{B}}$$

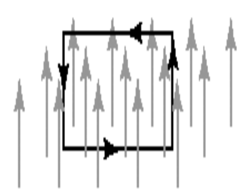
Lecture 4

Potential Energy of Dipole



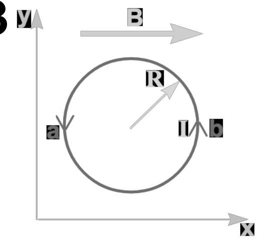
Lecture 15, ACT 2

A rectangular loop is placed in a uniform magnetic field with the plane of the loop parallel to the direction of the field. If a current is made to flow through the loop in the sense shown by the arrows, the field exerts on the loop:



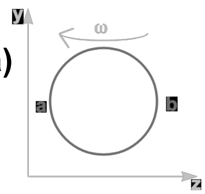
A) a net force. **B) a net torque.** **C) a net force and a net torque.**
D) neither a net force nor a net torque.

Lecture 15, ACT 3

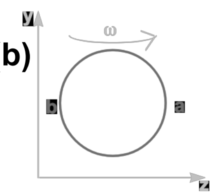


- A circular loop of radius R carries current I as shown in the diagram. A constant magnetic field B exists in the +x direction. Initially the loop is in the x-y plane.
  - The coil will rotate to which of the following positions?

(a)



(b)



(c) It will not rotate