SUNDAY Nov 17: SECOND HOUR EXAM 6:10-7:30 PM in SEC 111 (Ch. 25-29) -- no recitations the previous Friday and following Monday

Pre-recitation – review uniform circular motion

COME DOWN AND HAVE FUN WITH THE MAGNETIC FORCE DEMOS!
Magnetic field (for now, produced by a piece of lodestone)

Magnetic force on moving charges

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

Cross product of two vectors

- Magnitude, direction, right hand rule
- Expression in terms of vector components
i-clicker:
An proton is traveling in the positive x direction. It enters a magnetic field pointing in the positive z direction. In which direction is the force on the proton?

a) +x
b) -x
c) -y
d) +y
e) +z
i-clicker:
An proton is traveling in the positive x direction. It enters a magnetic field pointing in the positive z direction. In which direction is the force on the proton?

a) +x
b) -x
c) -y
d) +y
e) +z
i-clicker:
An electron is traveling in the positive z direction. It enters a magnetic field pointing in the positive x direction. In which direction is the force on the electron?

a) +x
b) -x
c) -y
d) +y
e) -z
i-clicker:
An electron is traveling in the positive z direction. It enters a magnetic field pointing in the positive x direction. In which direction is the force on the electron?

a) +x  
b) -x  
c) -y  
d) +y  
e) -z

Check with the demo!
i-clicker:
An electron is traveling in the positive z direction. It enters a magnetic field pointing in the positive x direction. In which direction is the force on the electron?

- a) +x
- b) -x
- c) -y
- d) +y
- e) -z
A particle of charge +1.0C with velocity (in m/s) 
\( \vec{v} = 2\hat{i} + 3\hat{j} \)
moves through the uniform magnetic field (in T) 
\( \vec{B} = 3\hat{i} - 1.5\hat{j} \)

What is the magnitude of the magnetic force on the particle?

a) 12 N 
b) 6.0 N 
c) 4.5 N 
d) 1.5 N 
e) None of the above
A particle of charge +1.0C with velocity (in m/s)
\[ \vec{v} = 2\hat{i} + 3\hat{j} \]
moves through the uniform magnetic field (in T)
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What is the magnitude of the magnetic force on the particle?

a) 12 N
b) 6.0 N
c) 4.5 N
d) 1.5 N
e) None of the above
Motion of a charged particle $q$ in a uniform field $B$ $v_0$ along a field line
Motion of a charged particle $q$ in a uniform field $B$ $v_0$ perpendicular to the field
Motion of a charged particle $q$ in a uniform field $B v_0$ perpendicular to the field

$F = q v_0 B$ out of the screen

perpendicular to the displacement

$B$ field does no work on the particle
does not change its speed
Motion of a charged particle $q$ in a uniform field $B$ $v_0$ perpendicular to the field

$B$ out of the screen so $v$ is perpendicular to $B$

Initially $F = q \, v_0 \, B$ downward
Motion of a charged particle $q$ in a uniform field $B$ $v_0$ perpendicular to the field

B out of the screen

Initially $F = q v_0 B$ downward
Motion of a charged particle $q$ in a uniform field $B$ $v_0$ perpendicular to the field

$B$ out of the screen

Direction is changing but SPEED IS CONSTANT (why?)
Motion of a charged particle $q$ in a uniform field $B$ $v_0$ perpendicular to the field

Speed is constant (why?)
Force is perpendicular to motion, constant magnitude
Uniform circular motion
Radius of the circle: $qv_0B = mv_0^2/r$ so $r = mv_0/qB$
Motion of a charged particle $q$ in a uniform field $B$
$v_{0x}$ perpendicular to the field
$v_{0z}$ parallel to the field

B out of the screen

helix
Motion of a charged particle in crossed E and B field

- B out of the screen
- E upward

Magnetic force downward
Electric force upward
If \( E = vB \), net force is zero and particle will not change velocity
Moving charges could be a current in wire

\[ I = nqvA \]

plus charges moving in direction of arrow
Or negative charges moving opposite to the arrow
product \( qv > 0 \) in both cases
The force will be the SAME

jumping wire demo
Nonzero current -> force
Force increases with current

Quantitative expression for how the force depends on \( I \) and \( B \)
Force on a current carrying wire in a uniform magnetic field

B points out of the screen, negative charges (e.g., electrons)
Direction of magnetic force?
Force on a current carrying wire in a uniform magnetic field

B points out of the screen

*Magnetic force is to the right*

Charges are constrained to move along the wire ->

Magnetic force on the charges is transmitted to the wire
i-clicker:
Negative charges are moving \textbf{up} in the wire which is in a magnetic field pointing \textbf{into} the screen. In which direction is the force on the wire?

a) To your right
b) To your left
c) Up
d) Down
e) zero
i-clicker:
Negative charges are moving up in the wire which is in a magnetic field pointing into the screen. In which direction is the force on the wire?

a) To your right
b) To your left
c) Up
d) Down
e) zero
Negative charges are moving **up** in the wire which is in a magnetic field pointing **into** the screen. In which direction is the force on the wire?

a) To your right  
b) To your left  
c) Up  
d) Down  
e) zero

Positive charges are moving **down** in the wire which is in a magnetic field pointing **into** the screen. In which direction is the force on the wire?

a) To your right  
b) To your left  
c) Up  
d) Down  
e) zero
Force on a current carrying wire in a uniform magnetic field

B points out of the screen, *minus charges moving down*
Magnetic force is to the right
Force on the charges is transmitted to the wire

\[ F = \sum |q| v B = L A n |q| v B = i L B \]

\( \vec{L} \) is a vector of length L in the direction of the current arrow
Force on a current carrying wire in a uniform magnetic field

B points out of the screen, **plus charges moving up**
Magnetic force is to the right
Force on the charges is transmitted to the wire

\[ F = \sum |q|vB = LA \, n|q|vB = iLB \]
Force on a current carrying wire in a uniform magnetic field

B points out of the screen
Magnetic force is to the right
Force on the charges is transmitted to the wire

\[ \vec{F}_B = i\vec{L} \times \vec{B} \]

\( \vec{L} \) is a vector of length L in the direction of the current arrow

Electrons are the free charges here
i-clicker:
What is the direction of the net force on the rectangular loop with a uniform B field out of the screen?

a) To the right  
b) To the left  
c) Out of the screen  
d) Into the screen  
e) zero
i-clicker:
What is the direction of the net force on the rectangular loop with a uniform B field out of the screen?

a) To the right  
b) To the left  
c) Out of the screen  
d) Into the screen  
e) zero

Forces on parallel segments are equal and opposite: cancel
i-clicker:
What is the direction of the net force on the rectangular loop with a uniform B field pointing to the right?

a) To the right
b) To the left
c) Out of the screen
d) Into the screen
e) zero
i-clicker:
What is the direction of the net force on the rectangular loop with a uniform B field pointing to the right?

a) To the right
b) To the left
c) Out of the screen
d) Into the screen
e) zero
Look at side view

\[ \vec{B} \]

\[ F = i a B \]

\[ b \]
The torque due to the tangential component of the force causes an angular acceleration around the rotation axis.

Torque along the rotation axis
= $F_t r$ (positive)
i-clicker:
What is the sign of the torque on the rectangular loop rotating on the fixed axis with a uniform B field pointing to the right?

a) Positive (up along axis)
b) Negative (down along axis)
c) Zero
d) Just guessing
i-clicker:
What is the sign of the torque on the rectangular loop rotating on the fixed axis with a uniform B field pointing to the right?

- a) Positive (up along axis)
- b) Negative (down along axis)
- c) Zero
- d) Just guessing

Torque = 2 \( (iBa)(b/2) = iB(ab) = iB \text{ area} \)