Name: _____

Class: _____

Due Date: _____

D.3 Motion in Electromagnetic Fields

Understandings

- The motion of a charged particle in a uniform electric field.
- The motion of a charged particle in a uniform magnetic field.
- The motion of a charged particle in perpendicularly oriented uniform electric and magnetic fields.
- The magnitude and direction of the force on a charge moving in a magnetic field as given by $F = qvB\sin\theta$.
- The magnitude and direction of the force on a current-carrying conductor in a magnetic field as given by $F = BIL\sin\theta$.
- The force per unit length between parallel wires as given by $\frac{F}{L} = \mu_0\frac{I_1 I_2}{2\pi r}$.

Equations

$F = qvB\sin\theta$

$F = BIL\sin\theta$

$\frac{F}{L} = \mu_0\frac{I_1 I_2}{2\pi r}$

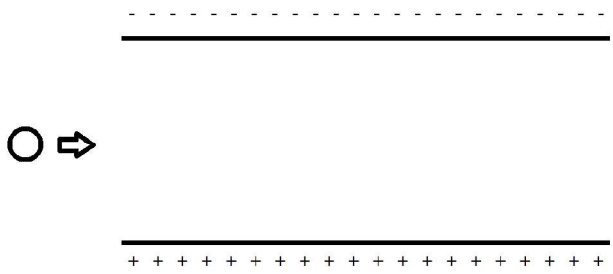
If you are interested in learning more about electricity and magnetism then please read the book *Electricity and Magnetism* by Edward M. Purcell and David J. Morin.

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. A proton, which has a mass of 1.67×10^{-27} kg and a charge of 1.6×10^{-19} C, is moving with a velocity of $5.6 \times 10^{6}\ \frac{\text{m}}{\text{s}}$ from left to right into a uniform electric field as shown in the figure below. The electric field has a magnitude of 560,000 N/C and is directed upward.



a. What will be the direction and magnitude of the gravitational force acting on this proton?

b. What will be the direction and magnitude of the electrostatic force acting on this proton?

c. What will be the direction and magnitude of the net force acting on the proton?

d. What will be the direction and magnitude of the acceleration of this proton?

e. What will be the velocity of this proton 1.25 microseconds after entering the electric field?

f. What will be the displacement of this proton 1.25 microseconds after entering the electric field?

2. Compare the following equations of force: Newton's Law of Gravitation, Coulomb's Law, and the magnetic force.

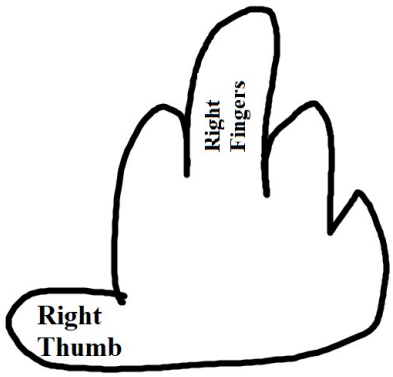
$\vec{F}_{\text{gravity}} = m_1\vec{g} = \frac{Gm_1m_2}{r^2}$ $\vec{F}_{\text{electric}} = q_1\vec{E} = \frac{kq_1q_2}{r^2}$ $\vec{F}_{\text{magnetic}} = q\vec{v} \times \vec{B}_{\text{external}}$ $= q\vec{v}\vec{B}_{\text{external}} \sin\theta$	a. Which force equations look similar to each other? What do they have in common? b. Which force equations look different from each other? What do they not have in common?

3. List some differences between the electric force and the magnetic force.

4. What are the units for the magnetic field $\vec{B}$?

5. Use the equation $\vec{F}_{\mathrm{B}} = q\vec{v} \times \vec{B}_{\mathrm{external}}$ with the right hand rule to find the direction of the magnetic force of the charged object.

http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magfor.html



$\vec{F}_{\mathrm{B}} = q\vec{v} \times \vec{B}_{\mathrm{external}}$

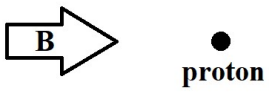
Step 1: Put your fingers from your right hand in the direction of qv.

Step 2: Bend your fingers in the direction of the external magnetic field.

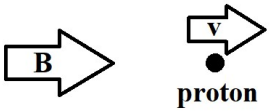
Step 3: Your thumb points in the direction of the magnetic force.

Note: If the charged object has a negative charge then just switch the direction of the answer. Please see the examples below!

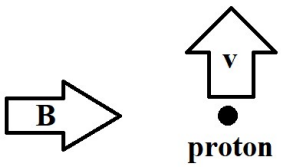
a. A proton is at rest. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



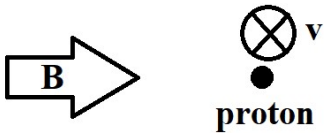
b. A proton moves to the right with a constant speed. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



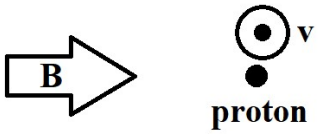
c. A proton moves up with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



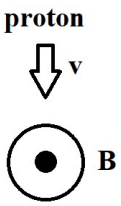
d. A proton moves into the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



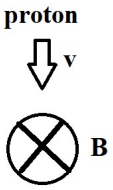
e. A proton moves out of the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



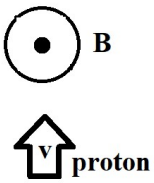
f. A proton moves down with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



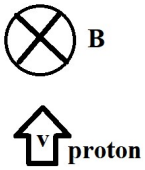
g. A proton moves down with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



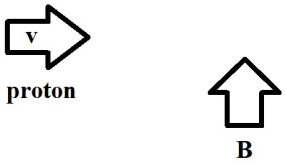
h. A proton moves up with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



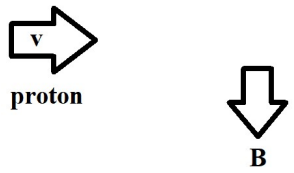
i. A proton moves up with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



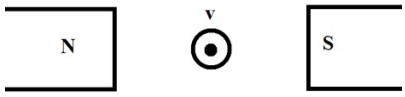
j. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points up. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



k. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points down. (What would be the direction of the magnetic force if the proton is replaced by an electron?)

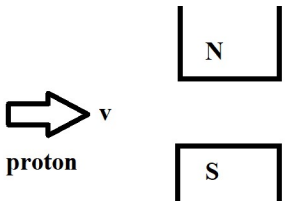


l. A proton moves out of the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)

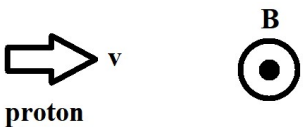


m. A proton moves into the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)

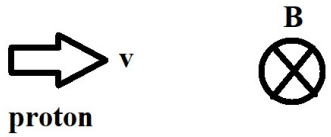
n. A proton moves to the right with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



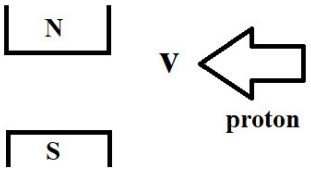
o. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



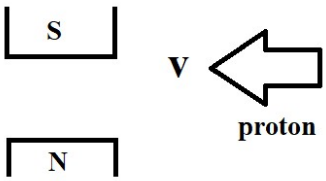
p. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



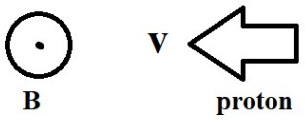
q. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



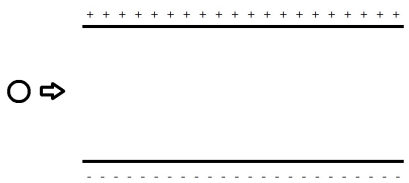
r. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



s. A proton is moving to the left with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



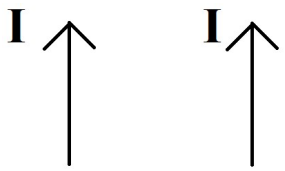
6. A proton is moving horizontally to the right. It enters a region between a uniform external electric field as shown below. Which direction should the external magnetic field point if the proton is to move to the right without deflection?



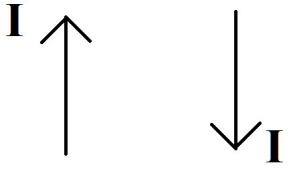
7. A proton is moving vertically downwards. It enters a region between a uniform external electric field as shown below. Which direction should the external magnetic field point if the proton is to move down without deflection?

8. Determine an equation for the charge to mass ratio for a charged particle entering a uniform magnetic field.

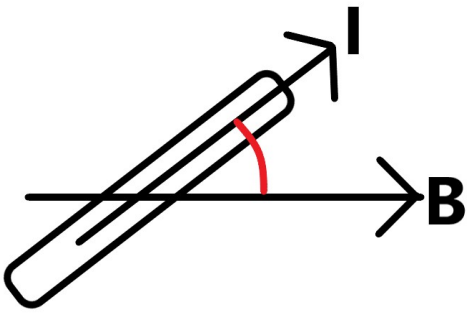
9. Use the equation $\vec{F}_{\mathrm{B}} = I\vec{l} \times \vec{B}_{\mathrm{ext}}$ and the right hand rule to determine if parallel wires with current moving in the same direction will *attract* or *repel*.



10. Use the equation $\vec{F}_{B} = I\vec{l} \times \vec{B}_{\mathrm{ext}}$ and the right hand rule to determine if parallel wires with current moving in opposite directions will *attract* or *repel*.



11. Describe the equation $F = BIL \sin\theta$ for a current carrying wire.



12. Describe the equation $\frac{F}{L} = \mu_0 \frac{I_1 I_2}{2\pi r}$ for two parallel current carrying wires.