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

$F = qvB\sin\theta$

$F = BIL\sin\theta$

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

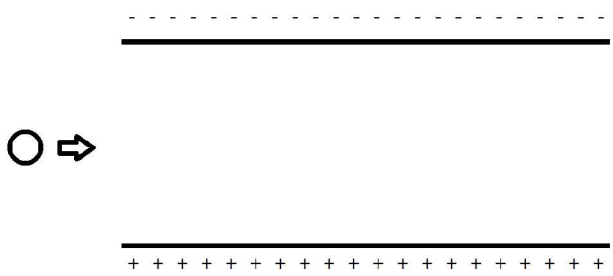
If you are interested in learning more about electricity and magnetism then please read the book *Electricity and Magnetism* by Edward M. Purcell and David J. Morin.

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. E: A proton, which has a mass of 1.67×10^{-27} kg and a charge of 1.60×10^{-1} C, is moving with a velocity of $5.60 \times 10^{6}\ \frac{\text{m}}{\text{s}}$ from left to right into a uniform electric field as shown in the figure below. The electric field has a magnitude of $5.60 \times 10^{5}\ \frac{\text{N}}{\text{C}}$ 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?

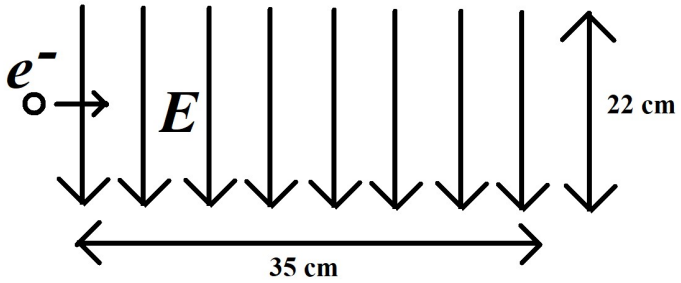
c. What will be the direction and magnitude of the net force acting on the proton?

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. E: An electron, which has a mass of 9.11×10^{-31} kg and a charge of -1.60×10^{-19} C, enters a uniform electric field with a velocity of $5.80 \times 10^{7}\ \frac{\text{m}}{\text{s}}$. The electric field has a magnitude of $2.90 \times 10^{4}\ \frac{\text{N}}{\text{C}}$, is pointing vertically downward and is contained within a limited area. The dimensional limits of the electric field is 35.0 cm horizontally and 22.0 cm vertically. The electron enters the uniform electric field from the middle of the vertical.



a. **Use a pencil!** Sketch the path of this particle through the electric field in the image above.

b. What will be the net force acting on this electron?

c. How long will it take for this electron to pass through this field?

d. Where, exactly, will the electron exit the field?

e. What will be the velocity of the electron as it exits the field?

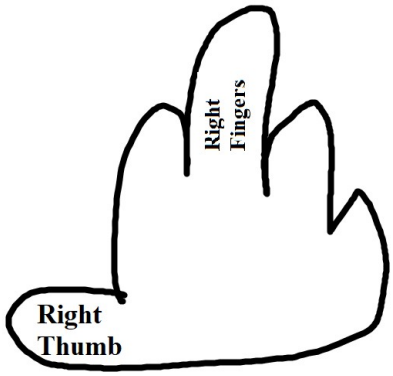
3. C: Compare the following equations of force: Newton's Law of Gravitation, Coulomb's Law, and the magnetic force.

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

4. C: List some differences between the electric force and the magnetic force.

5. C: What are the units and fundamental units for the magnetic field $\vec{B}$?

6. C: 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.



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

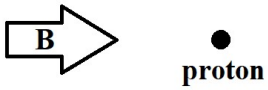
Step 1: Put your fingers from your right hand in the direction of qv.

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

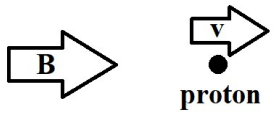
Step 3: Your thumb points in the direction of the magnetic force.

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

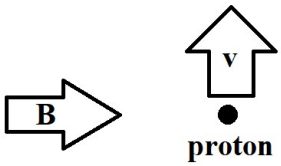
a. A proton is at rest. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



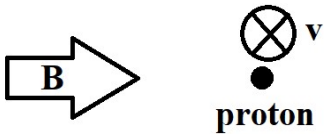
b. A proton moves to the right with a constant speed. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



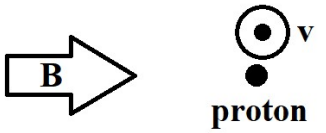
c. A proton moves up with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



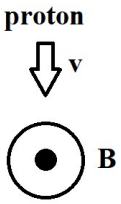
d. A proton moves into the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



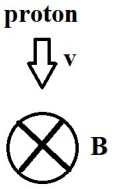
e. A proton moves out of the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



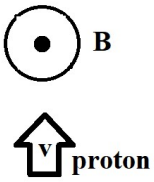
f. A proton moves down with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



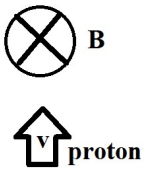
g. A proton moves down with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



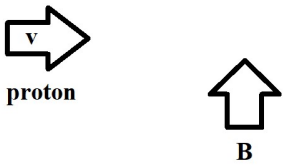
h. A proton moves up with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



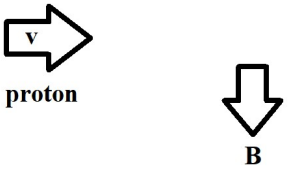
i. A proton moves up with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



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?)



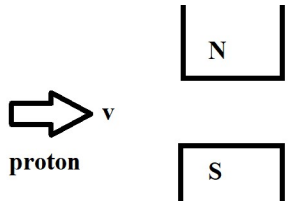
k. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points down. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



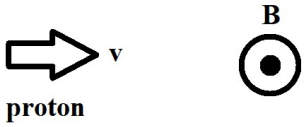
l. A proton moves out of the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)

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?)

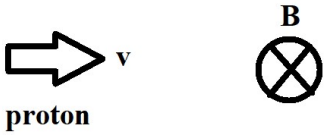
n. A proton moves to the right with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



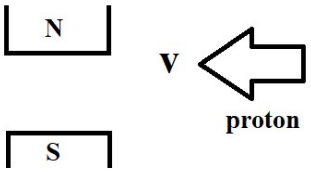
o. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



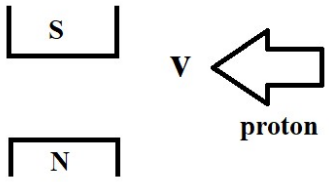
p. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



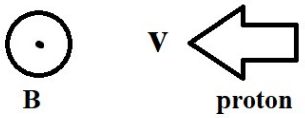
q. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



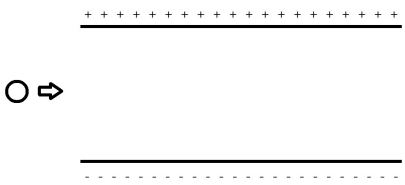
r. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



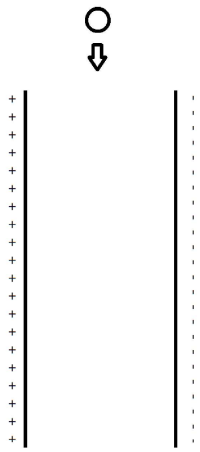
s. A proton is moving to the left with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



7. E: 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?

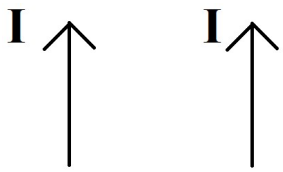


8. E: A proton is moving vertically downwards. It enters a region between a uniform external electric field as shown below. Which direction should the external magnetic field point if the proton is to move down without deflection?

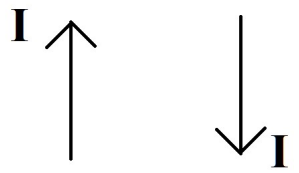


9. C: Determine an equation for the charge to mass ratio for a charged particle entering a uniform magnetic field. The velocity of the charged particle is perpendicular to the external magnetic field.

10. C: 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*.



11. C: 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*.



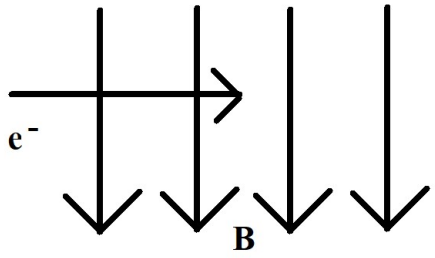
12.C: Describe the equation $F = BIL\sin\theta$ for a current carrying wire.

13.E: A proton is moving with a velocity of 820. m/s through a magnetic field which has a field intensity 1.20 Tesla. Assume that this proton is moving at right angles to the field.

a. What will be the magnitude of the resultant magnetic force?

b. What will be the force on the proton if the direction of motion of the proton is parallel to the direction of the magnetic field lines?

14.E: A magnetic field, which has an intensity of 0.950 Tesla, is directed vertically downward. An electron is moving horizontally through the field from left to right with a speed of $1.20 \times 10^4 \ \frac{\text{m}}{\text{s}}$.



a. What will be the direction of the magnetic force acting on this electron?

b. Describe the path of motion of this electron as it moves through the magnetic field.

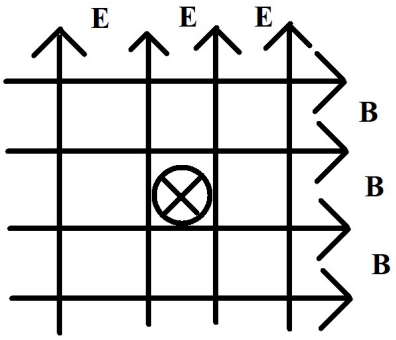
c. What will be the magnitude of the magnetic force acting on this electron?

d. What will be the radius of the circle in which this electron will move?

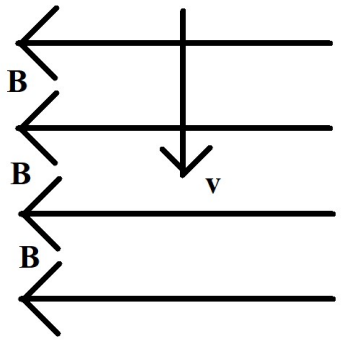
15. A proton is moving with a velocity of $2.1 \times 10^4 \ \frac{\text{m}}{\text{s}}$ through a uniform magnetic field such that the proton moves in a circular path which has a radius of 4.50 cm. What is the strength of the magnetic field B_{ext}?

16. E: An alpha particle is moving with a velocity of $2.00 \times 10^4 \ \frac{\text{m}}{\text{s}}$ through a uniform magnetic field which has a strength of 2.20 T at right angles to the field. What will be the magnitude of the resulting magnetic force?

17.E: A positively charged particle moves through an area of space where both an electric field, which has an intensity of $E = 1.20 \times 10^4 \ \frac{\text{N}}{\text{C}}$, and a magnetic field, which has an intensity of $B = 2.40$ T, are present. The two fields are mutually perpendicular and the velocity of the positively charged particle is moving perpendicularly into the page such that the charged particle passes through the fields undeflected. What is the velocity of the positively charged particle?



18.E: A magnetic field has a strength of 0.780 T. A positive charge particle of 1.20 μC enters the field from the top of the page with a velocity of 550. m/s.



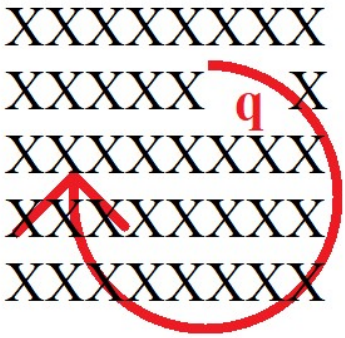
a. What will be the direction of the resultant magnetic force?

b. What will be the magnitude of the magnetic force acting on this positive particle?

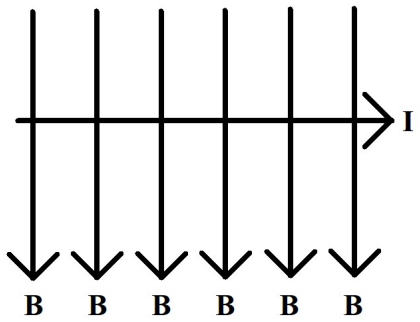
c. What will be the direction of the force if the particle is negative?

d. What will be the direction of the force if the negative particle is moving from left to right?

19.E: A doubly ionized gold atom is moving in a circular path in a uniform magnetic field. The radius of the path is 12.8 cm and the gold atom is moving with a velocity of $6.50 \times 10^5 \frac{\text{m}}{\text{s}}$. What is the strength of the required magnetic field B? $q = -3.2 \times 10^{-19}$ C and $m = 3.29 \times 10^{-25}$ kg



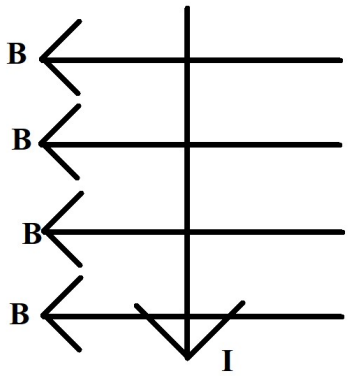
20.E: A piece of wire 15.0 cm long has a current of 3.10 A flowing through it and is sitting in a uniform magnetic field which has an intensity of 0.450 T. The wire is oriented perpendicularly to the magnetic field.



a. What will be the magnitude of the resulting magnetic force?

b. What will be the direction of the resulting magnetic force?

21.E: A conventional current of $I = 5.30$ A is flowing through a wire oriented perpendicularly to a magnetic field. The strength of the magnetic field is $B = 0.600$ T and the length of the wire sitting in the magnetic field is 40.0 cm.

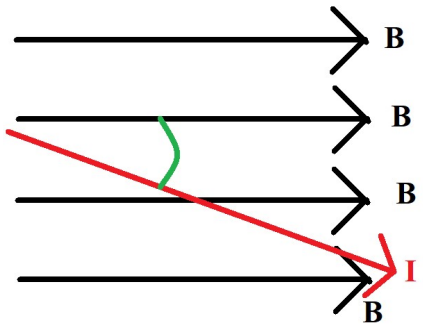


a. What will be the magnitude of the resulting magnetic force?

b. What will be the direction of the resulting magnetic force?

c. How could this wire be oriented so that it will feel no magnetic force?

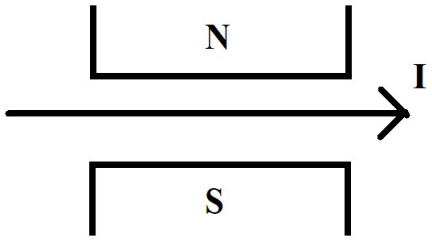
22.E: A wire 30.0 cm long is sitting in a uniform magnetic field. The strength of the magnetic field is $B = 0.220$ T and a current of $I = 3.25$ A is flowing through the wire. The wire is oriented at an angle of 38.0° relative to the magnetic field.



a. What will be the magnitude of the resulting magnetic force?

b. What will be the direction of the resulting magnetic force?

23.E: A wire is sitting in a uniform magnetic field between the poles of a permanent magnet. The magnet is 3.00 cm wide. When a conventional current of 6.25 A flows through this wire it feels a magnetic force of 0.0160 N.

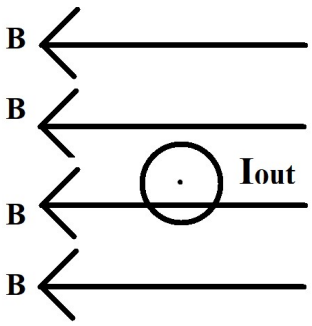


a. What is the strength of the magnetic field generated by the permanent magnet?

b. What will be the direction of the magnetic force acting on the wire?

c. What will be the direction of the magnetic force if the direction of the current is reversed?

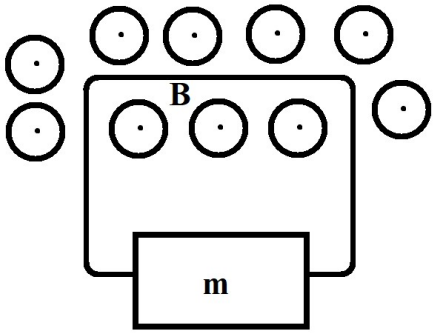
24.E: A conventional current of 7.50 A is flowing out of the page where the magnetic field strength is 2.20 T.



a. What is the magnitude of the resulting magnetic force for each meter of length of this wire?

b. What is the direction of the resulting magnetic force?

25.E: A loop of wire is attached to a mass of 50.0 g. One end of the loop is sitting in a magnetic field directed out of the page which has a magnitude of 3.00 T. The length of the wire sitting in the magnetic field is 35.0 cm.



a. What is the magnitude of the conventional current in the wire if the loop is to support the weight of the hanging mass?

b. What will be the direction of the required conventional current to support the hanging mass?

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