

ADNOC SCHOOL - MZ

SCIENCE DEPARTMENT

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ADNOC SCHOOLS

Chapter: 24 Magnetic field

Section 24.: Magnetic field and forces



- HS-PS3-2 Energy

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects)

Week 4

Objectives:

- Identify the direction of the force on a current carrying wire placing in a magnetic field.
- Illustrate what affects the force on a current carrying wire in a magnetic field.
- understand and apply the concepts of a magnetic fields and forces by predicting the path of a charged particle in a magnetic field.

Vocabularies:

Polarized, Domain, Magnetic field, Electric motor, Solenoid, Magnet, charged particles, armature.

Starter Activity: Applying Magnetic Forces

MAIN IDEA

Many devices, including earbuds and electric motors, rely on forces from magnetic fields in order to work.

K What I Know	W What I Want to Find Out	L What I Learned

Applying Magnetic Forces

Explain how a current-carrying conductor placed in an external magnetic field experiences a magnetic force

Apply the right-hand rule to find the direction of the force on a current-carrying wire placed in an external magnetic field

Apply the equation to calculate the magnitude of the force on a straight segment of a current-carrying wire placed in a uniform magnetic field

$$F = ILB \sin \theta$$

Indicate the direction of magnetic forces on a current-carrying rectangular loop of wire in a magnetic field, and determine how the loop will tend to rotate as a consequence of these forces

A *Magnetic Field* is a property of space around a magnet causing a force on other magnets.

- Every magnet has two poles, North and South.
- Like poles repel and unlike poles attract.
- Magnetic fields are produced by moving charge, such as current moving in a wire.
- The Earth has a magnetic field.

The next two slides contain
vocabulary and equations, you
should commit them to
memory

Vocabulary

electromagnet

A magnet with a field produced by an electric current.

law of poles

Like poles repel each other and unlike poles attract.

magnetic domain

Cluster of magnetically aligned atoms.

magnetic field

The space around a magnet in which another magnet or moving charge will experience a force.

right-hand rules

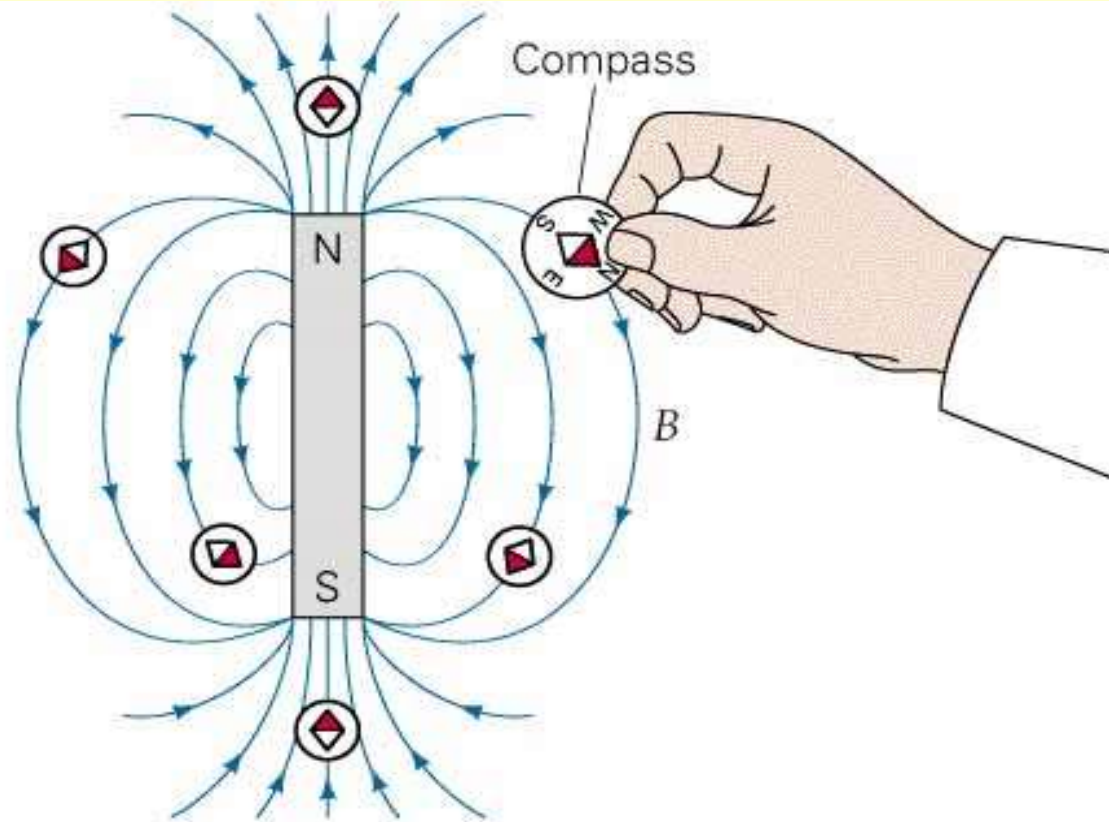
Used to find the magnetic field around a current-carrying wire or the force acting on a wire or charge in a magnetic field.

solenoid

A long coil of wire in the shape of a helix (spiral); when current is passed through a solenoid it produces a magnetic field similar to a bar magnet.

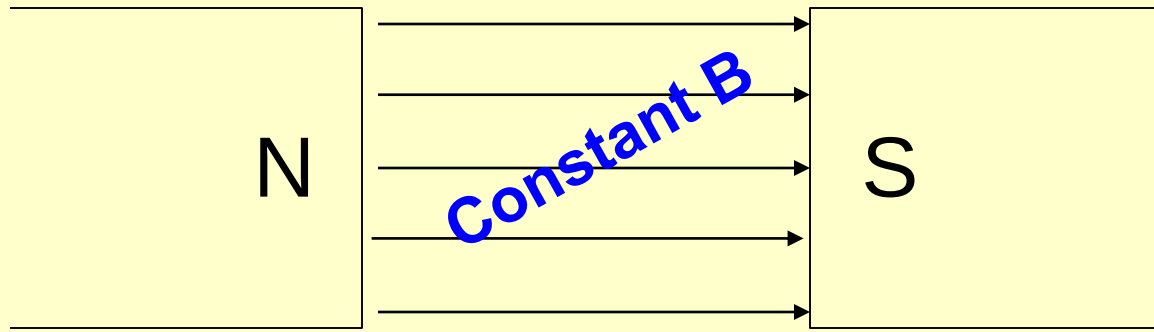
Let's Get Started!

By definition magnetic field lines go out of the north pole and into the south pole. Here is two dimensional representation of a the field lines around a bar magnet. A compass will always point in the direction of the magnetic field lines. (Toward the magnetic south.)



(a)

Magnetic Field due to two bar magnets:



The force on a current carrying wire in a magnetic field

What do you think the reason that make the bar move ??

What is the things that make the things move ??

It's the force



The force on a current carrying wire in a magnetic field.

- A current carry wire has charge moving through it.
- Each of the moving charges will experience a force due to the magnetic field
- The individual magnetic forces on each charge will produce a net force on the entire wire.
- The magnitude of the force is given by the equation below:

$$F_B = BIL \sin \theta$$

The force on a current carrying wire in a magnetic field.

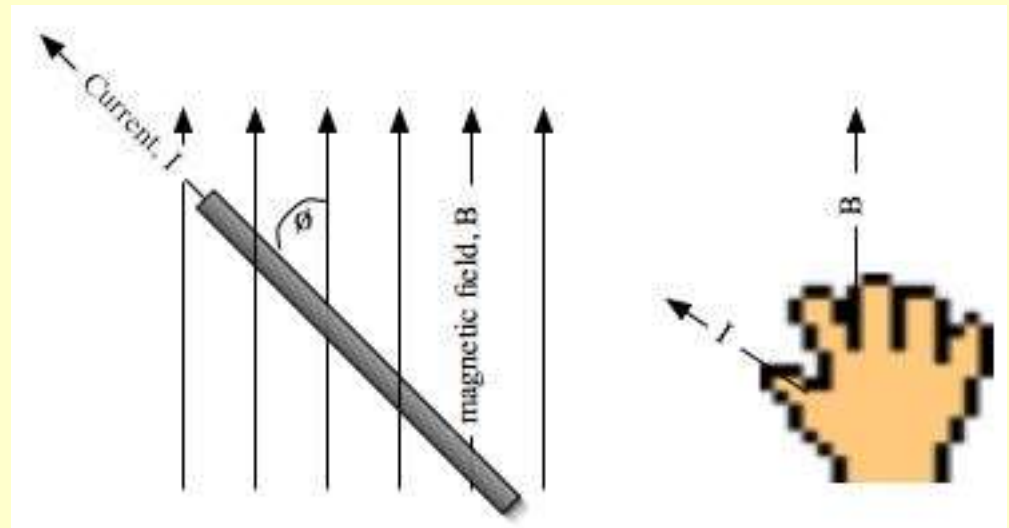
$$F_B = BIL \sin \theta$$

L = length of wire in a magnetic field (m)

I = current (A) in the wire

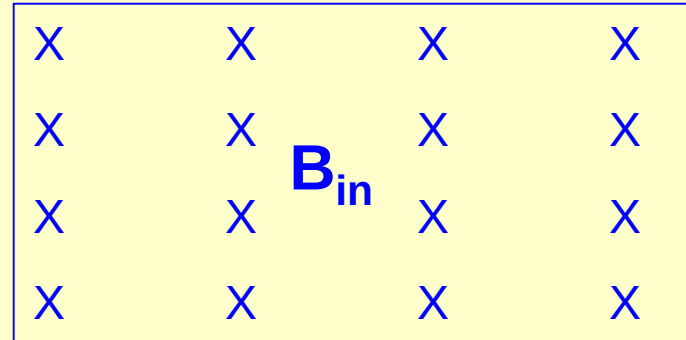
θ = the angle between the wire
And the magnetic field

B = The strength of magnetic field (**T**)

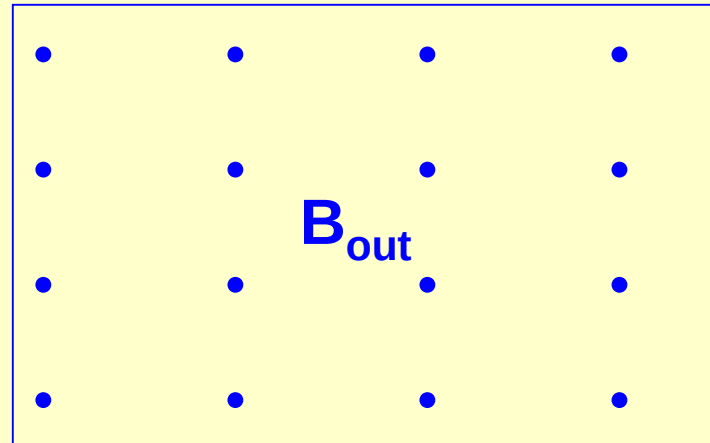


To draw field lines perpendicular to the page we will use the following representations:

A field going into the page will be represented with X's

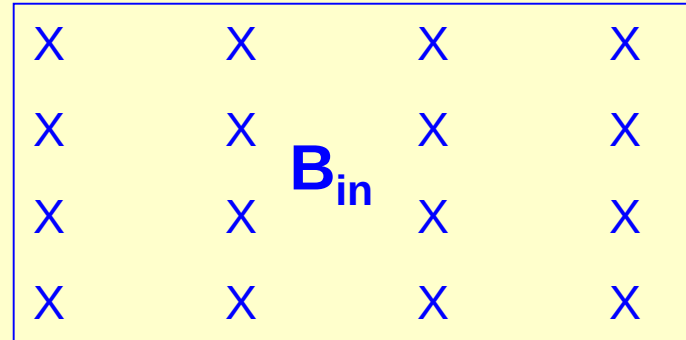


A field going out of the page will be represented with •'s

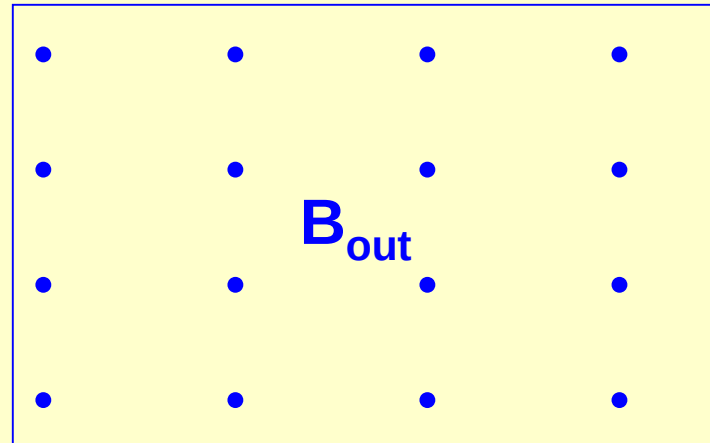


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A field going into the page will be represented with X's



A field going out of the page will be represented with •'s

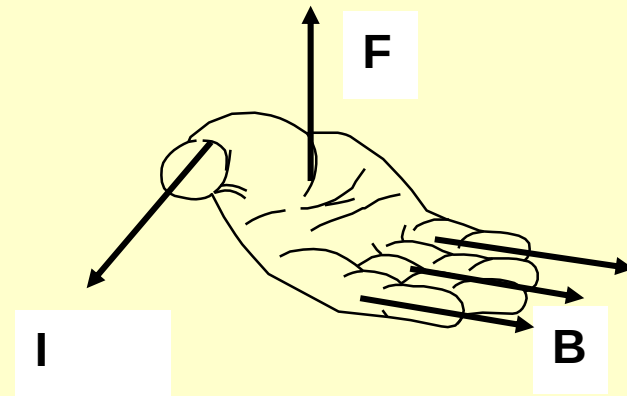
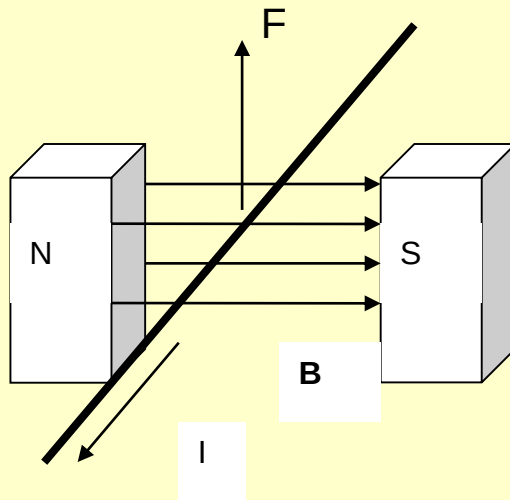


The direction is given by right-hand rule #1:

Fingers: Point in the direction of the field.

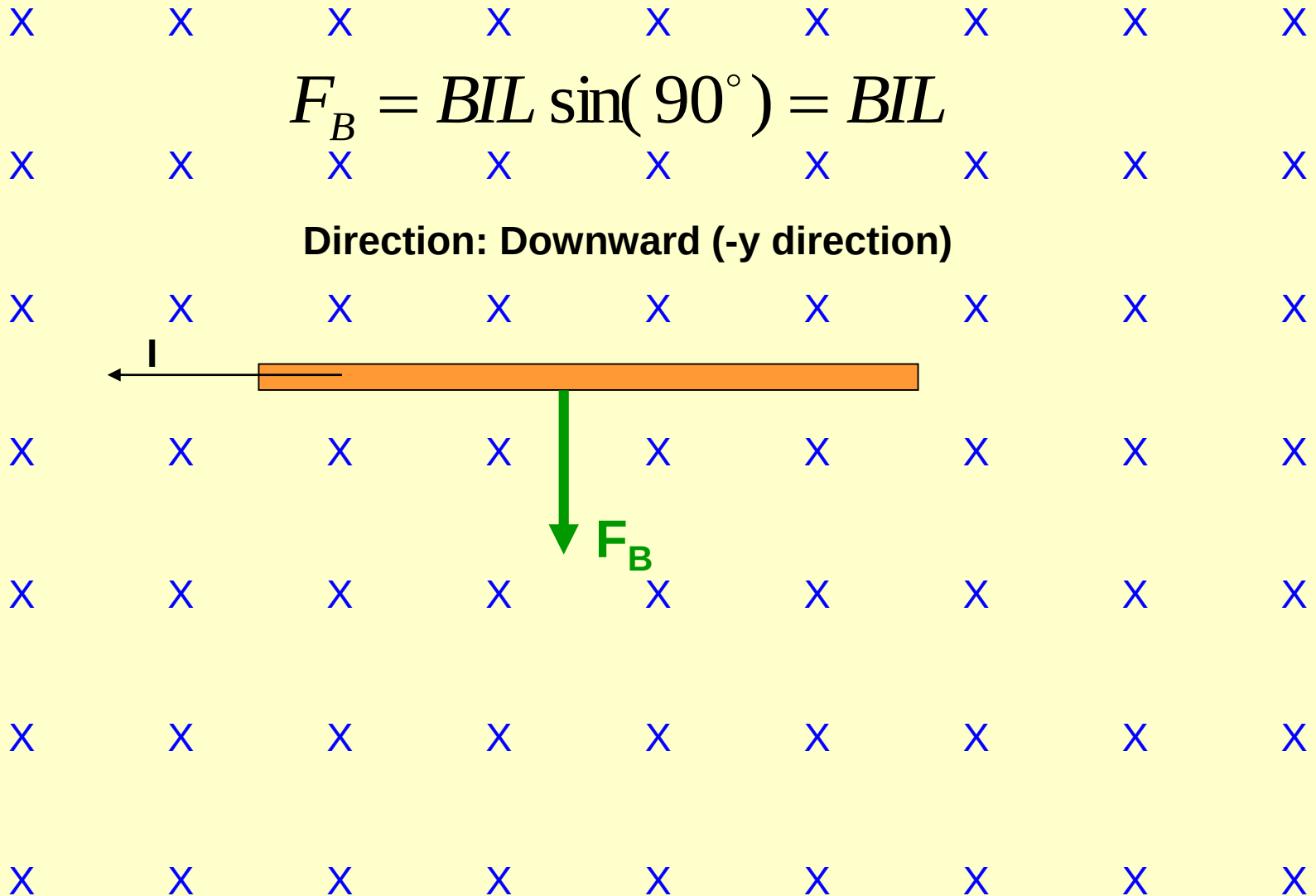
Thumb: Points in the direction of the current flow.

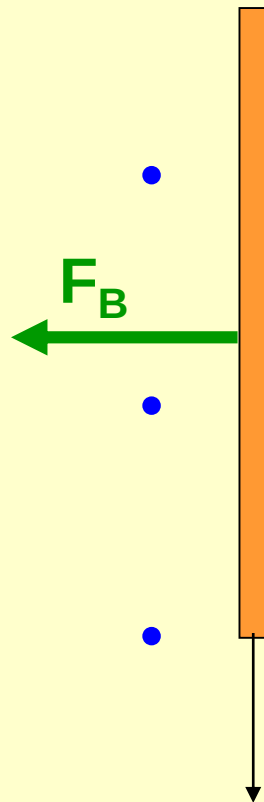
Palm of hand: Points in the direction of the force on a positive charge.



$$F_B = BIL \sin(90^\circ) = BIL$$

Direction: Downward (-y direction)





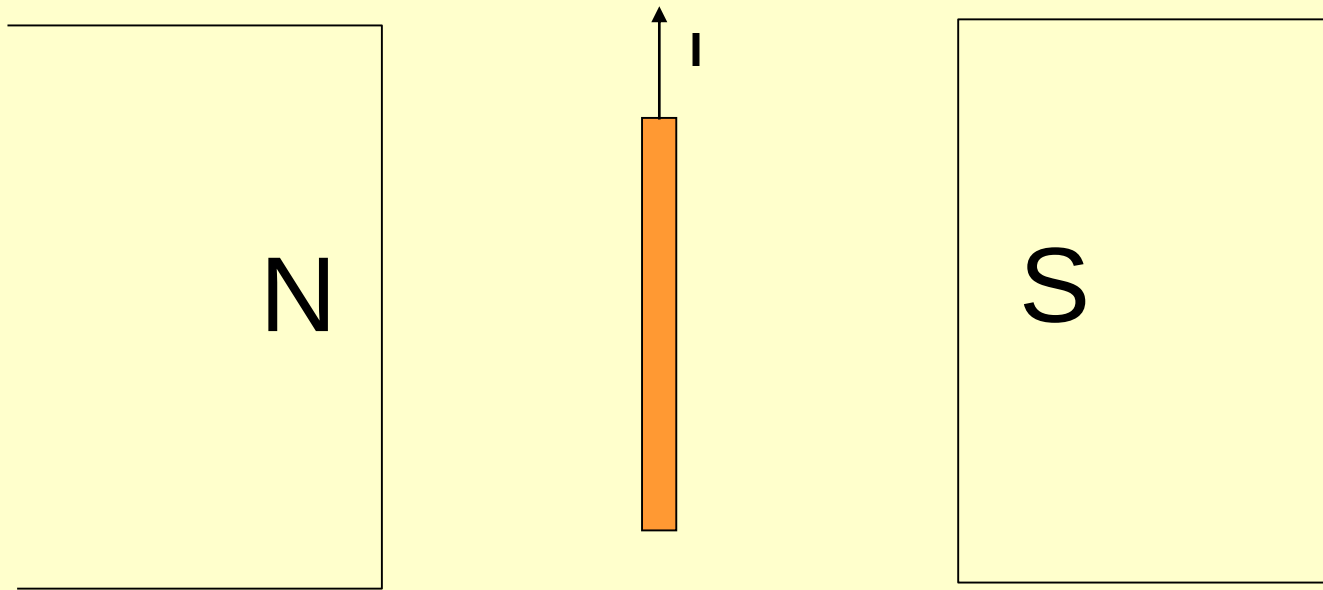
$$F_B = BIL \sin(90^\circ) = BIL$$

Direction: To the left (-x direction)

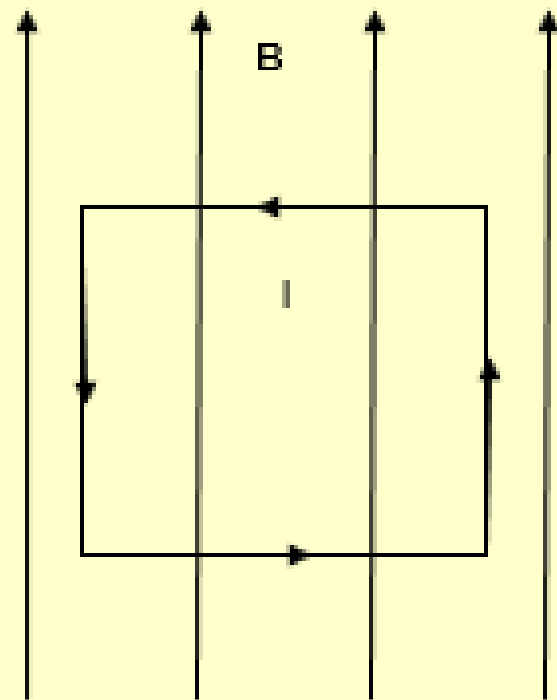
Notes:

- 1. If the current and the magnetic field are parallel the force will be zero because the angle between B and L is 0**
- 2. If the current and the magnetic field are perpendicular the force will be greatest because $\sin 90$ between B and L is 1**

Example 2: A wire carrying a 20A current and having a length of 0.10m is placed between the poles of two magnets as shown below. The magnetic field is uniform and has a value of 0.8T. Determine the magnitude and direction of the magnetic force acting on the wire.



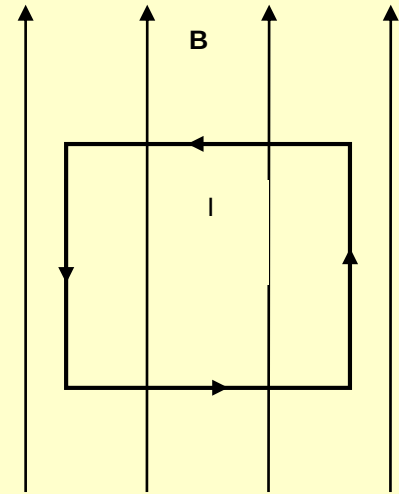
4.2.4 Indicate the direction of magnetic forces on a current-carrying rectangular loop of wire in a magnetic field, and determine how the loop will tend to rotate as a consequence of these forces



Example 3

A wire is bent into a square loop and placed completely in a magnetic field $B = 1.2 \text{ T}$. Each side of the loop has a length of 0.1m and the current passing through the loop is 2.0 A . The loop and magnetic field is in the plane of the page.

- (a) Find the magnitude of the initial force on each side of the wire.



CALCULATE THE STRENGTH OF A MAGNETIC FIELD A straight wire carrying a 5.0-A current is in a uniform magnetic field oriented at right angles to the wire. When 0.10 m of the wire is in the field, the force on the wire is 0.20 N. What is the strength of the magnetic field (B)?

B is uniform, and because B and I are perpendicular to each other, $F = ILB$.

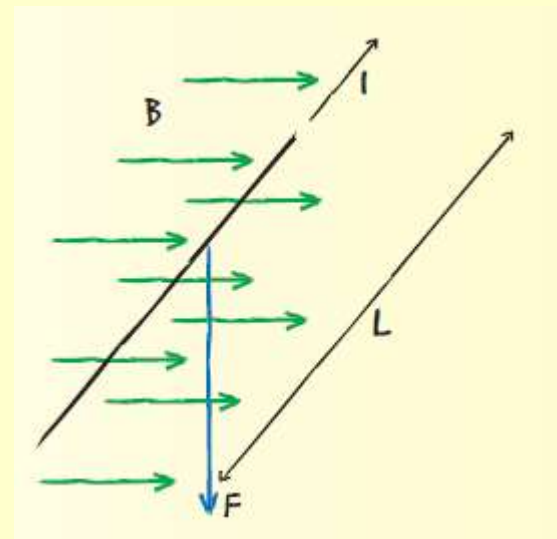
$$F = ILB$$

Solve for B .

$$B = \frac{F}{IL}$$
$$= \frac{0.20 \text{ N}}{(5.0 \text{ A})(0.10 \text{ m})}$$

$$= \frac{0.20 \text{ N}}{(5.0 \text{ A})(0.10 \text{ m})}$$
$$= 0.40 \text{ N/A}\cdot\text{m} = 0.40 \text{ T}$$

B is 0.40 T from left to right and perpendicular to I and F .



19. Explain the method you could use to determine the direction of force on a current-carrying wire at right angles to a magnetic field. Identify what must be known to use this method.
20. A wire that is 0.50 m long and carrying a current of 8.0 A is at right angles to a 0.40-T magnetic field. How strong is the force that acts on the wire?
21. A wire that is 75 cm long and carrying a current of 6.0 A is at right angles to a uniform magnetic field. The magnitude of the force acting on the wire is 0.60 N. What is the strength of the magnetic field?
22. A 40.0-cm-long copper wire carries a current of 6.0 A and weighs 0.35 N. A certain magnetic field is strong enough to balance the force of gravity on the wire. What is the strength of the magnetic field?
23. How much current would be required to produce a force of 0.38 N on a 10.0-cm length of wire at right angles to a 0.49-T field?
24. **CHALLENGE** You are making your own loudspeaker. You make a 1-cm-diameter coil with 20 loops of thin wire. You use hot glue to fasten the coil to an aluminum pie plate. The ends of the wire are connected to a plug that goes into the earphone jack on an MP3 music player. You have a bar magnet to produce a magnetic field. How would you orient the magnetic field to make the plate vibrate and produce sound?

Recap

1. A wire that is 0.50 m long and carrying a current of 8.0 A is at right angles to a uniform magnetic field. The force on the wire is 0.40 N. What is the strength of the magnetic field?

Let's Get Started!

The Magnetic Force on a moving charge in an external magnetic field.

- A moving charge creates a magnetic field, therefore it will experience a magnetic force as it moves through an external magnetic field.
- The direction of the force is given by right-hand rule #1.
- The magnitude of this force is given by the equation:

$$F_B = qvB\sin \theta$$

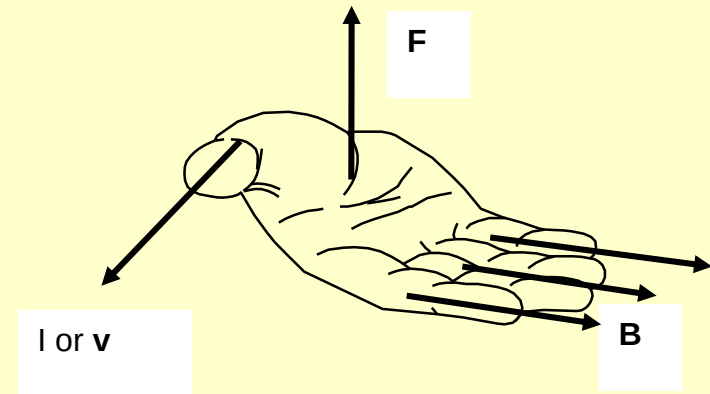
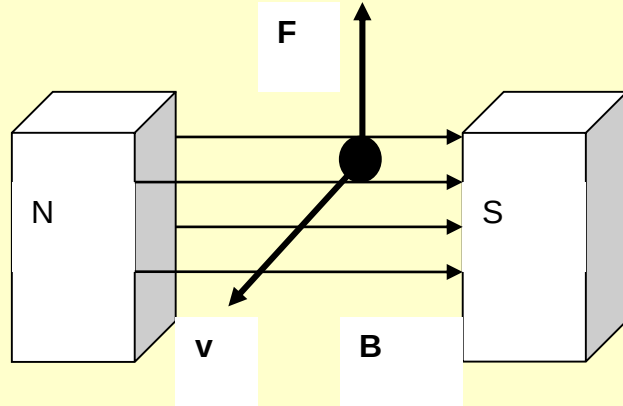
The direction is given by right-hand rule :

Fingers: Point in the direction of the field.

Thumb: Points in the direction of the charge velocity.

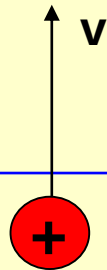
Palm of hand: Points in the direction of the force on a positive charge.

Back of hand: Points in the direction of the force on a negative charge.



Example: A magnetic field is directed to the right. Predict the direction and magnitude of the magnetic force on the following charges moving through the field.

B

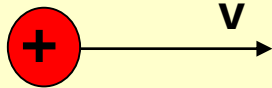


$$F_B = qvB\sin(90^\circ) = qvB$$

Direction: Into the page.

Example: A magnetic field is directed to the right. Predict the direction and magnitude of the magnetic force on the following charges moving through the field.

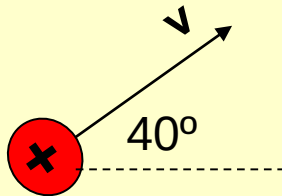
B



$$F_B = qvB\sin(0^\circ) = 0$$

Example: A magnetic field is directed to the right. Predict the direction and magnitude of the magnetic force on the following charges moving through the field.

B

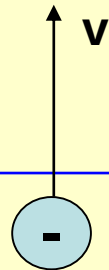


$$F_B = qvB\sin(40^\circ) = .64qvB$$

Direction: Into the page.

Example: A magnetic field is directed to the right. Predict the direction and magnitude of the magnetic force on the following charges moving through the field.

B

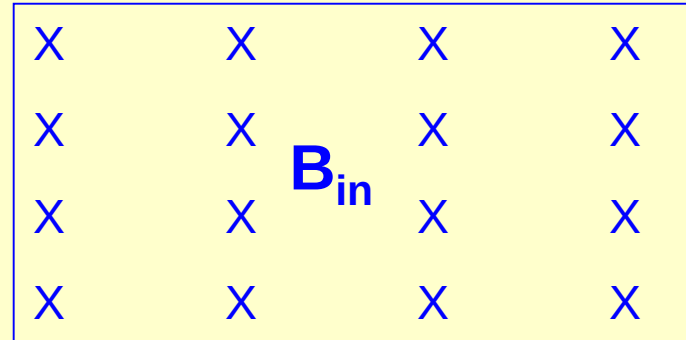


$$F_B = qvB\sin(90^\circ) = qvB$$

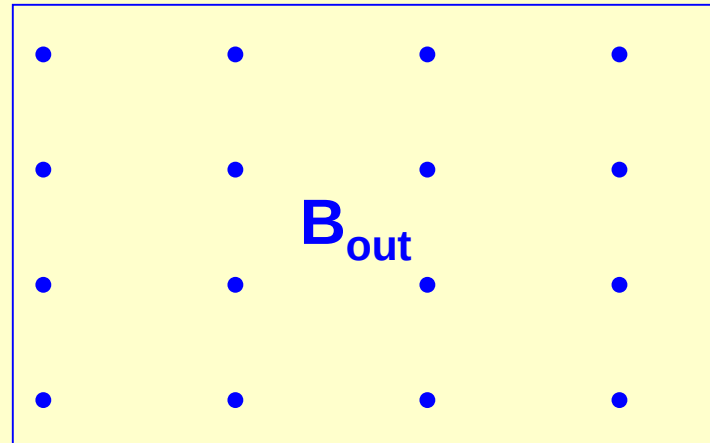
Direction: Out of the page.

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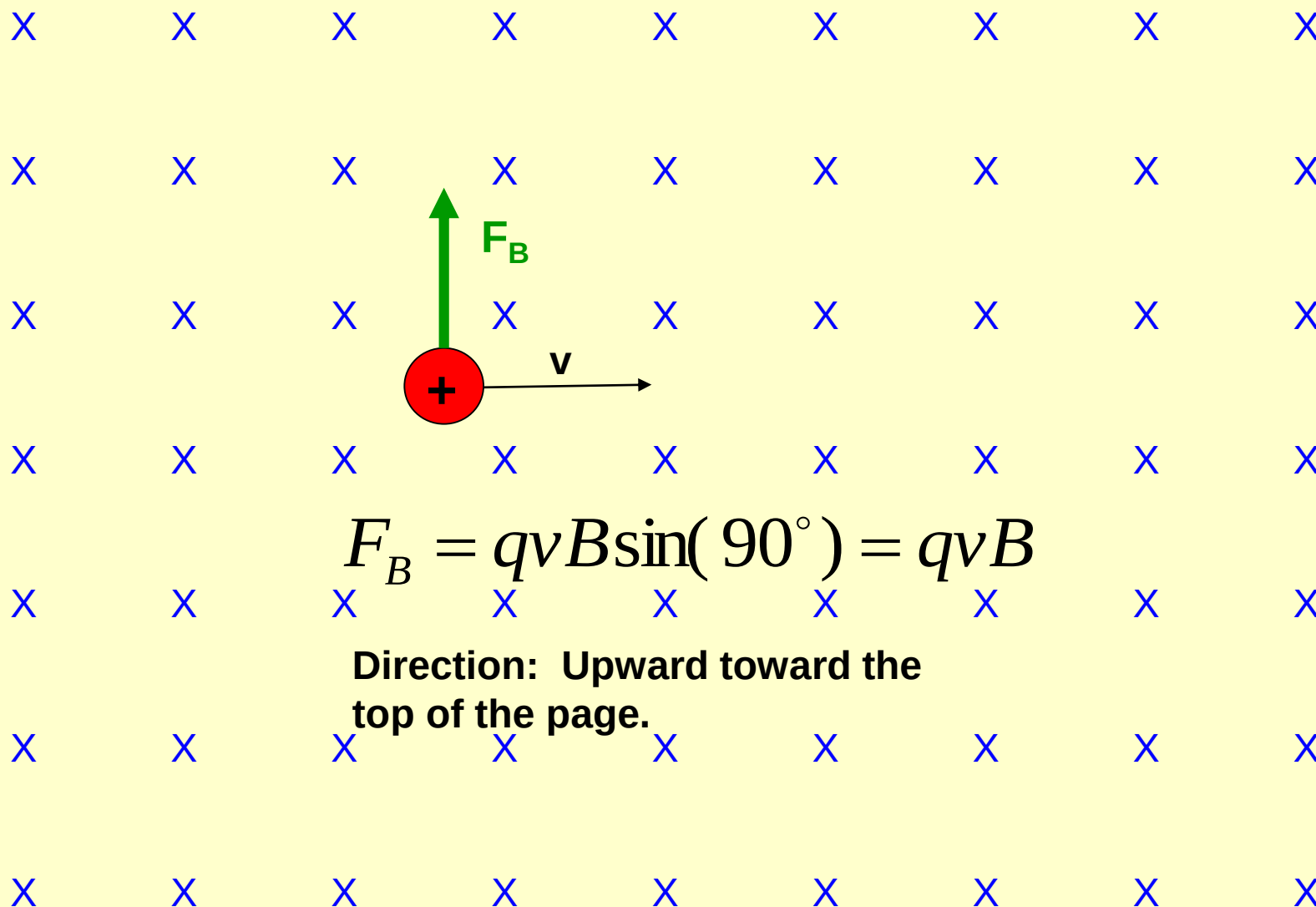


A field going out of the page will be represented with •'s



More Examples:

$\mathbf{B}_{\text{in}}$

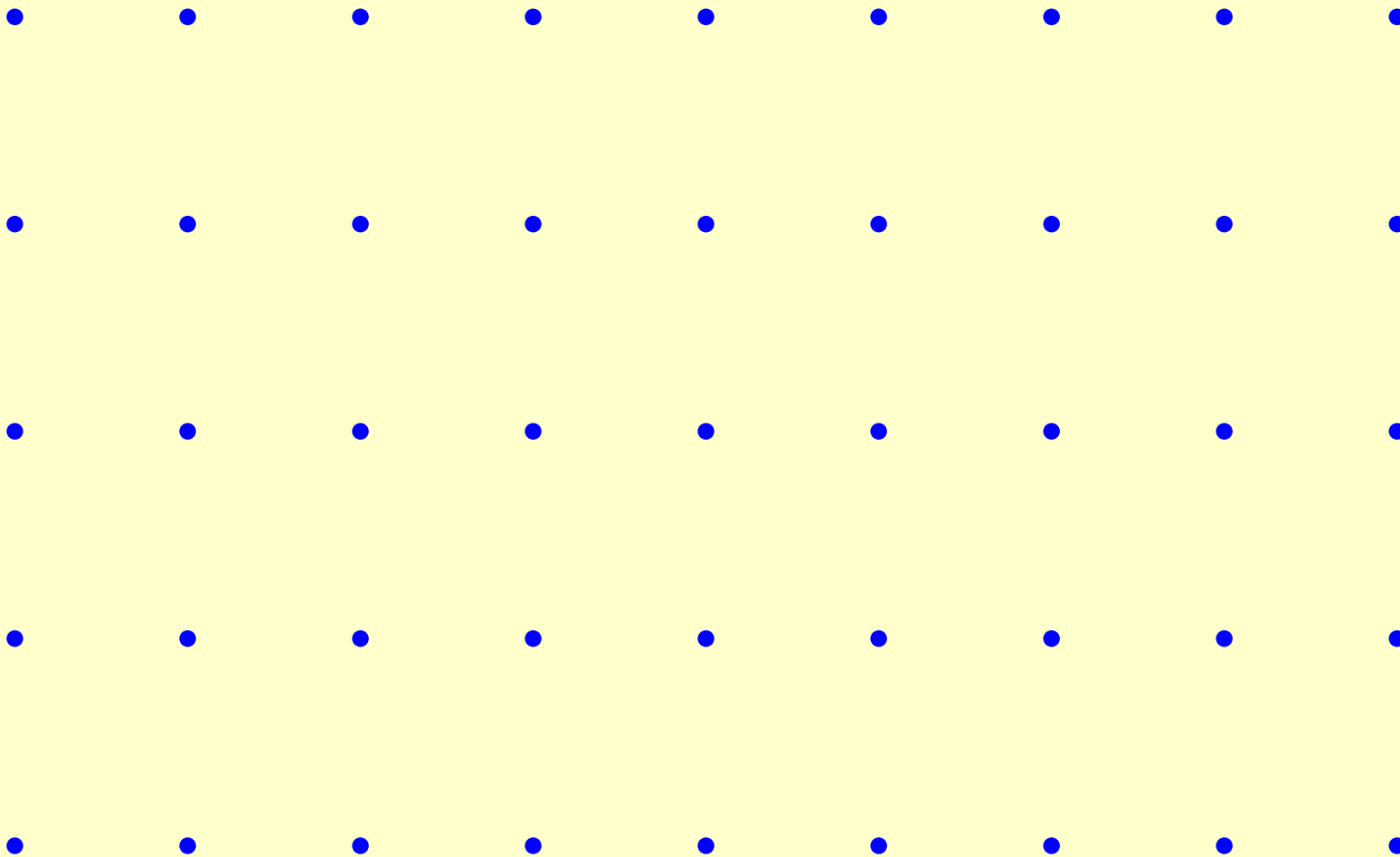


$$F_B = qvB\sin(90^\circ) = qvB$$

Direction: Upward toward the top of the page.

Note :

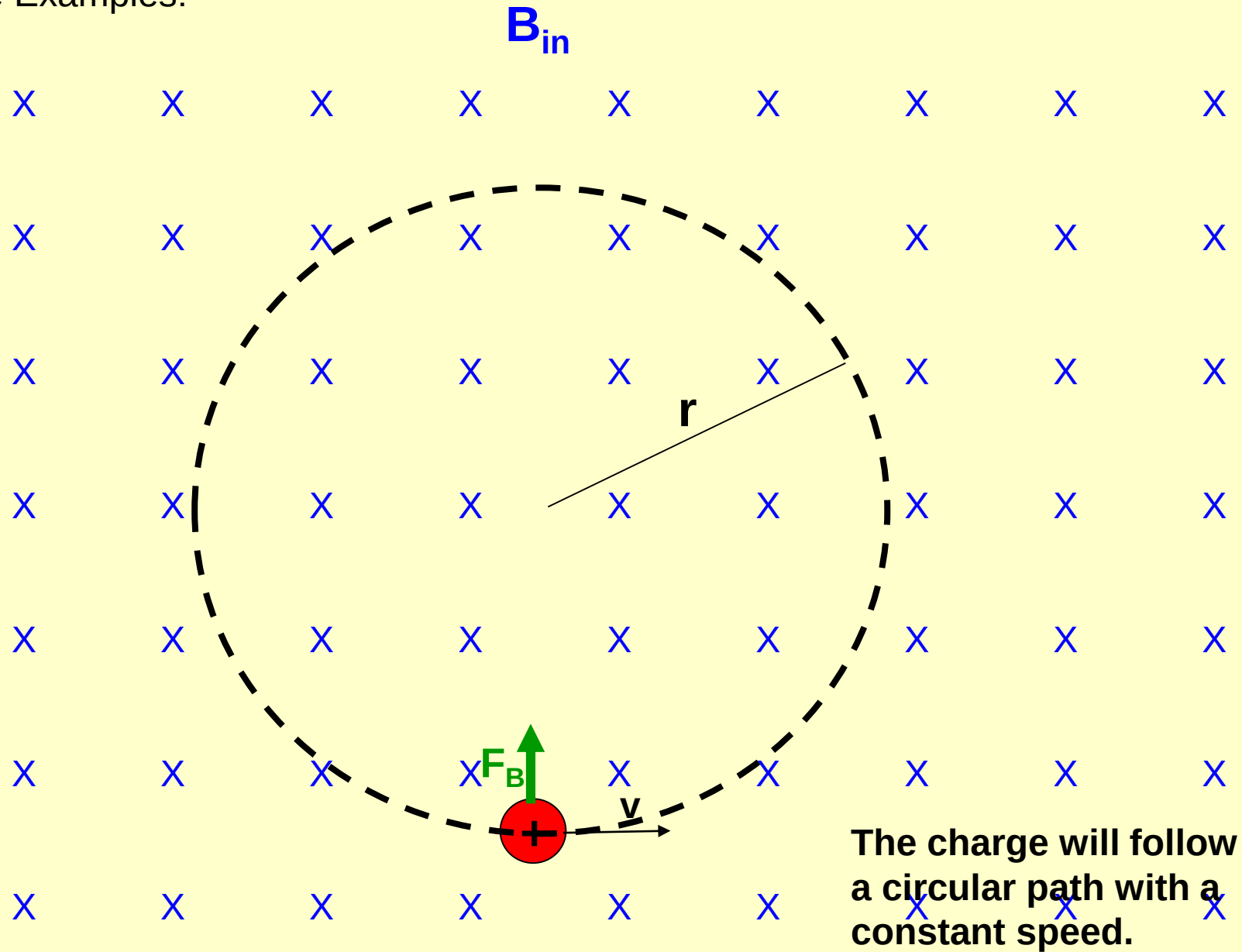
The force is perpendicular on B and V



A 7x10 grid of 'X' marks on a yellow background. The 'X' marks are arranged in a regular pattern, with one 'X' in each cell of the grid. The grid is composed of 7 rows and 10 columns, totaling 70 'X' marks.

Let's predict the path of a moving charge in a magnetic field.

More Examples:



Example 1

A proton enters a magnetic field **B** which is directed into the page. The proton has a charge $+q$ and a velocity **v** which is directed to the right, and enters the magnetic field perpendicularly.

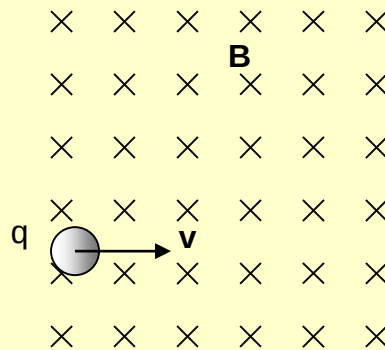
$$q = +1.6 \times 10^{-19} \text{ C}$$

$$v = 4.0 \times 10^6 \text{ m/s}$$

$$B = 0.5 \text{ T}$$

Determine

- (a) the magnitude and direction of the initial force acting on the proton
- (b) the subsequent path of the proton in the magnetic field
- (c) the radius of the path of the proton
- (d) the magnitude and direction of an electric field that would cause the proton to continue moving in a straight line.



Important Note:
the force on the electron is opposite the force given by the right-hand rule due to the electron's negative charge

EXAMPLE PROBLEM 2

Get help with force

FORCE ON A CHARGED PARTICLE IN A MAGNETIC FIELD A beam of electrons travels at 3.0×10^6 m/s through a uniform magnetic field of 4.0×10^{-2} T at right angles to the field. How strong is the force acting on each electron?

KNOWN

$$v = 3.0 \times 10^6 \text{ m/s}$$

$$B = 4.0 \times 10^{-2} \text{ T}$$

$$q = -1.602 \times 10^{-19} \text{ C}$$

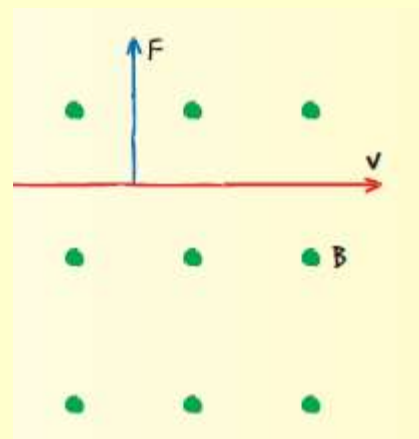
UNKNOWN

$$F = ?$$

$$F = qvB$$

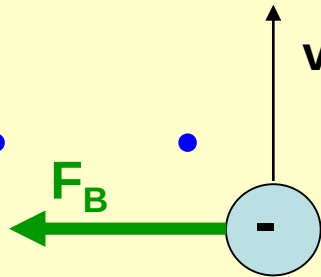
$$= (-1.602 \times 10^{-19} \text{ C})(3.0 \times 10^6 \text{ m/s})(4.0 \times 10^{-2} \text{ T})$$

$$= -1.9 \times 10^{-14} \text{ N}$$



More Examples:

$\mathbf{B}_{\text{out}}$



$$F_B = qvB \sin(90^\circ) = qvB$$

Direction: Left. Negative x direction.

PRACTICE PROBLEMS

Do additional problems. [Online Practice](#)

25. In what direction is the force on an electron if that electron is moving east through a magnetic field that points north?
26. What are the magnitude and direction of the force acting on the proton shown in **Figure 20**?
27. A stream of doubly ionized particles (missing two electrons and thus carrying a net positive charge of two elementary charges) moves at a velocity of 3.0×10^4 m/s perpendicular to a magnetic field of 9.0×10^{-2} T. How large is the force acting on each ion?
28. Triply ionized particles in a beam carry a net positive charge of three elementary charge units. The beam enters a magnetic field of 4.0×10^{-2} T. The particles have a speed of 9.0×10^6 m/s and move at right angles to the field. How large is the force acting on each particle?
29. A singly ionized particle experiences a force of 4.1×10^{-13} N when it travels at a right angle through a 0.61-T magnetic field. What is the particle's velocity?
30. **CHALLENGE** Doubly ionized helium atoms (alpha particles) are traveling at right angles to a magnetic field at a speed of 4.0×10^4 m/s. The force on each particle is 6.4×10^{-16} N. What is the magnetic field strength?

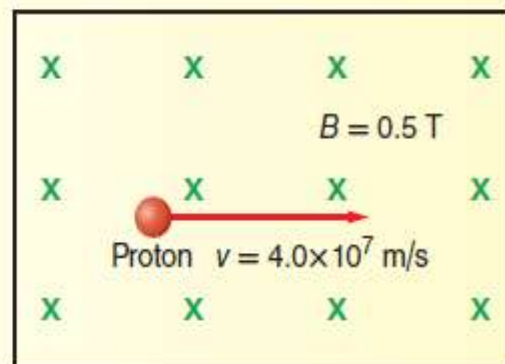


Figure 20

Applications on magnetic forces:.

1. Electrical motor

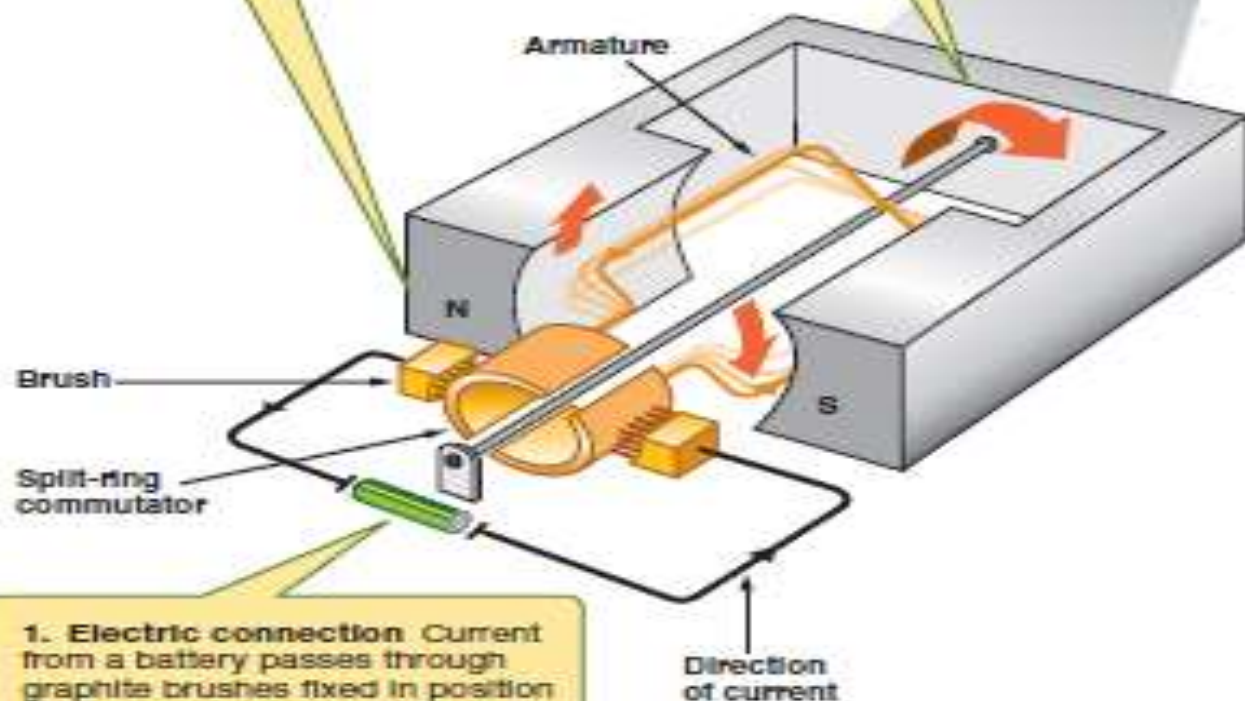
2. Electrical motor

Electrical motor: is an apparatus that converts electrical energy into mechanical energy.

- Electric motors rely on a multilooped wire coil called an **armature**
- Current enters the armature through a split-ring commutator, which reverses the direction of current as the armature turns, as shown in the simple electric motor in **Figure**

2. Current reversal Current goes through the brush to the split-ring commutator, which passes it on to the armature. The magnet either repels or attracts the armature, depending on the direction of current. When the armature reaches the vertical position, each half of the commutator changes brushes. This reverses current direction so that the armature can rotate an additional 180° .

3. Continuous rotation Current reverses with each half-turn of the armature; this results in continuous rotation.



1. Electric connection Current from a battery passes through graphite brushes fixed in position but pressed against a split-ring commutator. The commutator is attached to a wire loop—the armature—along an axle in a magnetic field.

<https://nationalmaglab.org/education/magnet-academy/watch-play/interactive/dc-motor>