Jesse Benitez Electricity and Magnetism

AP Review Sheet

Chapter 11: Magnetic Forces and Fields

Background/Summary: In this unit, you will learn how to deal with magnetic fields, calculate magnetic forces, and analyze complex machinery that takes advantage of magnetic principles.

	Electric Fields	Magnetic Fields
Source	Generated by the presence of a charge	Generated by charge in motion
Direction	Direction + charge would accelerate if released in field	Direction a compass would point if placed in field
Unit	N/C or V/m	T (Teslas)
Field Lines	From + to -	From North to South

Key Concepts:

1. **Magnetic Forces**

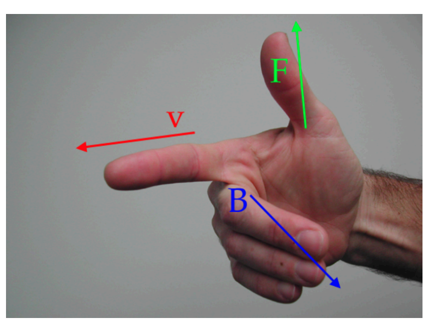
When charge moves through a magnetic field, it may or may not feel a force, depending on its motion. If there is a force, it will be:

$$F = qv \times B$$

Where the magnitude is:

$$|F| = q\,|v|\,|B|\,sin\Theta$$

To determine the direction of the force on a + charge, use the Right Hand Rule as shown below.



2. **Newton's Law**

Magnetic forces are centripetal in nature, acting perpendicular to the fields themselves. This means that B field DO NO Work on the charges feeling their effects.

This is also important because problems often ask you do find the velocities and radii associated with the charge's centripetal path. These problems can be completed with the following relationship, based on the centripetal form of Newton's Second Law:

$$\sum F_{cent}:$$
$$q\vec{v}x\vec{B} = m\vec{a}_{cent}$$
$$\Rightarrow \quad qvB\sin 90^\circ = m\frac{v^2}{R}$$

3. **Lorentz Relationship**

This relationship is fairly straightforward and is applied when both electric and magnetic forces act. The relationship is as follows:

$$\vec{F}_{net} = F_E + F_B$$
$$= q\vec{E} + q\vec{v}x\vec{B}$$

4. **Magnetic forces on current carrying wires**

Because wires have charge moving within them, they can experience magnetic forces if the wire and field are properly oriented. The magnitude of the force can be calculated using the following relationship:

$$F = iL \times B$$

To determine direction, use the Right Hand Rule, assuming that current is in the direction of + charge flow.

If you come across a wire that is not straight, use the following integrals to sum up the differential displacement ds:

$$\vec{F}_{wire} = i\int_a^b d\vec{s}x\vec{B}$$

5. **Solenoids**

Coil of wires that produces a B field down its axis.

Magnitude:

$$B_s = \mu_0 nI$$

Direction:

Lay your hand in the direction of the current
And your thumb will point in the direction of
The B field

Important Equations:

Magnetic Force: $\vec{F}_M = q\vec{v} \times \vec{B}$

Magnetic Force on a Wire: $\vec{F} = \int I \, d\vec{\ell} \times \vec{B}$

Magnetic Field due to wire: $B = \dfrac{\mu_0 I}{2\pi r}$

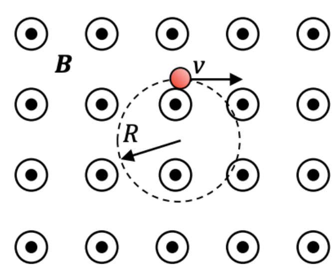
Magnetic Field Down a Solenoid: $B_s = \mu_0 n I$

Although they are not part of this unit, the following equations may be helpful when solving magnetic field problems:

Ampere's Law: $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$

Biot Savart: $d\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{I \, d\vec{\ell} \times \hat{r}}{r^2}$

Practice Problems:



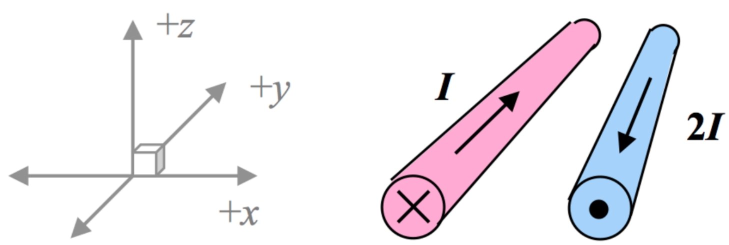
1. A charged particle of mass *m* is exposed to a constant magnetic field of magnitude *B* and directed out of the page, in which the particle moves in a clockwise circle of radius *R* with a speed *v*, as shown. In a separate experiment, the same particle is traveling with a speed 2*v* in a constant magnetic field of the same magnitude *B*, now directed *into* the page. Which of the following statements is true?
   a. Now the particle travels in a clockwise circle of radius *R*.
   b. Now the particle travels in a counterclockwise circle of radius *R*.
   c. Now the particle travels in a counterclockwise circle of radius *2R*.
   d. Now the particle travels in a clockwise circle of radius *R*/2.
   e. Now the particle travels in a counterclockwise circle of radius *R*/2.

2.

A charged particle moves through a region of space at constant speed, without deflecting. From this, one can conclude that in this region:

a. There must be no magnetic field.
b. There must be no magnetic field and no electric field.
c. There could be electric and magnetic fields, oriented in the same direction.
d. There could be electric and magnetic fields, oriented in opposite directions.
e. There could be electric and magnetic fields, oriented perpendicular to each other.

3.



Two long parallel wires, oriented along the *y*-axis as shown, contain currents *I* and 2*I*, flowing in opposite directions. Which of the following statements is true?

a. The magnetic field due to *I* circles that wire in a counterclockwise direction.
b. The magnetic force from wire 2*I* on wire *I* is twice as strong as the force on wire *I* from wire 2*I*.
c. The magnetic force between the two wires is proportional to the inverse square of the distance between them.
d. The force on wire 2*I* is in the +*x* direction.
e. The force on wire 2*I* is in the –*z* direction.

Solutions to Practice Problems:

1. The correct answer is *c*. Using the Right Hand Rule, we can determine that the magnetic field now motivates the particle to move in the counterclockwise direction. To determine the radius of the particle's new motion, we must use Newton's Second Law:

$$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$$

$$F_c = \frac{mv^2}{r}$$

$$F_c = \mathbf{F}_B$$

$$\frac{mv^2}{r} = q\mathbf{v} \times \mathbf{B}$$

$$r = \frac{mv}{qB}$$

As we can see from this relationship, the increased velocity will lead to an increased radius of motion.

2. The correct answer is *e*. A magnetic field causes a particle to accelerate in the plane perpendicular to that of the field. Because there is no acceleration, the electric field must be counteracting the magnetic force. As electric fields motivate particles to in the plane of the field, the electric field must be oriented perpendicular to the magnetic field.

3. The correct answer is *d*. The magnetic field around I circles it in the clockwise direction (determined using the RHR for wires). At the position of wire 2I, the field is oriented downwards. By applying the RHR for forces, we can determine that the force on wire 2I is in the +x direction. The magnitude of the force applied from I on 2I and 2I on I are equal, according to Newton's Third Law. To determine the magnitude of the force, we must use the relationship for the magnetic field from a wire:

$$B = \frac{\mu_0 I}{2\pi r}$$

Combining that relationship with the force on a wire,

$$F_B = I\ell \times B$$

We get:

$$F_B = (2I)\ell \times \frac{\mu_0 I}{2\pi r}$$

To determine the force per unit length, we can divide the force by the length of the wires to get the answer:

$$\frac{F_B}{\ell} = \frac{\mu_0 2I^2}{2\pi r}$$