17 Magnetism and Electromagnetic Induction

17-1 Magnetic Forces and Fields

Vocabulary **Magnetic Field:** An area of influence around a moving charge. The size of the field is related to the amount of magnetic force experienced by the moving charge when it is at a given location in the field.

$$\textbf{magnetic field} = \frac{\textbf{force}}{(\textbf{charge})(\textbf{speed})} \qquad \text{or} \qquad B = \frac{F}{qv}$$

The SI unit for magnetic field is the **tesla** (**T**), which equals one **netwon per amp·meter** (**N/A·m**).

When solving for the magnetic force, rewrite this equation as $F = qvB$.

The magnitude of the magnetic force can also be written in terms of the current, I, flowing through a length of wire, L.

$$\textbf{force} = (\textbf{current})(\textbf{length of wire})(\textbf{magnetic field}) \qquad \text{or} \qquad F = ILB$$

Unlike gravitational force or electric force, magnetic force is perpendicular to the plane formed by the field and the moving charge, and is greatest when the magnetic field and the current are perpendicular to each other.

The easiest way to detect a magnetic field is with a compass.

Solved Examples

Example 1: A proton speeding through a synchrotron at 3.0×10^7 m/s experiences a magnetic field of 4.0 T that is produced by the steering magnets inside the synchrotron. What is the magnetic force pulling on the proton?

Solution: Remember, the charge of a proton or an electron is 1.60×10^{-19} C.

Given: $q = 1.60 \times 10^{-19}$ C
$v = 3.0 \times 10^7$ m/s
$B = 4.0$ T

Unknown: $F = ?$
Original equation: $F = qvB$

Solve: $F = qvB = (1.60 \times 10^{-19}\text{ C})(3.0 \times 10^7\text{ m/s})(4.0\text{ T}) = \mathbf{1.9 \times 10^{-11}\ N}$

Example 2: A 10.0-m-long high-tension power line carries a current of 20.0 A perpendicular to Earth's magnetic field of 5.5×10^{-5} T. What is the magnetic force experienced by the power line?

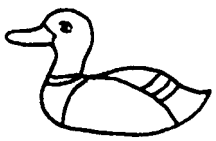
Given: $I = 20.0$ A
$L = 10.0$ m
$B = 5.5 \times 10^{-5}$ T

Unknown: $F = ?$
Original equation: $F = ILB$

Solve: $F = ILB = (20.0\text{ A})(10.0\text{ m})(5.5 \times 10^{-5}\text{ T}) =$ **0.011 N**

Practice Exercises

Exercise 1: Dean is hunting in the Northwest Territories at a location where Earth's magnetic field is 7.0×10^{-5} T. He shoots by mistake at a duck decoy, and the rubber bullet he is using acquires a charge of 2.0×10^{-12} C as it leaves his gun at 300. m/s, perpendicular to Earth's magnetic field. What is the magnitude of the magnetic force acting on the bullet?



Answer: _____

Exercise 2: A wasp accumulates 1.0×10^{-12} C of charge while flying perpendicular to Earth's magnetic field of 5.0×10^{-5} T. How fast is the wasp flying if the magnetic force acting on it is 6.0×10^{-16} N?

Answer: _____

Exercise 3: Kron, the alien freedom fighter from the planet Krimbar, shoots his gun that fires protons at a speed of 3.0×10^{6} m/s. a) What is Krimbar's magnetic field if it creates a force of 2.88×10^{-15} N on the protons? b) How does this compare to Earth's magnetic field?

Answer: **a.** _____

Answer: **b.** _____

Exercise 4: The magnetic field in Boston, Massachusetts has a horizontal component to the north of 0.18×10^{-4} T and a vertical component of 0.52×10^{-4} T straight downward. a) What is the magnitude and direction of Earth's magnetic field in Boston? b) If a 2.0-m-long household wire is carrying a current of 15 A in a direction perpendicular to the field, what is the magnitude of the magnetic force experienced by the wire?

Answer: **a.** _____

Answer: **b.** _____

Chapter 17

1. 4.2×10^{-14} N
3. a) 6.0×10^{-3} T