

# MAGNETIC FIELDS

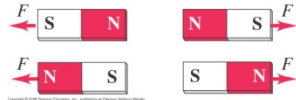
## Properties of Magnetism Based on Observation

1. There are two magnetic poles – A north pole and a south pole.
2. Like poles repel and unlike poles attract.

(a) Opposite poles attract.



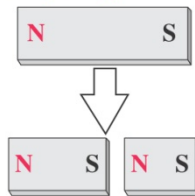
(b) Like poles repel.



3. There are no magnetic monopoles.

In contrast to electric charges, magnetic poles always come in pairs and can't be isolated.

Breaking a magnet in two ...



... yields two magnets, not two isolated poles.

4. The direction of the external magnetic field (**B**-field) is from North to South.

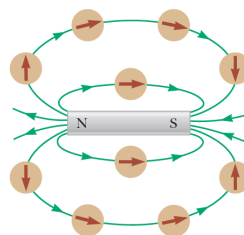
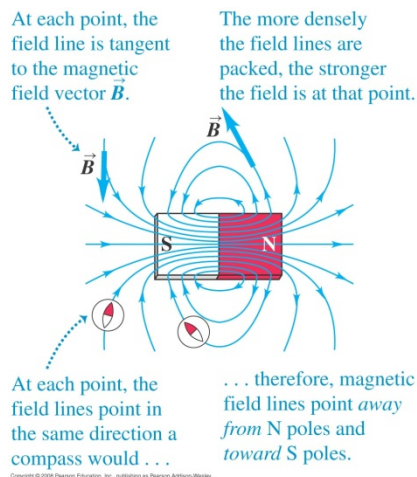
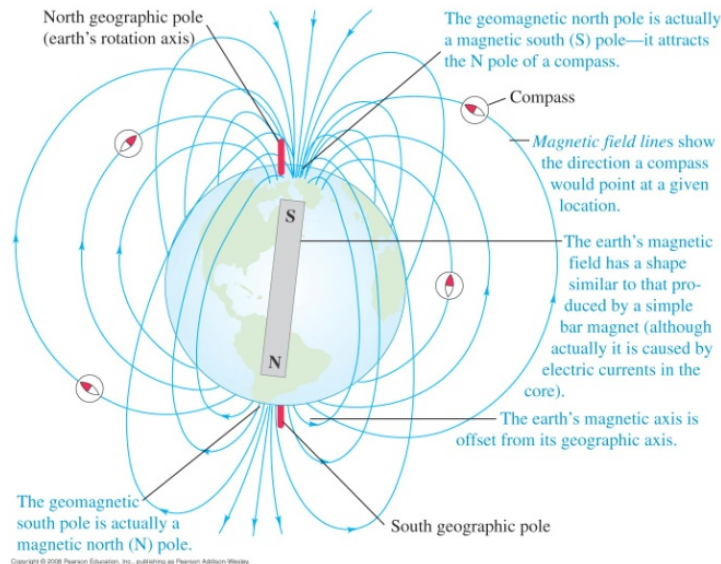
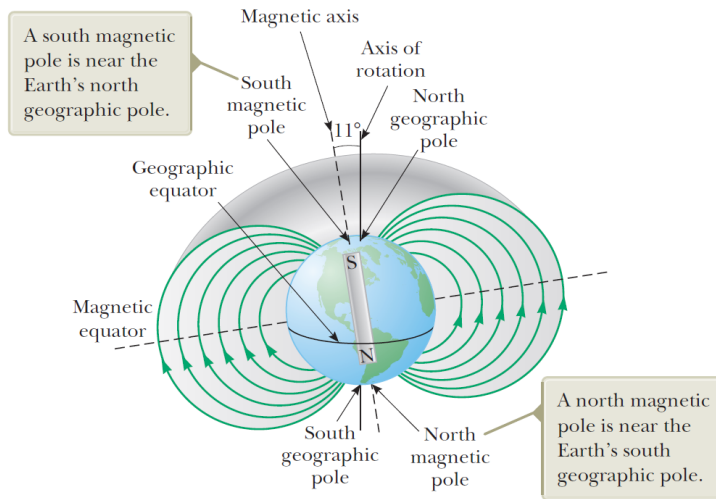


Figure 29.1 Compass needles can be used to trace the magnetic field lines in the region outside a bar magnet.

The direction of the magnetic field  $B$  at any point is the direction in which a compass needle points at that point.

## 5. Earth's Magnetic Field



6. A magnetic field exerts a force on any moving charge moving in a magnetic field  $\mathbf{B}$ .

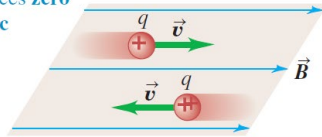
$$\vec{F}_B = q\vec{v} \times \vec{B} \quad \text{Magnetic Force on a Moving Charged Particle}$$

$$F_B = qvB \sin \theta \quad \text{Magnitude of Magnetic Force}$$

$$\vec{F}_B = q \begin{bmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{bmatrix}$$

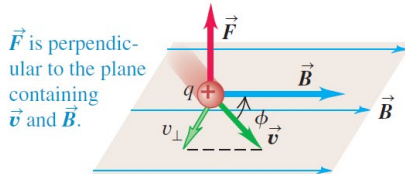
(a)

A charge moving **parallel** to a magnetic field experiences **zero magnetic force**.



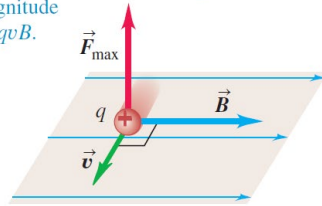
(b)

A charge moving at an angle  $\phi$  to a magnetic field experiences a magnetic force with magnitude  $F = |q|v_{\perp}B = |q|vB \sin \phi$ .



(c)

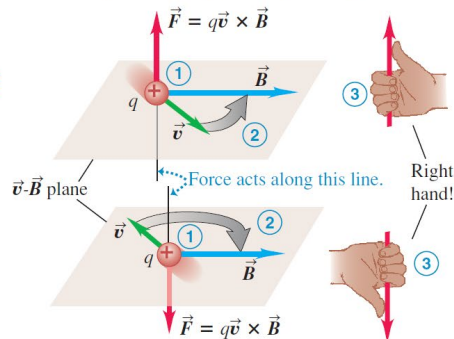
A charge moving **perpendicular** to a magnetic field experiences a maximal magnetic force with magnitude  $F_{\max} = qvB$ .



(a)

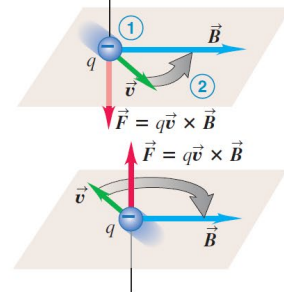
**Right-hand rule** for the direction of magnetic force on a **positive** charge moving in a magnetic field:

- ① Place the  $\vec{v}$  and  $\vec{B}$  vectors tail to tail.
- ② Imagine turning  $\vec{v}$  toward  $\vec{B}$  in the  $\vec{v}$ - $\vec{B}$  plane (through the smaller angle).
- ③ The force acts along a line perpendicular to the  $\vec{v}$ - $\vec{B}$  plane. Curl the fingers of your *right hand* around this line in the same direction you rotated  $\vec{v}$ . Your thumb now points in the direction the force acts.



(b)

**If the charge is negative**, the direction of the force is **opposite** to that given by the right-hand rule.



## Units

$$[B] = \frac{F}{qv} = \frac{N}{C \frac{m}{s}} = \frac{N}{Am}$$

$$1 \text{ Tesla} = 1T = 1 \text{ N/Am}$$

1 Tesla is a relative large value of magnetic field. A smaller common unit is the Gauss (G):

$$1G = 10^{-4} \text{ T.}$$

$$B_{\text{earth}} \approx 0.5 \text{ G}$$

$$B_{\text{Lab}} \approx 45 \text{ T (largest steady B-field produced in the lab)}$$