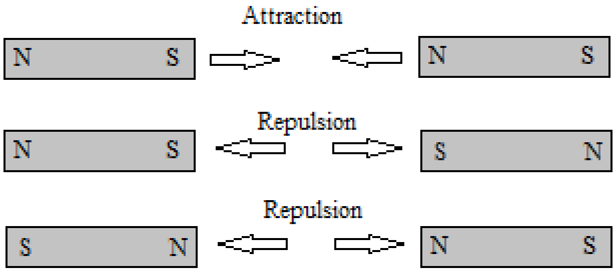
Part M Notes

Magnetism and Magnetic Field Lines

Magnets have two “poles, one “north,” the other “south.” Bar magnets are “magnetic dipoles,” as is Earth.

Opposite polarities attract.
Same polarities repel.



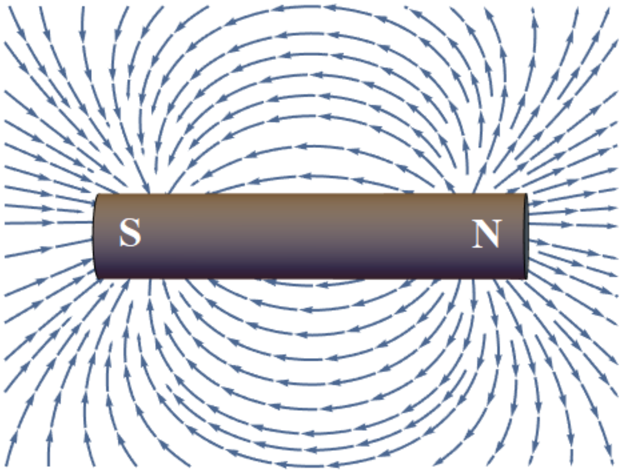
Magnetic Compass

A compass needle is a miniature bar magnet, one end of which is “north,” and the other end of which is “south.”

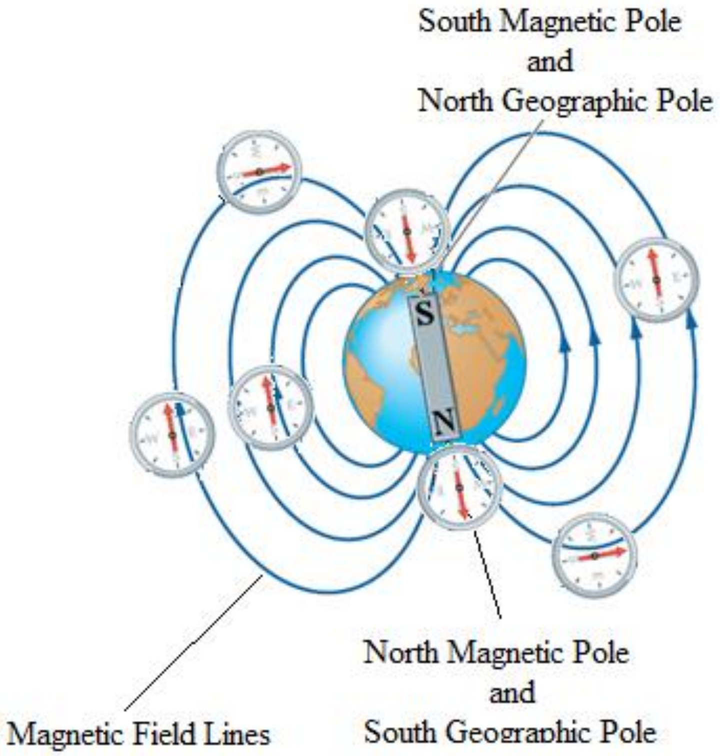
Magnetic Field of a Bar Magnet

The drawing below indicates the direction and intensity of the magnetic effect surrounding a bar magnet. The more tightly spaced are the curves at a given point, the greater is the magnetic “intensity.”

The arrow’s direction show how a compass needle would be aligned if a compass were placed at the point. Note that the field arrows leave the north pole, and land on the south pole.



A “magnetic field” is a region in which the orientation of a magnetic compass needle is influenced, i.e., can be twisted. Magnetic fields exist in the regions surrounding magnets, as well as near current-carrying wires. Earth acts like it had embedded in it an 8000-mile long bar magnet, with its north magnetic pole at antarctica, and its south magnetic pole in the arctic. Earth’s magnetic field can be “mapped” using a compass, as suggested below.



If a compass needle is placed anywhere in a magnetic field it will align itself tangent to the magnetic field line at that point.

The magnetic field intensity is symbolized as B, and is in units of “tesla” (T).

1.0 “gauss” (G) = 1.0×10^{-4} T.

Earth’s magnetic field lines leave Antarctica, and wrap around Earth; they are parallel to the ground at the equator, and point toward the north geographic pole.

Near Earth’s surface at the equator, B = 0.5 G.

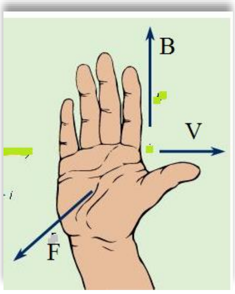
Magnetic Force and the Right-Hand Rule

If a charged object whose charge magnetude is Q is moving with speed v in a direction *perpendicular* to the magnetic field direction (perpendicular to to a magnetic field line), the magnetic force on the charge is given by the equation below:

$$F = QvB$$

This equation will not be used to calculate forces; what will matter to us about forces acting on moving charges is the *direction* of the magnetic force.

Use the "right-hand rule" to determine the direction of the force on a moving charge:



1. Flatten palm, fingers, and thumb.

2. Point thumb in the direction along which the positive charge is moving.

3. While preserving the thumb's direction, twist flat hand until the fingers point in the direction of the magnetic field arrows, then observe the direction toward which the palm faces.

4. The palm faces in direction of the force if the charge is positive.
5. Back of hand faces in the direction of the force if the charge is negative.

Note: The magnetic force on a charge moving *parallel* or *anti-parallel* to the magnetic field direction is zero.

<u>Example</u>:

Suppose a magnetic field created in a laboratory points from floor to ceiling, and an electron is fired parallel to a wall you're facing, from your left to your right.

In which direction will the electron be deflected?

Answer:

Away from you, toward the wall.

Example A:

A proton is fired upward at the equator, i.e., perpendicular to the ground. In which direction will it be deflected?

Answer: Westward

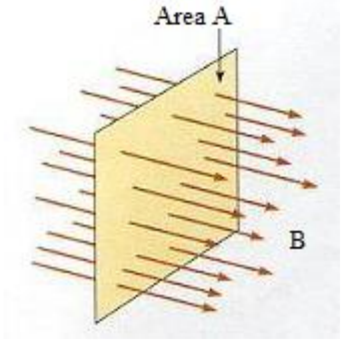
Example B:

A proton at the magnetic north pole is fired upward. In which direction will it be deflected?

Answer:

The magnetic field lines at the magnetic north pole point upward. Charges moving parallel to magnetic field lines experience zero magnetic force and therefore are not deflected at all.

Magnetic Flux



Symbol: Φ
Units: T-m^2
$\Phi = BA$

Flux Changes

Φ_o = Initial Flux
$= B_oA$

Φ = Final Flux
$= BA$

$\Delta\Phi$ =Flux Change
$= \Phi - \Phi_o$

$|\Delta\Phi|$ = Absolute Value of Flux Change

Faraday’s Law

When the flux through a wire coil changes over time, there is induced in the coil a voltage, and the coil acts just as if there were a battery in the wire driving current around the coil. The average voltage induced in the coil during the period of time the flux is changing is given by “Faraday’s Law”:	 N = Number of Turns t = Time $V_{ave} = N \lvert\Delta\Phi\rvert /t$ When the flux stops changing, there is zero induced voltage.

Example:

A circular wire coil containing 100 turns has a radius of 1.20 m. It faces a magnetic field whose intensity decreases from 0.006 T to 0.002 T in 50 milliseconds.

What average voltage was induced in the coil?

$N = 100$
$A = \pi\,(1.20)^2$
$\quad = 4.52\ \text{m}^2$
$t = 50 \times 10^{-3}$ s

Φ_o = Initial Flux
$\quad = B_oA$
$\quad = 0.006\,(4.52)$
$\quad = 0.027\ \text{T-m}^2$

Φ = Final Flux
$\quad = BA$
$\quad = 0.002\,(4.52)$
$\quad = 0.009\ \text{T-m}^2$

$\Delta\Phi$ =Flux Change
$\quad = \Phi - \Phi_o$
$\quad = -0.018\ \text{T-m}^2$

$|\Delta\Phi|$ = Absolute Value of Flux Change
$\quad = 0.018\ \text{T-m}^2$

$V_{ave} = N\,|\Delta\Phi|\,/t$
$\quad = 100\,(0.018)/50 \times 10^{-3}$
$\quad = 36.00$ V