Magnetic Forces and Magnetic Fields

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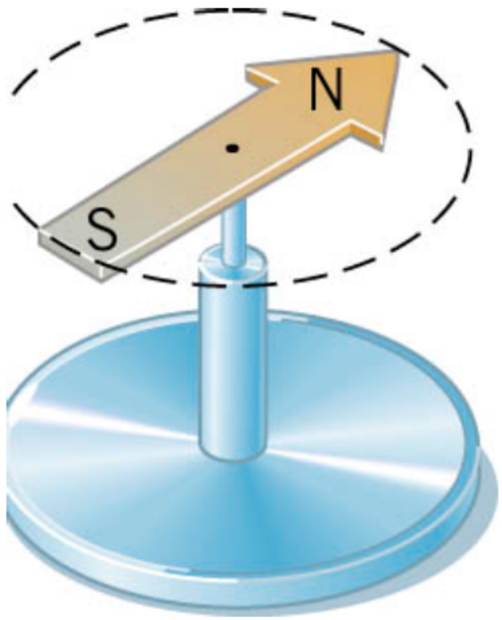
Items

1. Magnets
2. Magnetic Field of Force
3. Force of Magnetic Field on a Charge- Applications
4. Right Hand Rule -1 (RHR-1)

Magnets

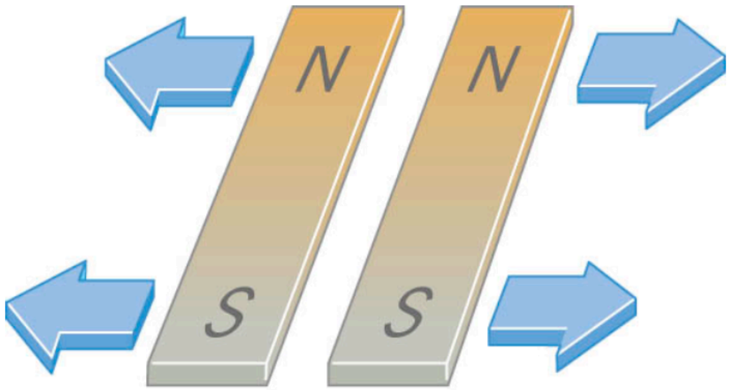
- **Magnets:** Certain materials such as lodestone are capable of exerting magnetic forces.

- **Poles**: Concentrated force areas on the opposite ends of magnet. There are two poles: North-seeking pole and South-seeking pole. The North pole points more or less to the Earth's North.

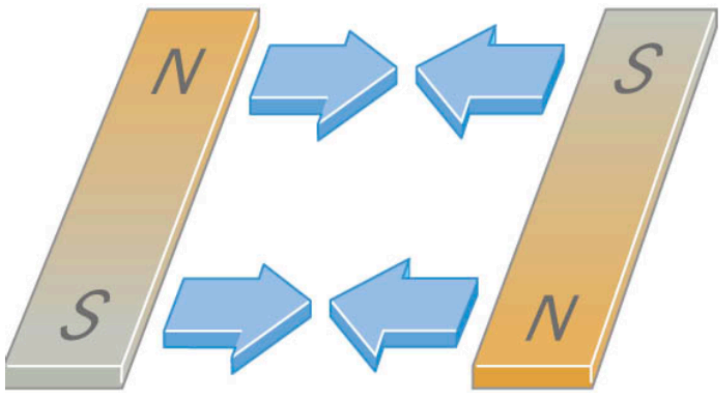


Fundamental Law of Magnetic Poles

(a) Similar poles repel
(b) Opposite poles attract.



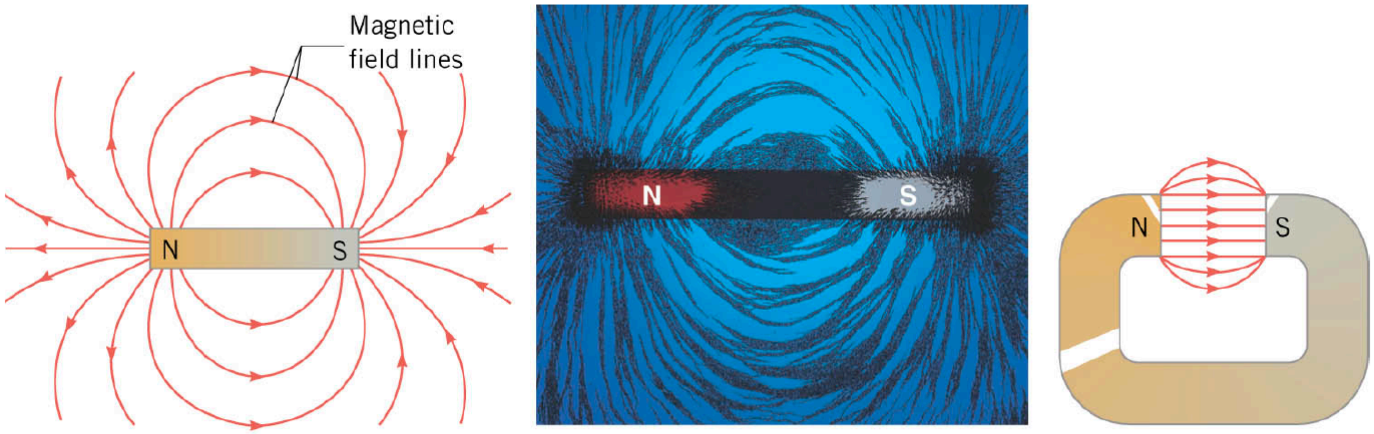
Like poles repel
(*a*)



Unlike poles attract
(*b*)

Magnetic Field of Force:

- A space around a magnetic in which there is magnetic force.
- It is represented by magnetic field lines in the gap of a horseshoe magnet.

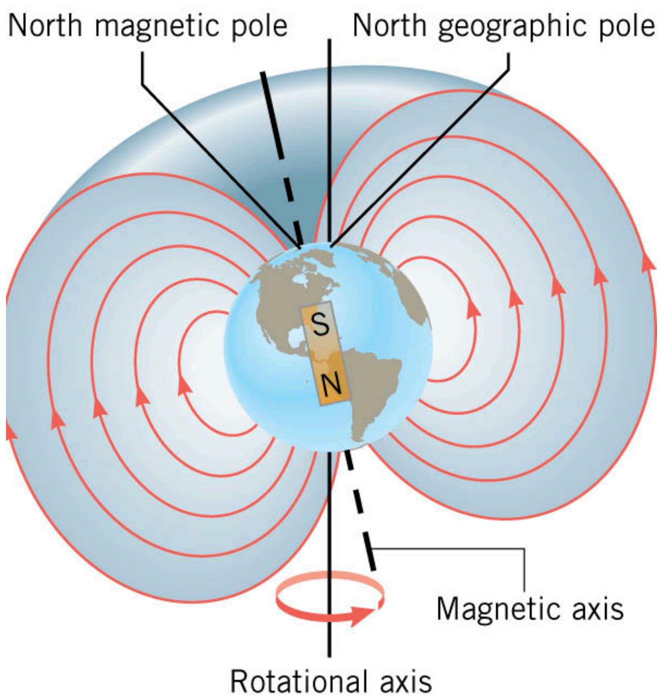


(a) (b) (c)

Features of magnetic field lines:

- They emanate (start) on N-pole and terminate (stop) on S-pole.
- The direction of the magnetic field vector is tangent to them.
- Number of lines/area is proportional to the strength of the magnetic field.
- They form closed loops -- separate S or N poles do not exist in nature.

The Earth behaves magnetically almost as if a bar magnet were located near its center

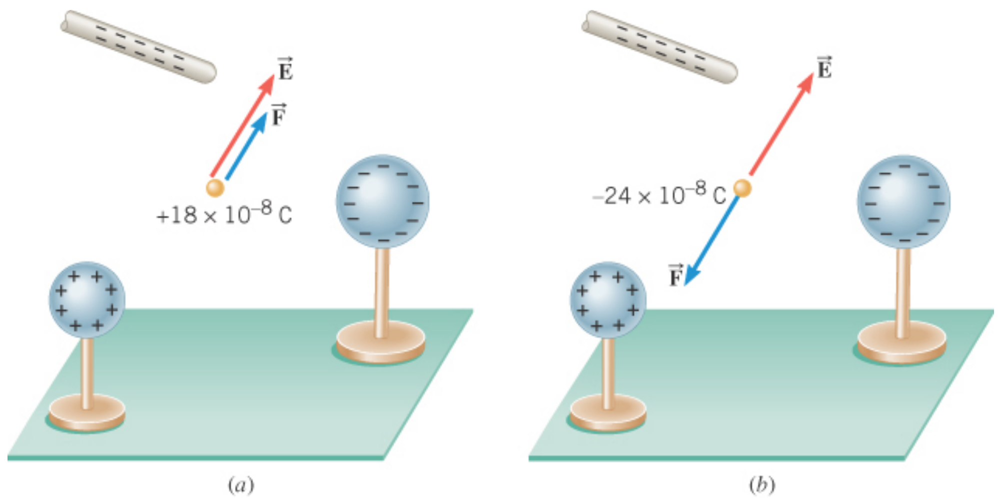


The compass needle points about 6.5^{o} West of true North (this angle is called the angle of declination).

The Force That a Magnetic Field Exerts on a Charge

When a charge is placed in an electric field, it experiences a force, according to

$$\vec{\mathbf{F}} = q\vec{\mathbf{E}}$$



A magnet force can be exerted on charged particle moving in a magnetic field.

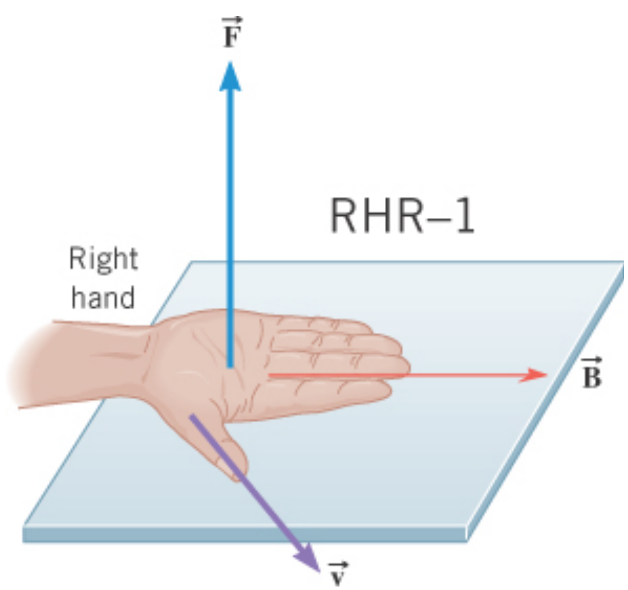
Right Hand Rule No. 1 (RHR-1)

(RHR-1) is used to find the direction of the magnetic force on a moving charge.

1) Extend the right hand so the fingers point along the direction of the magnetic field and the thumb points along the velocity of the charge.

2) The palm of the hand then faces in the direction of the magnetic force that acts on a positive charge.

If the moving charge is negative, the direction of the force is opposite to that predicted by RHR-1.



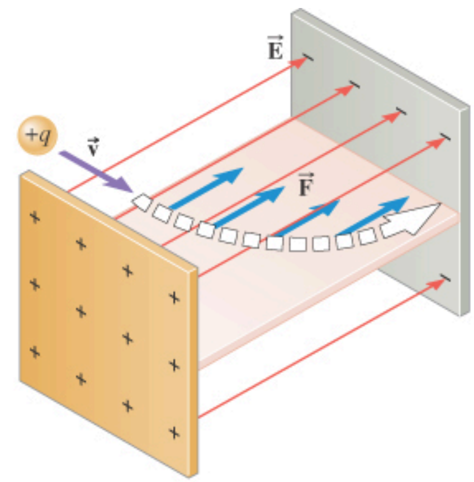
Electrical, Magnetic Forces and Work

The electrical force:

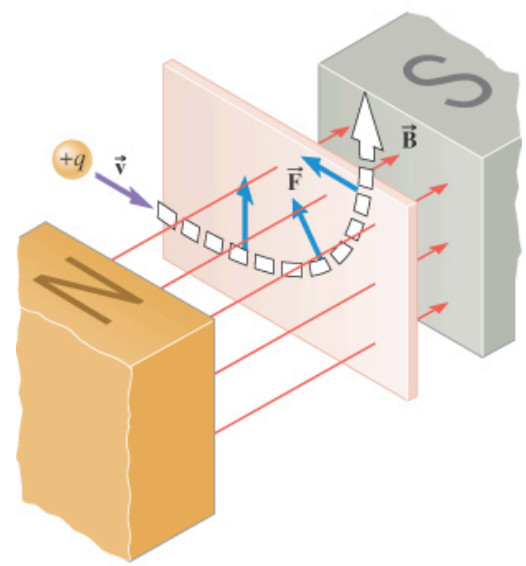
can do work on a charged particle
since it can displace the particle
in the direction of the force and
thus change its kinetic energy.

The magnetic force:

cannot do work on a charged particle
since it acts perpendicular
to the motion of the particle so
that no displacement occurs
along the direction of the force
and thus its speed remains constant
and its kinetic energy does not change.



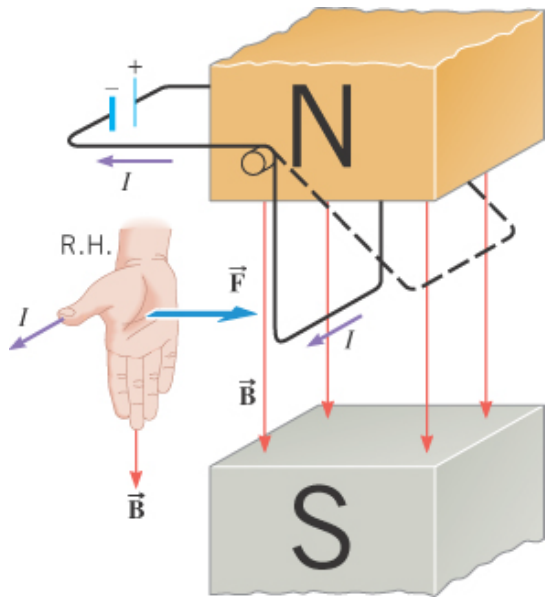
(a)



(b)

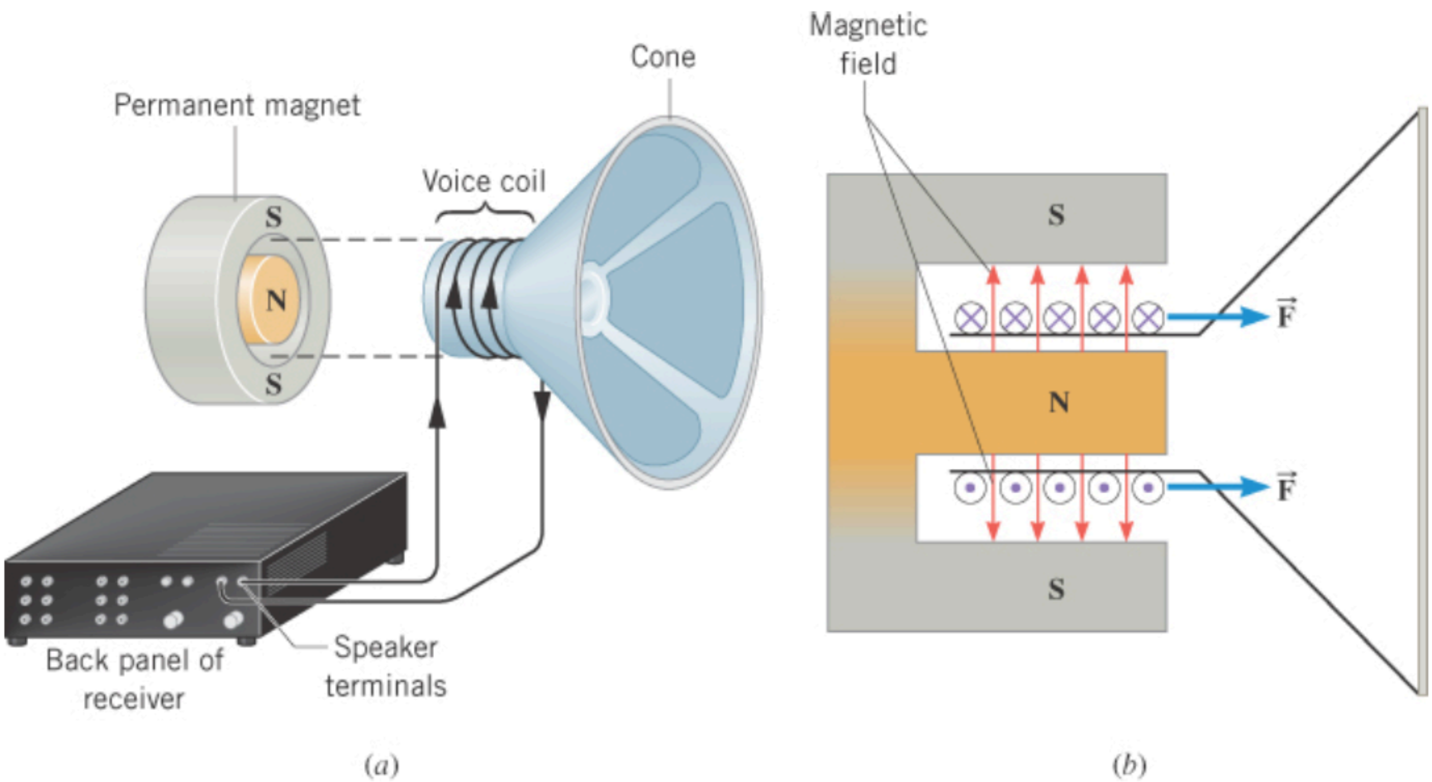
Principle of Force on charged Currents in magnetic Fields

- A magnetic force can also be exerted on a current of charged particles moving in a magnetic field, e.g. a current in a wire.
- Use RHR-1 to find the direction of the force on a wire by putting the thumb in the direction of the velocity of moving positive charges, i.e. the thumb points in the direction of the conventional current.



The magnetic force on the moving charges pushes the wire to the right

Applications: The Force and Acceleration in a Loudspeaker

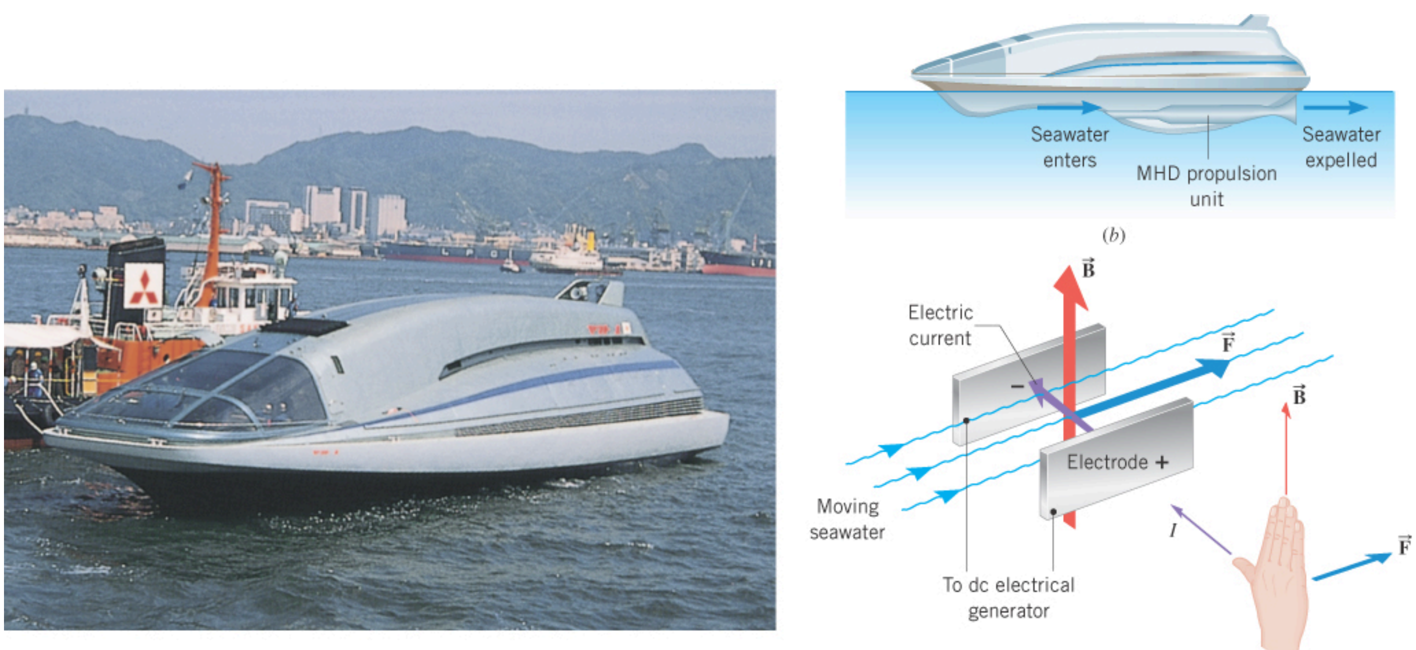


Applications: Magnetohydrodynamic (MHD) propulsion for ships and submarines.

MHD propulsion uses the principle of forces on charged currents in magnetic fields.

As water is expelled from the rear of the ship by the magnetic force, Newton's 3rd law causes the ship to recoil forward with the same force.

This has promise to be a low-noise, reliable and inexpensive system.

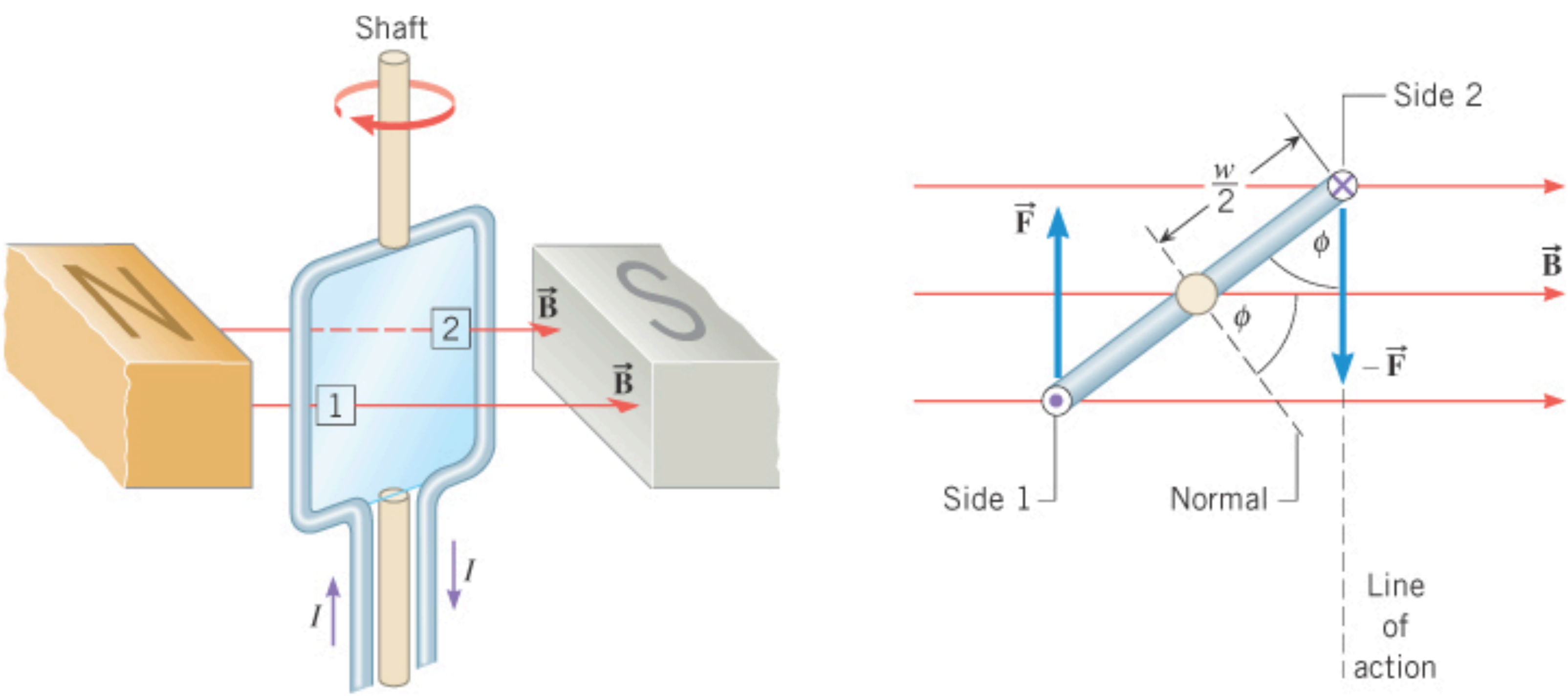


(a) (c)

Applications: The Torque on a Current-Carrying Coil

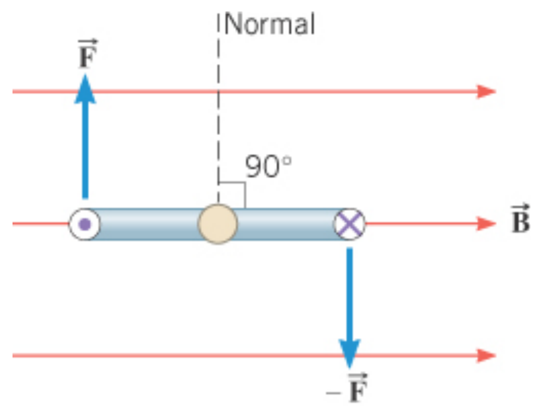
First, consider the forces on a current-carrying loop in a magnetic field:

The two forces on the loop have equal magnitude but an application of RHR-1 shows that they are opposite in direction.

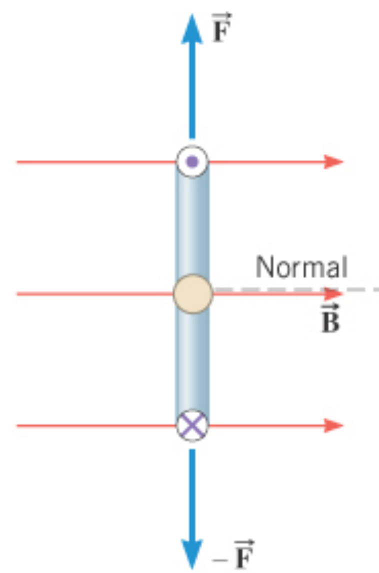


(a) (b)

The loop tends to rotate
such that its normal
becomes aligned with the magnetic field.



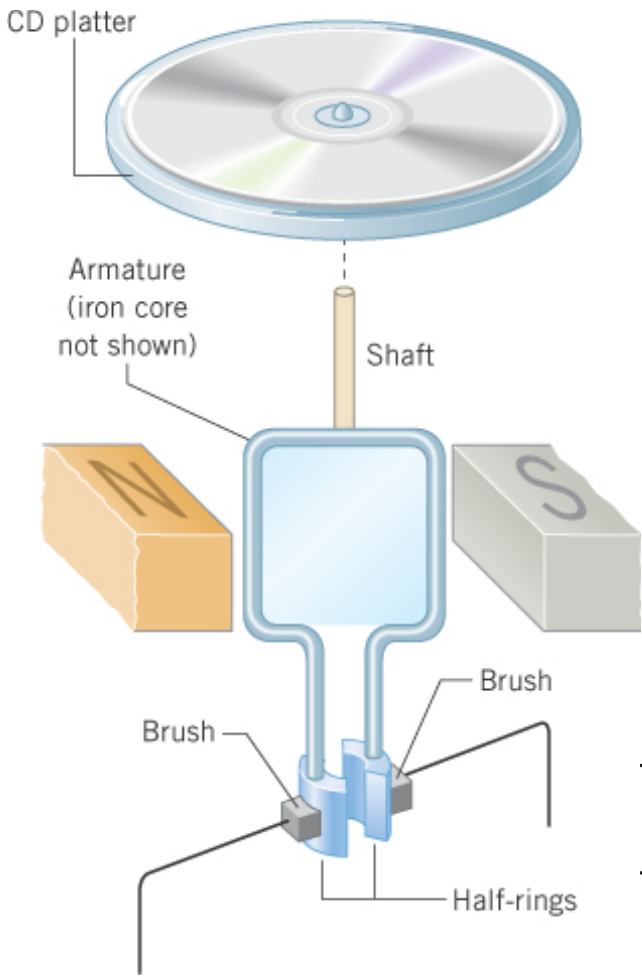
(*a*) Maximum torque



(*b*) Zero torque

Applications: The Torque on a Current-Carrying Coil

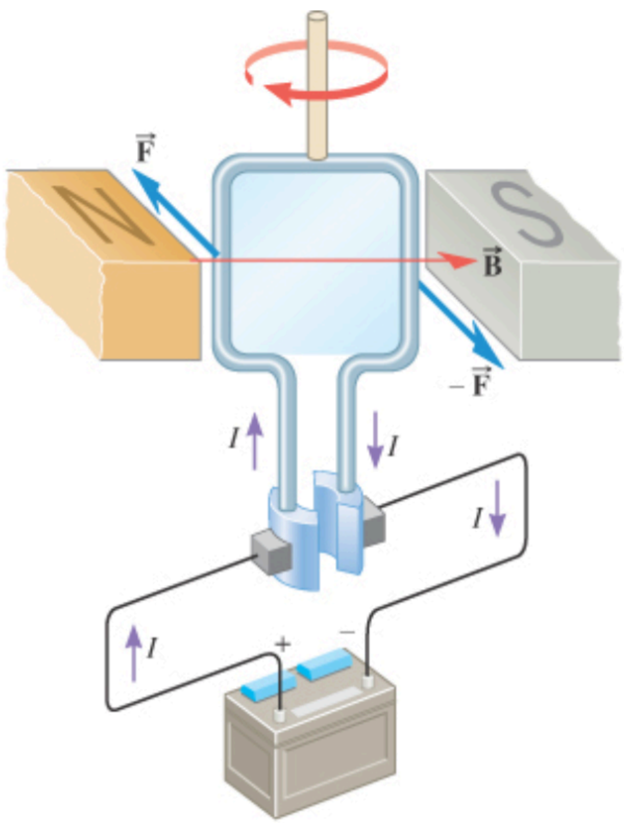
The basic components of a dc motor.



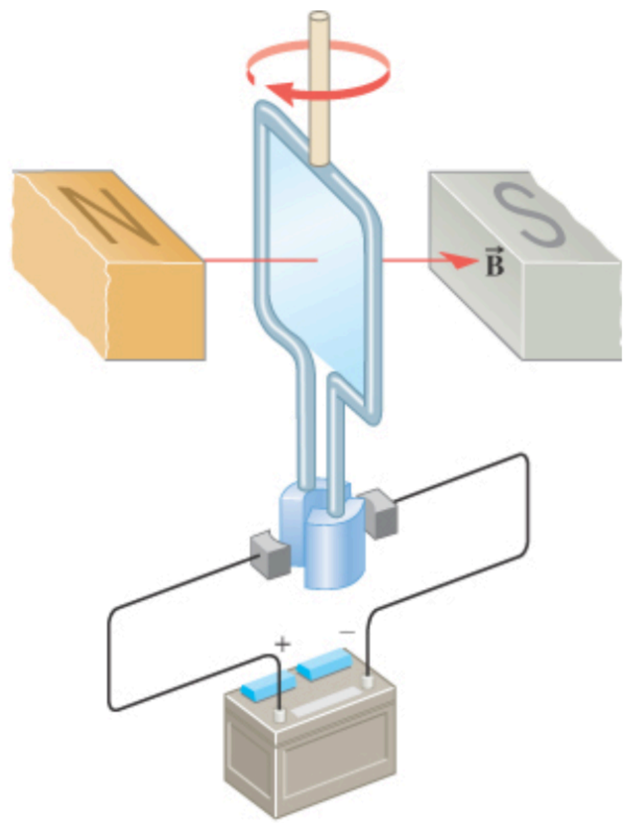
} Split-ring commutator

Applications: The Torque on a Current-Carrying Coil

How a dc motor works.



When a current exists in the coil, the coil experiences a torque.



Because of its inertia, the coil continues to rotate when there is no current.

References:

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Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current.* *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

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