

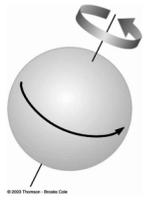
Electromagnetism

Cause of Magnetism

A stationary electric charge . . .

A moving electric charge . . .

What causes magnetism?



Non-magnetic material

Examples:

Reason:



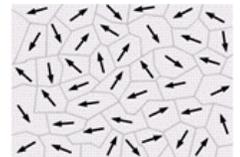
Non-magnetic material

Magnetic material

Examples:

Reason:

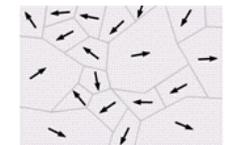
Domain:



Unmagnetized
magnetic material

Magnetized material

Reason:



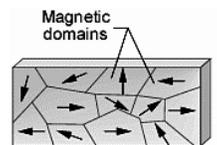
Magnetized
magnetic material

Induced Magnetism:

1. What does the strength of a magnet depend on?

Hard (permanent) magnet:

Soft (temporary) magnet:



(a) Unmagnetized iron

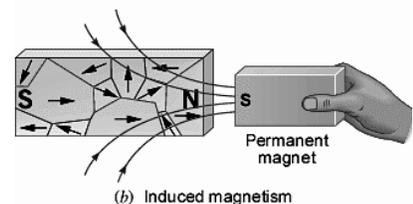
2. How does a magnet become weak or lose its magnetism?

i)

ii)

iii)

iv)

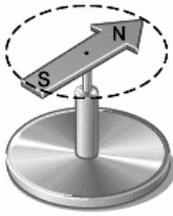


(b) Induced magnetism

3. What will happen if you break a magnet in half?

Magnetic Fields

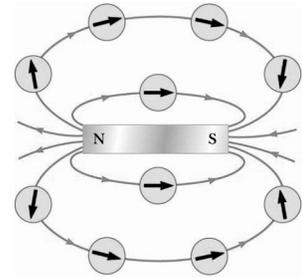
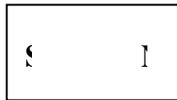
The Compass



- 1.
- 2.
- 3.

Sketch in the magnetic field lines below.

a)

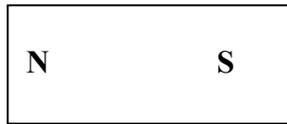
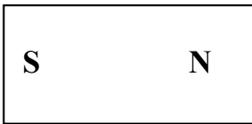


Mapping magnetic field lines using a compass

Magnetic Field Lines

- 1.
- 2.
- 3.
- 4.
- 5.

b)

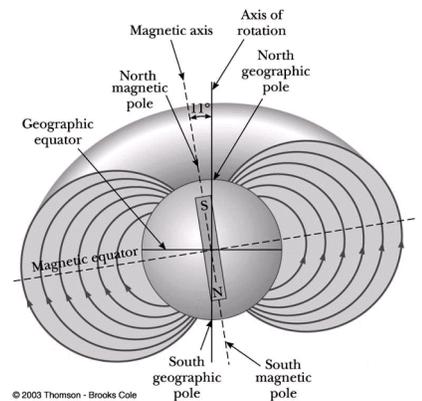


c)



Why does the Earth have a magnetic field?

The north magnetic pole of the Earth acts like . . .



Magnetic Fields in Three Dimensions

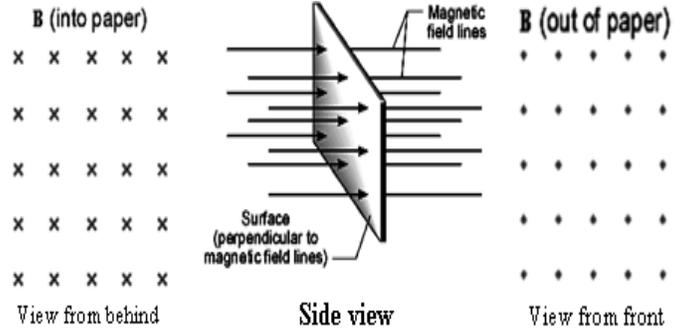
Magnetic Flux:

Magnetic Field Strength, Magnetic Field Intensity, Magnetic Flux Density:

Symbol:

Units:

Type:



Electromagnetism

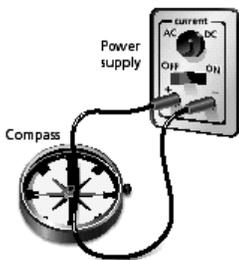
1. In 1819, Danish physicist and chemist Hans Christian Oersted was the first to notice
2. He noticed that
3. This demonstrated the principle that



Hans Christian Oersted
(Denmark, 1777 – 1851)

Not only was this astounding and unexpected, but further investigation showed that the magnetic field produced by the current in the wire had an unusual shape.

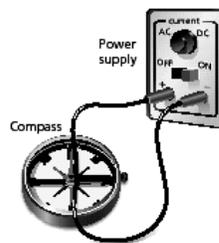
Current off



Oersted placed a compass beneath a wire with no current.

Direction of Compass Needle:

Current on

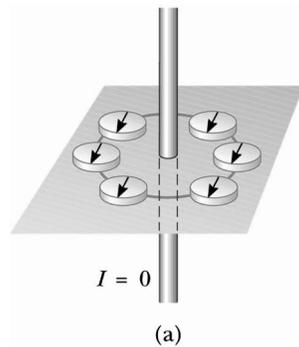


When the current was turned on, the compass needle deflected.

Direction of Compass Needle:

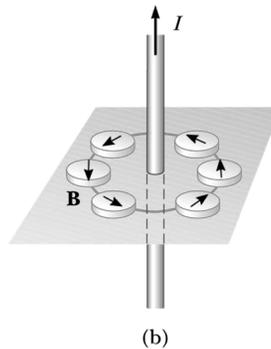


Iron filings sprinkled around a wire with current show a very different magnetic field from those of bar magnets.



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Current off



© 2003 Thomson - Brooks Cole

Current on

Direction of Compass Needle when current is on:

Direction of magnetic field around wire:

Draw the magnetic field lines around a current bearing wire:

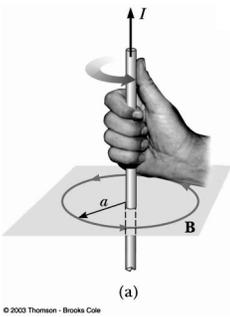
a) head-on view

b) side view

c) side view

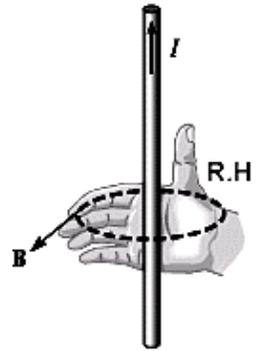
Right Hand Rule: Magnetic Field around a Wire

The direction of the curl of these field lines (clockwise or counterclockwise) can be determined by a **Curled Hand** right hand rule.



Thumb:

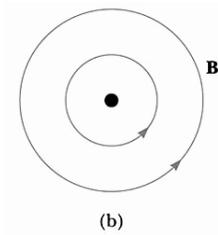
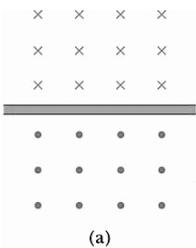
Fingertips:



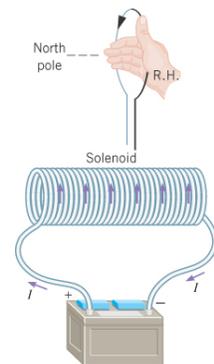
1. Draw the magnetic field around the wire in each case below. Use the Right Hand Rule for Fields to determine its direction.



2. The magnetic field produced by the current is shown in each case. Use the Right Hand Rule for Fields to determine the direction of the current flow in each wire shown below.



3. What is the direction of the magnetic field inside the wire loop shown below? The Solenoid?



**Eqn $B =$

$B =$

$B =$

Force on a Wire

If a wire with current flowing through it is placed in an external magnetic field, it will experience a force. Why?

Right Hand Rule: Magnetic Force on a Wire

The direction of the force exerted on a wire bearing current when placed in an external magnetic field can be determined by a **Flat Hand** right hand rule.

Flat Hand:

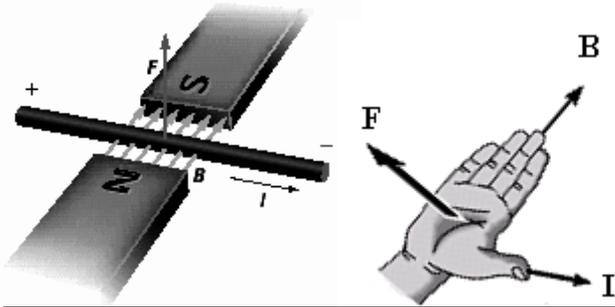
Fingers:

Thumb:

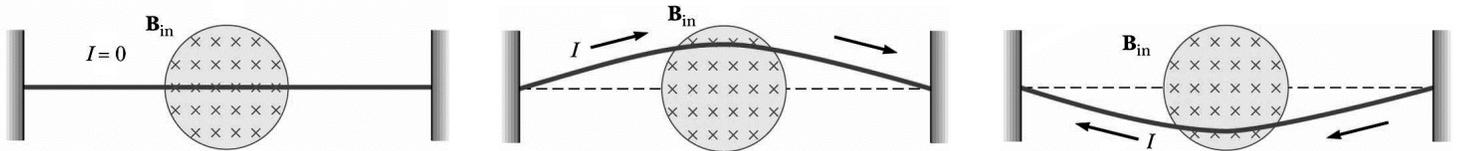
Palm:

Maximum force occurs when:

No force occurs when:



Use the right hand rule for forces to confirm the direction of the force in each case.

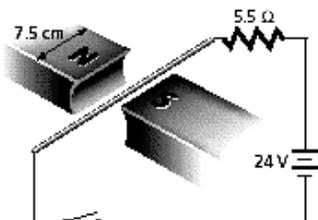


Magnitude of the force on a wire:

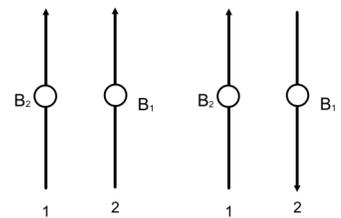
Variable:				
Quantity:				
Units:				
Type:				

Magnetic Force between Two Wires

- Find the magnitude and direction of the force on the wire when the switch is closed. The strength of the magnetic field is 1.9 T.



- Why do two wires carrying current attract or repel each other?

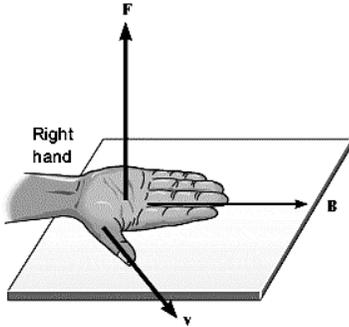


General Rule:

Magnetic Force on a Moving Charged Particle

Why is there a magnetic force on a charged particle as it moves through a magnetic field?

Right Hand Rule: Magnetic Force on a Charged Particle



Flat Hand:

Right Hand:

Left Hand:

Maximum force occurs when:

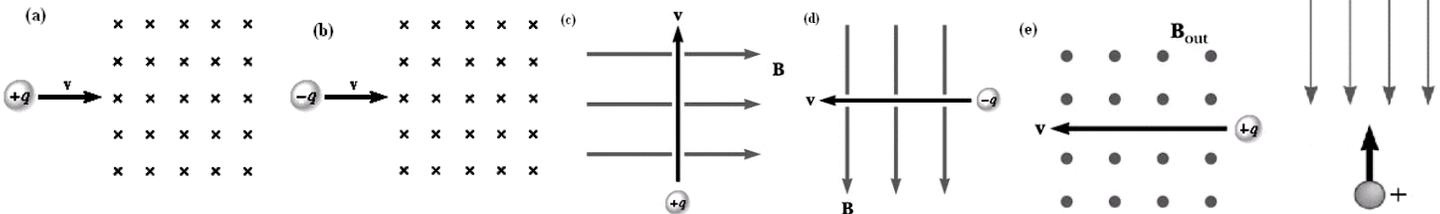
No force occurs when:

Fingers:

Thumb:

Palm:

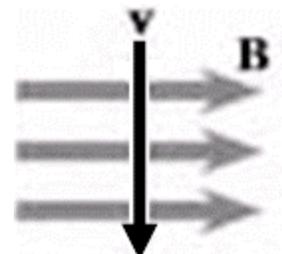
Find the direction of the magnetic force on each particle below as each enters the magnetic field shown. (f)



Magnetic Force on a Moving Charged Particle:

Variable:				
Quantity:				
Units:				
Type:				

1. a) Find the magnitude and direction of the magnetic force on a proton as it travels through a magnetic field whose strength is 2.0 T at a speed of 3.0×10^7 m/s.



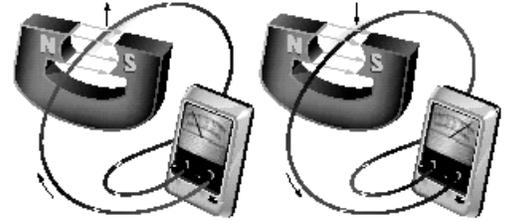
- b) What would change if the particle were an electron?

Electromagnetic Induction

Why will moving a wire through a magnetic field induce a potential difference and a current in the wire?

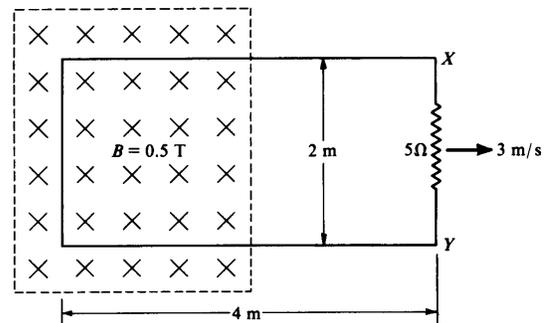
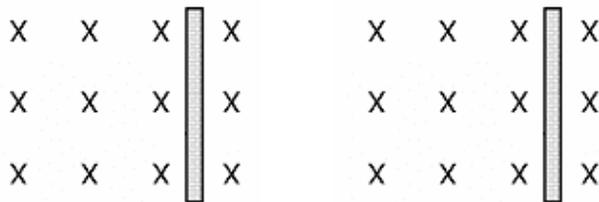
emf (electromotive force):

Maximum emf (and current) is induced when . . .

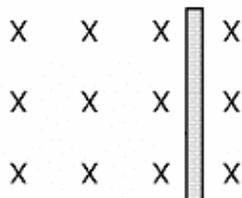


Induced EMF:

Variable:				
Quantity:				
Units:				
Type:				



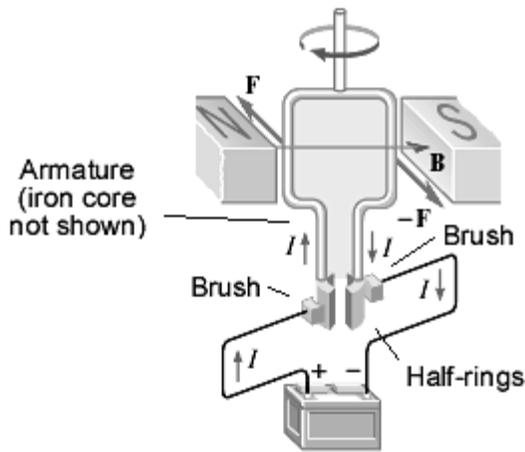
1. What is the potential difference induced in a 1.5 meter length of wire moving perpendicular to a 0.4 T magnetic field at a speed of 2.1 m/s?
2. In which direction should the wire be moved to induce the most potential difference?



3. A wire loop as shown is pulled to the right at a constant speed of 3 m/s.
 - a) Determine the induced potential difference between points X and Y.
 - b) Determine the magnitude of the induced current.
 - c) Which way will the current flow?

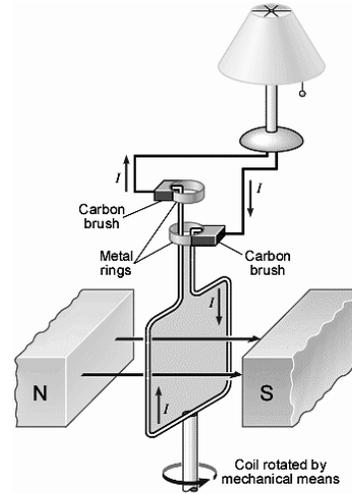
Motors and Generators

Motor:



Operating Principle:

Generator:

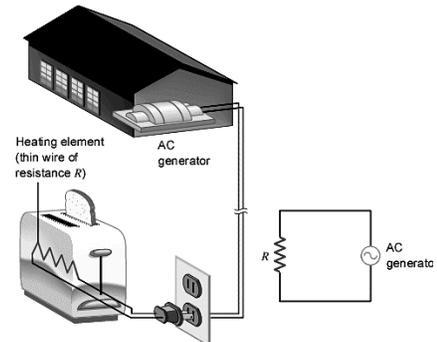


Operating Principle:

Why is household electricity AC instead of DC?

- 1)
- 2)

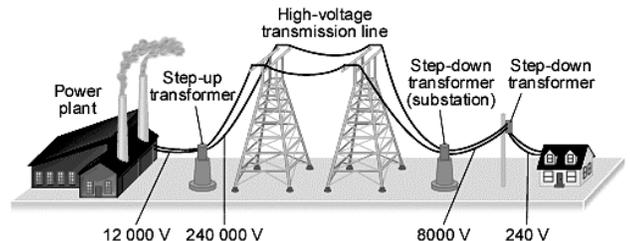
Why is electricity sent at very high voltages in transmission lines?



Household alternating current is produced by large AC generators at the power plant that use turbines to rotate coils of wire in magnetic fields.

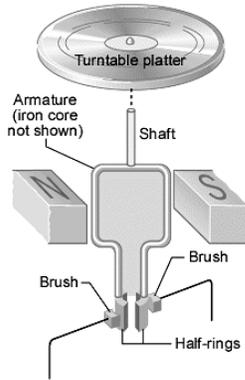
For economic reasons, there is no ideal value of voltage for electrical transmission. Typical values are shown below.

1. AC power is generated at a power plant at 12,000 V and then stepped up to 240,000 V by step-up transformers.
2. The high-voltage, low-current power is sent via high-voltage transmission lines long distances.
3. In local neighborhoods, the voltage is stepped-down (and current is stepped-up) to 8000 V at substations.
4. This voltage is stepped-down even further at transformers on utility poles on residential streets.



The DC Electric Motor

Motor:



The electric motor is found in many devices, such as CD players, tape decks, automobiles, washing machines, and air conditioners. Figure 21.23 shows that a direct-current (dc) motor consists of a coil of wire placed in a magnetic field and free to rotate about a vertical shaft. The coil of wire contains many turns and is wrapped around an iron cylinder that rotates with the coil, although these features have been omitted to simplify the drawing. The coil and iron cylinder assembly is known as the armature. Each end of the wire coil is attached to a metallic half-ring. Rubbing against each of the half-rings is a graphite contact

Figure 21.23 The basic components of a dc motor. The platter of a turntable is shown as it might be attached to the motor.

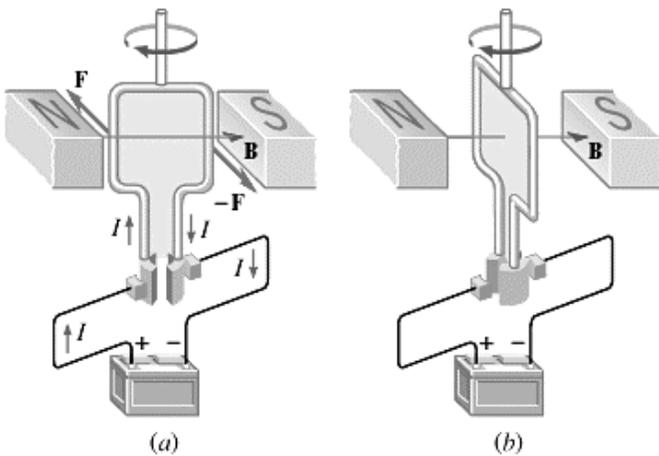


Figure 21.24 (a) When a current exists in the coil, the coil experiences a torque. (b) Because of its inertia, the coil continues to rotate when there is no current.

The operation of a motor can be understood by considering Figure 21.24. In part *a* the current from the battery enters the coil through the left brush and half-ring, goes around the coil, and then leaves through the right half-ring and brush. According to the right-hand rule for the magnetic force on a wire, the directions of the forces F and $-F$ on the two sides of the coil are as shown in the drawing. These forces produce the torque that turns the coil. Eventually the coil reaches the position shown in part *b* of the drawing. In this position the half-rings momentarily lose electrical contact with the brushes, so that there is no current in the coil and no applied torque. However, like any moving object, the rotating coil does not stop immediately, for its inertia carries it onward. When the half-rings reestablish contact with the brushes, there again is a current in the coil, and a magnetic torque again rotates the coil in the same direction. The split-ring commutator ensures that the current is always in the proper direction to yield a torque that produces a continuous rotation of the coil.

Armature:

Brushes:

Half-rings:

Split-ring commutator: