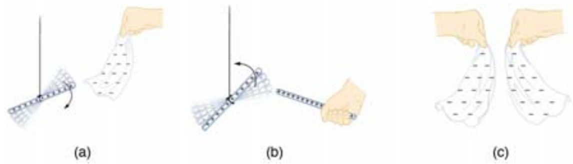
Chap 16 Electric and Magnetic Forces

Quick Facts

Electric and magnetic phenomena observed as early as 700 BC

Two types of charges exist (called positive and negative).

Like charges repel and unlike charges attract one another



Nature's basic carrier of positive charge is the proton.

Nature's basic carrier of negative charge is the electron.

More Facts

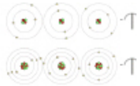
Electric charge is always conserved

Charge is quantized

- **Electrons have a charge of –e**
- **Protons have a charge of +e**
- **SI unit of charge is the Coulomb (C)**

  $e = 1.6 \times 10^{-19}$ C

Materials can be categorized into conductors, insulators and semiconductors

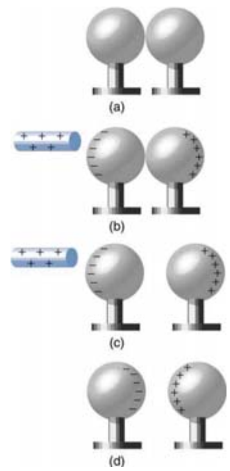


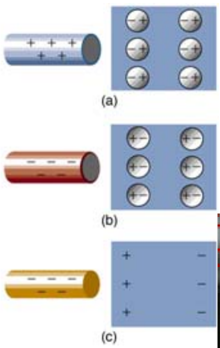
Conductor: A material whose conduction electrons are free to move throughout. Most metals are conductors.

Insulator: A material whose electrons seldom move from atom to atom.

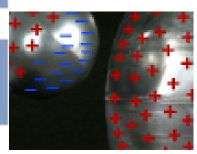
Conduction, Induction, and Polarization

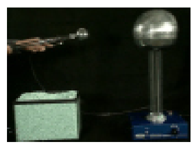
If a conductor carries excess charge, the excess is distributed over the surface of the conductor.





Insulating materials can become polarized.

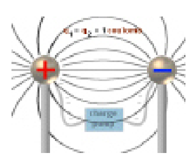




induction

Coulomb's Law

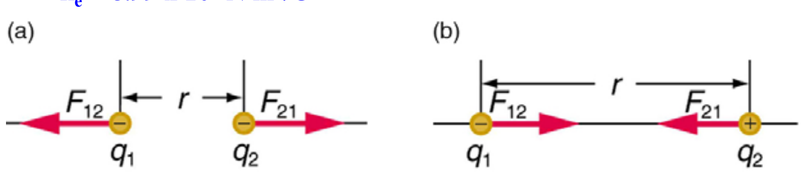
Coulomb shows that an electrical force is inversely proportional to the square of the separation between the two particles and is along the line joining them. It is proportional to the product of the magnitudes of the charges q_1 and q_2 on the two particles. It is attractive if the charges are of opposite signs and repulsive if the charges have the same signs



$$F = k_e \frac{|q_1||q_2|}{r^2}$$

k_e is called the *Coulomb Constant*

$k_e = 8.99 \times 10^9$ N m^2/C^2

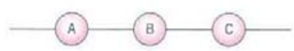


Examples

2. If you double the distance between two charged objects, how does this affect the electric force between them? What if you triple the distance?

3. If you double the charge on one of two charged objects, how does the force between them change?

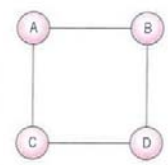
4. Three small spheres carry equal amounts of positive electric charge. They are equally spaced and lie along the same line, as shown. What is the direction of the net electric force on each charge due to the other two charges?



Questions 4, 5

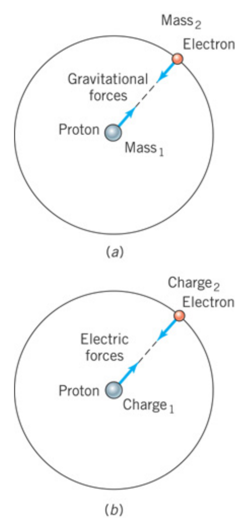
5. Three small spheres carry electric charge. They are equally spaced and lie along the same line, as shown. They all have the same amount of charge, but sphere A and C are positive and sphere B is negative. What is the direction of the net electrical force on each sphere due to the other two spheres?

6. Four small charged spheres sit at the corners of a square, as shown in the figure. Sphere A is negatively charged and the other three have an equal amount of positive charge. Reproduce the figure and draw an arrow at sphere A that represents the net electric force on sphere A due to the other three charges. Repeat this for spheres B, C, and D. Which sphere has the greatest net force acting on it?



Electric and Gravitational Forces Compared

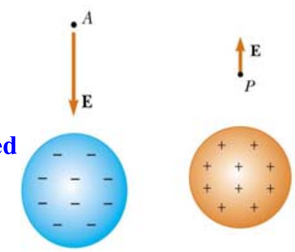
In a hydrogen atom, an electron (mass = 9×10^{-31} kg) circles about a proton (mass = 1.7×10^{-27} kg). The charge on the proton is 1.6×10^{-19} C, and the charge on the electron has the same magnitude, but is negative. A typical separation of these two particles in an atom is 10^{-10} m. Compare the electric and the gravitational forces between them.



Electric Field

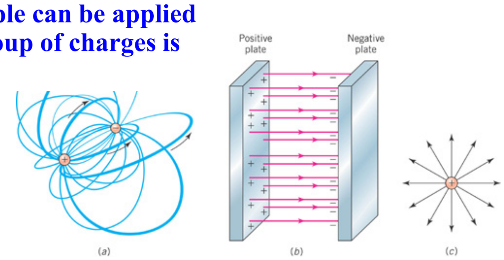
The electric field is a vector quantity

The direction of the field is defined to be the direction of the electric force that would be exerted on a small positive test charge placed at that point



The electric field exists whether or not there is a test charge present

The Superposition Principle can be applied to the electric field if a group of charges is present



Example

1. The electric field at a point in space is defined as the force per unit charge at that point in space. That is, it is the force that would be exerted on a 1-coulomb charge if one were at that point in space. Therefore, we can write the electric field E of a charge q at a distance d from that charge, experienced by a charge $Q = 1$ coulomb, as

$$E = \frac{F}{Q} = k\frac{q}{d^2}$$

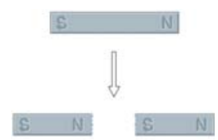
The electric field has a direction such that it points toward negative charges and points away from positive charges. Suppose you rub a balloon in your hair and it acquires a static charge of -3.0×10^{-9} coulombs.

a. What are the units of electric field?
b. What is the strength and direction of the electric field created by the balloon at a location 1 meter due north of the balloon?
c. What is the strength and direction of the electric field created by the balloon at a location 2 meters above the balloon?
d. Your hair acquired an equal amount of positive charge when you rubbed the balloon on your head. What is the strength and direction of the electric field created by your head, at the location of your feet, 1.5 meters down?

Magnetism

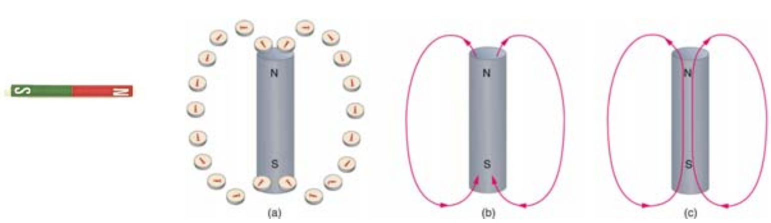
Magnets

- *Poles* of a magnet (*north* and *south*) are the ends where objects are most strongly attracted.
- Like poles repel each other and unlike poles attract each other
- Magnetic poles cannot be isolated
- An unmagnetized piece of iron can be magnetized by stroking it with a magnet
- Magnetism can be induced
- *Soft* and *Hard* magnetic materials.
- If a magnet is broken in half, each half has two poles:



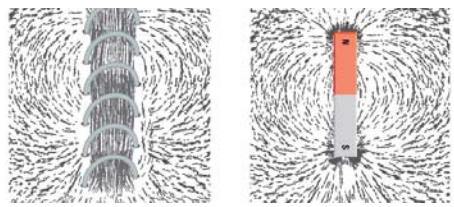
Magnetic Fields

- A vector quantity, symbolized by B
- Direction is given by the direction a *north pole* of a compass needle points in that location
- A compass can be used to show the direction of the magnetic field lines
- Magnetic field lines cannot cross



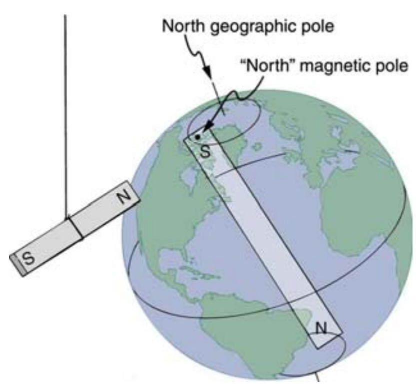
Magnetic Field Lines

Iron filings are used to show the pattern of the magnetic field lines

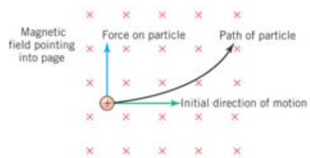


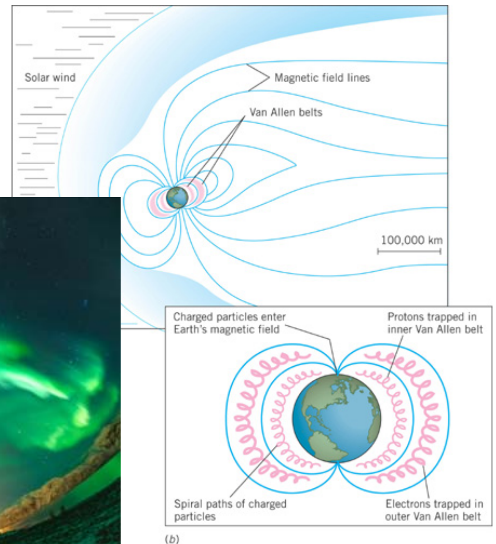
Earth's Magnetic Field

- **The Earth's geographic north pole corresponds to a magnetic south pole and the geographic south pole corresponds to a magnetic north pole**
- **The direction of the Earth's magnetic field reverses every few million years**
- **The Earth's magnetic field resembles that achieved by burying a huge bar magnet deep in the Earth's interior**
- **The most likely source of the Earth's magnetic field is believed to be electric currents in the liquid part of the core**



Magnetic Forces on Charged Particles





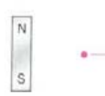
(b)

Examples

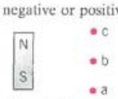
15. The magnetic field at the equator points north. If you t a positively charged object (for example, a baseball some electrons removed) to the east, what is the dire of the magnetic force on that object?

16. The magnetic field at the equator points north. If you t a negatively charged object (for example, a baseball some extra electrons) to the east, what is the directi the magnetic force on that object?

17. A charged particle is located on the right side of a bar magnet and is moving to the right, as shown. If the particle is being deflected in such a way that its path is curving out of the page, is the particle negative or positive?



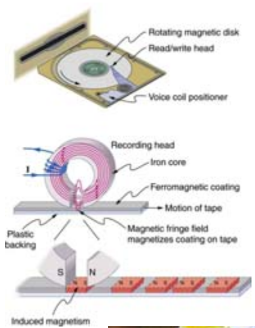
18. Two identical bar magnets are aligned as shown. What is the approximate direction of the magnetic field created by this arrangement at locations a, b, and c?

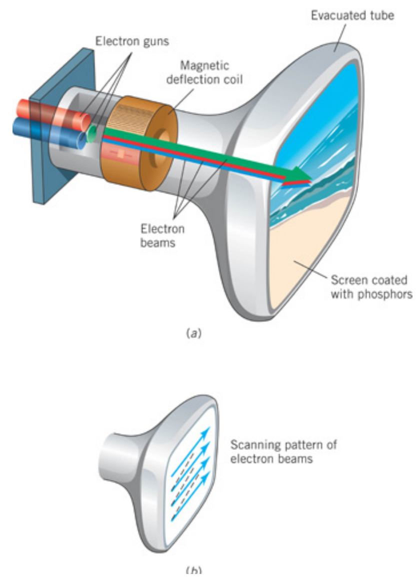


19. A small bar magnet pulls on a larger one with a forc 100 newtons. What is the magnitude of the force the la one exerts on the smaller one?

20. A charge of +1 coulomb is placed at the 0-cm mar a meter stick. A charge of −1 coulomb is placed at 100-cm mark of the same meter stick. Is it possible to p a proton somewhere on the meter stick so that the net f on it due to the charges at the ends is 0? If so, where sh it be placed? Explain.

Magnetism Applications Abound





Examples

1. Based on electric charges and separations, which of the following atomic bonds is strongest? [*Hint:* You are interested only in the relative strengths, which depend only on the relative charges and distances.]

a. A +1 sodium atom separated by 2.0 distance u from a −1 chlorine atom in table salt

b. A +1 hydrogen atom separated by 1.0 distance unit fr a −2 oxygen atom in water

c. A +4 silicon atom separated by 1.5 distance units from a −2 oxygen atom in glass

d. Which force is greater and by how many orders of magnitude?

2. Assume that in interstellar space the distance between two electrons is about 0.1 cm.

a. Is the electric force between the two electrons repulsive or attractive?

b. Calculate the electric force between these two electrons.

c. Calculate the gravitational force between these two electrons. Is this an attractive or repulsive force?

3. Repeat Problem 2 for two protons at the same distance from one another.

4. Assume that you have two objects, one with a mass of 10 kg and the other with a mass of 15 kg, each with a charge of -3.0×10^{-2} C and separated by a distance of 2 meters. What is the electric force that these objects exert on one another? What is the gravitational force between them?

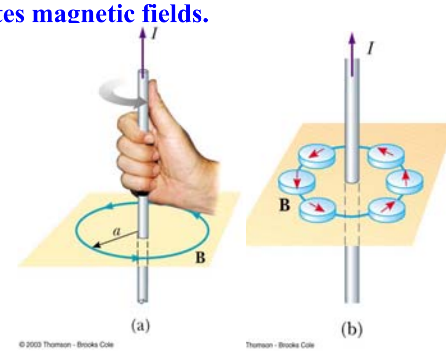
Chap 17 Electromagnetic Interactions

Magnetic Effect from Electricity

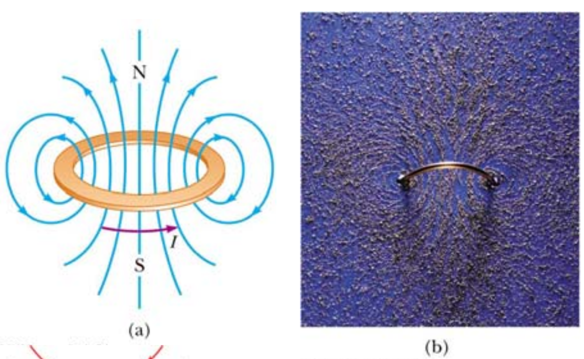
The motion of electric charges creates magnetic fields.

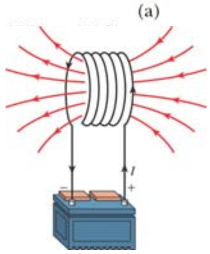
- **A current-carrying wire produces a magnetic field**
- **Direction of the magnetic field is given by the Right Hand Rule**
- **The magnitude of the field at a distance r from a wire carrying a current of I is**

$$B = \frac{\mu_o I}{2\pi r}$$

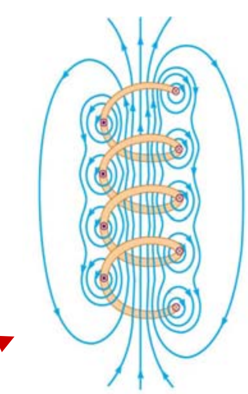


Electromagnets

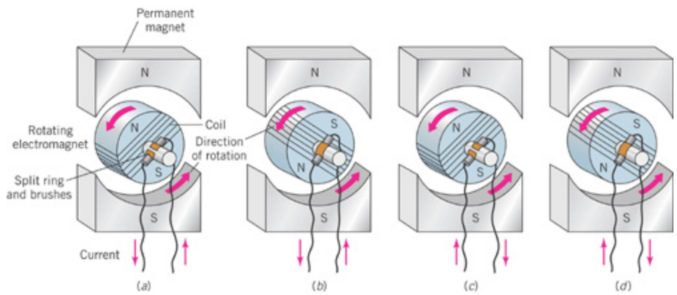


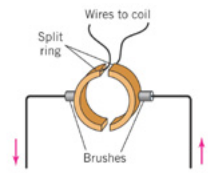


solenoid



Electric Motors





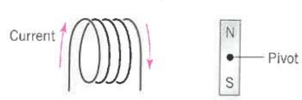
(e) Close-up of split ring and brushes

Examples

1. The figure represents two long, straight, parallel wires extending in a direction perpendicular to the page. The current in the left wire runs into the page and the current in the right wire runs out of the page. What is the direction of the magnetic field created by these wires at locations a, b, and c? (b is at the exact midpoint between the wires.)

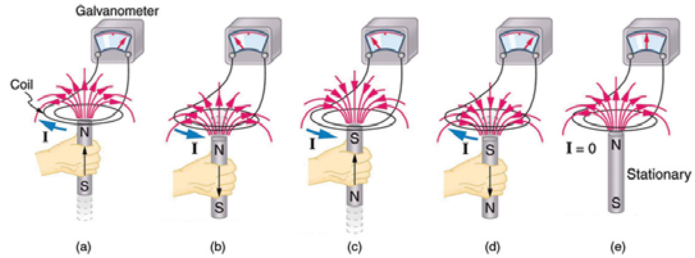
2. The figure represents two long, straight, parallel wires extending in a direction perpendicular to the page. The current in both wires flows out of the page. What is the direction of the magnetic field created by these wires at locations a, b, and c? (b is at the exact midpoint between the wires.)

3. An electric current runs through a coil of wire as shown in the figure. A permanent magnet is located to the right of the coil. If the magnet is free to rotate, will it rotate clockwise or counterclockwise? Explain.



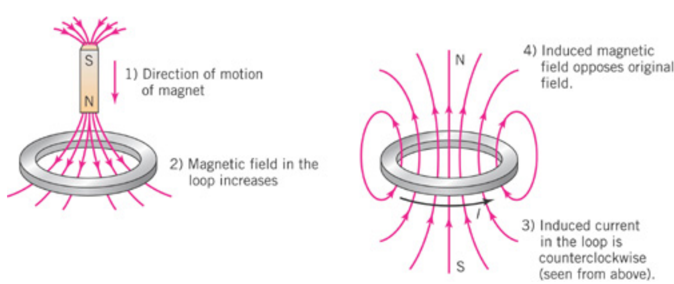
Electric Effect from Magnetism

Induced emf - Faraday’s Experiment



- When a magnet moves toward a loop of wire, the ammeter shows the presence of a current
- When the magnet moves away from the loop, the ammeter shows a current in the opposite direction
- If polarity of the magnet is reversed, the direction of the current is reversed
- When the magnet is held stationary, there is no current

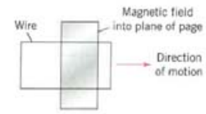
Changing Magnetic Fields Produce Electric Fields



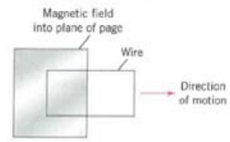
The direction of induced current is such that it opposes the change (in magnetic field/flux) that produces it.

Examples

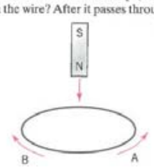
13. A rectangular piece of wire is moving to the right as shown. It passes through a region where there is a magnetic field pointing into the page, as shown (magnetic field indicated by the shaded region). When the loop of wire is in the position shown in the figure, is there an induced current in the loop? Explain.



14. A rectangular piece of wire is moving to the right as shown. It passes through a region where there is a magnetic field pointing into the page, as shown (magnetic field indicated by the shaded region). When the loop of wire is in the position shown in the figure, is there an induced current in the loop? If there is an induced current, does it run clockwise or counterclockwise? Explain.

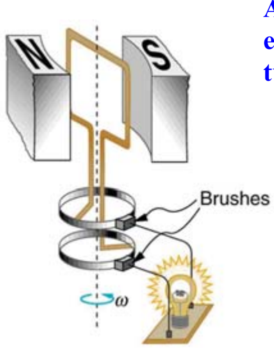


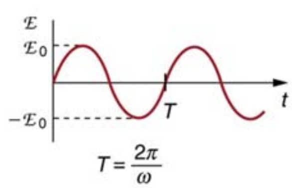
15. A bar magnet is dropped, north pole down, so that it falls through a circular piece of wire, as shown. What is the direction of the induced current in the loop (A or B) before it passes through the wire? After it passes through the wire?

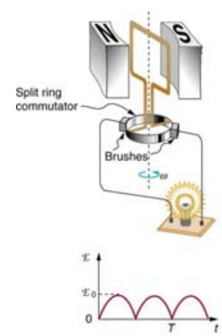


Electric Generators

An electric generator converts mechanical energy into electric energy. An outside source of energy is used to turn the coil, thereby generating electricity.

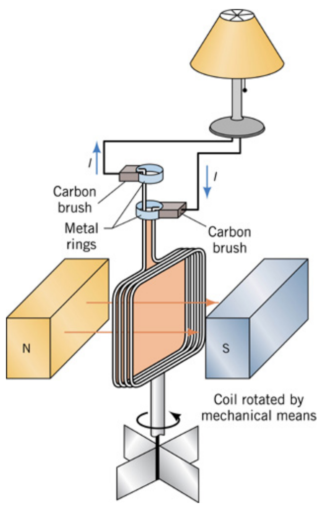


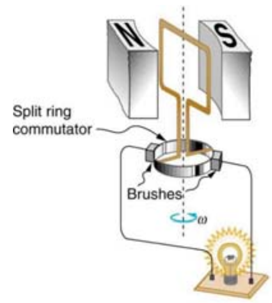


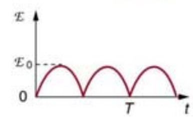


A split ring commutator generates DC power

Electric Generator







A split ring commutator generates DC power

Examples

3. In the laboratory, you have arranged to have a magneti
that is pointing north with a strength of $B = 0.5$ T an
tric field that points downward with a strength of $E =$
10^6 N/C. An electric charge with a magnitude $q = 1($
passes through the laboratory. The force on the charg
to the electric field is given by $F = qE$. The force o
charge due to the magnetic field is given by $F = qvB$, v
v is the speed of the particle. The direction of the mag
force is given by the right-hand rule, as describe
Chapter 16.

a. What direction would the charge have to travel in
that the charge passes through the room undefle
Neglect the gravitational force. (*Hint:* What dire
does the charge have to travel so that the directi
the electric force is opposite to the direction of the
netic force?)

b. What is the strength of the electric force?

c. How fast would it have to travel so that it passes thr
the room undeflected?