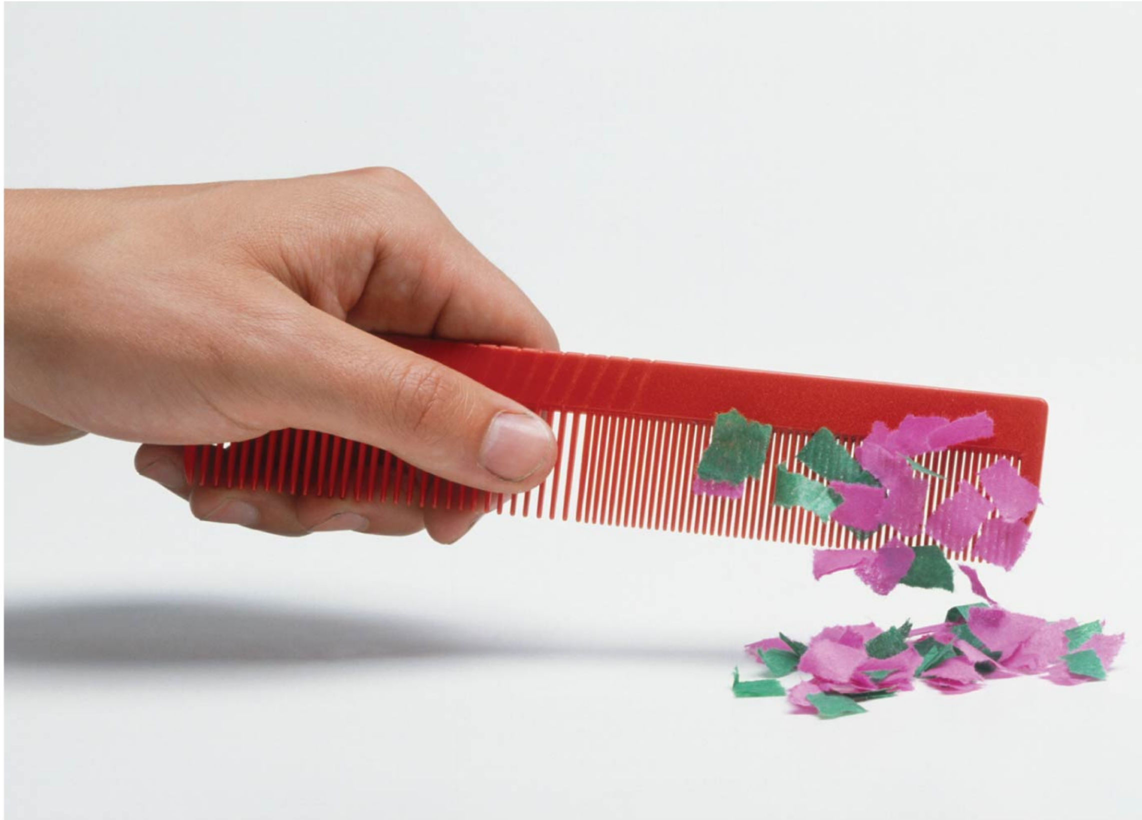
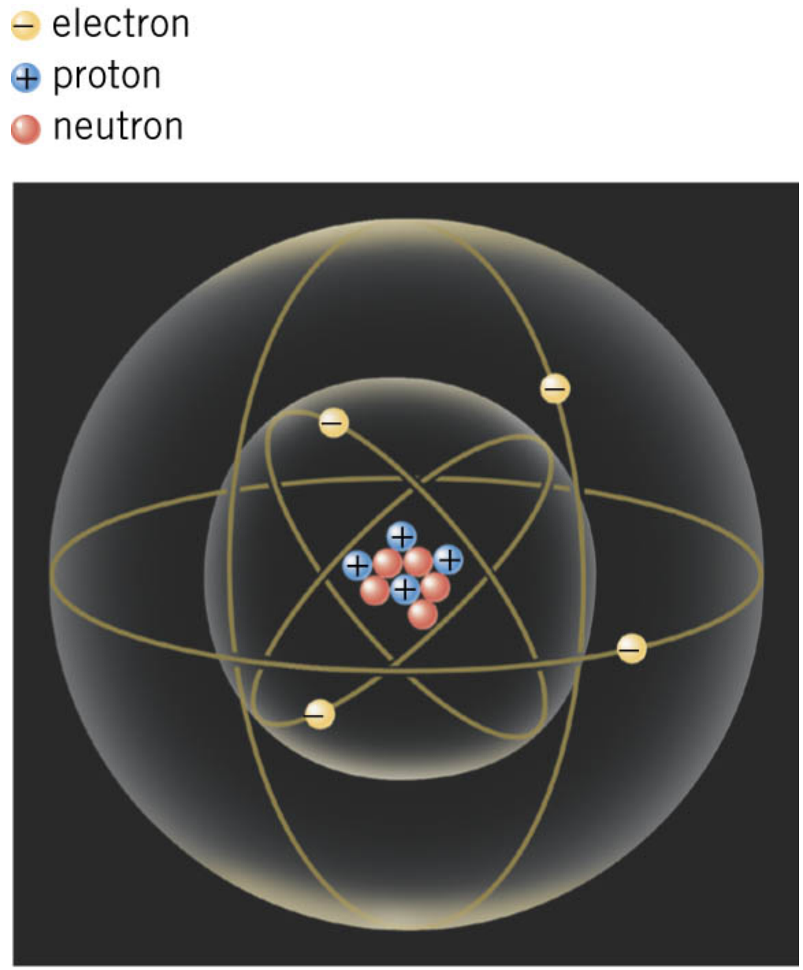
Electric Charge and Electric Field
Coulombs law



18.1 The Origin of Electricity

The electrical nature of matter is inherent in atomic structure.



$$m_p = 1.673 \times 10^{-27}\,\mathrm{kg}$$

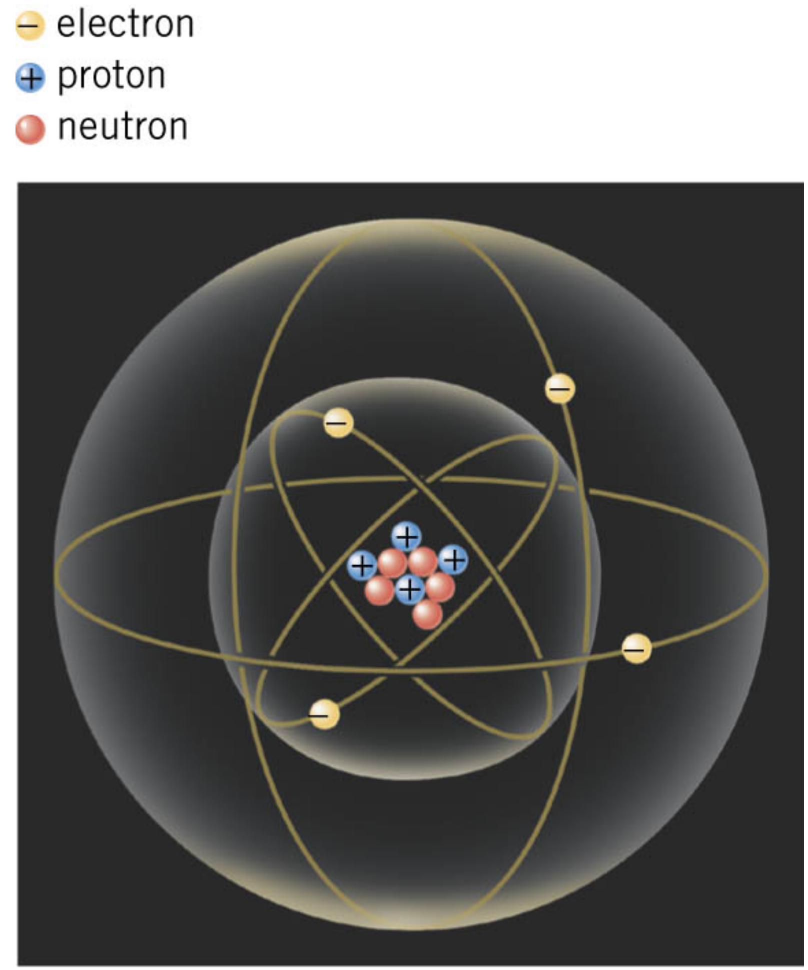
$$m_n = 1.675 \times 10^{-27}\,\mathrm{kg}$$

$$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$$

$$e = 1.60 \times 10^{-19}\,\mathrm{C}$$

coulombs

18.1 *The Origin of Electricity*



In nature, atoms are normally found with equal numbers of protons and electrons, so they are electrically neutral.

By adding or removing electrons from matter it will acquire a net electric charge with magnitude equal to *e* times the number of electrons added or removed, *N*.

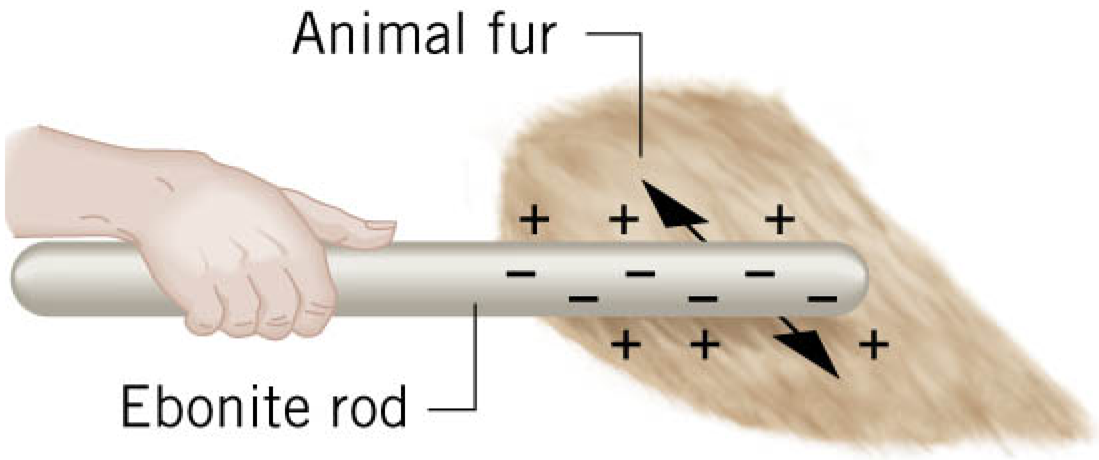
$$q = Ne$$

Example 1 A Lot of Electrons

How many electrons are there in one coulomb of negative charge?

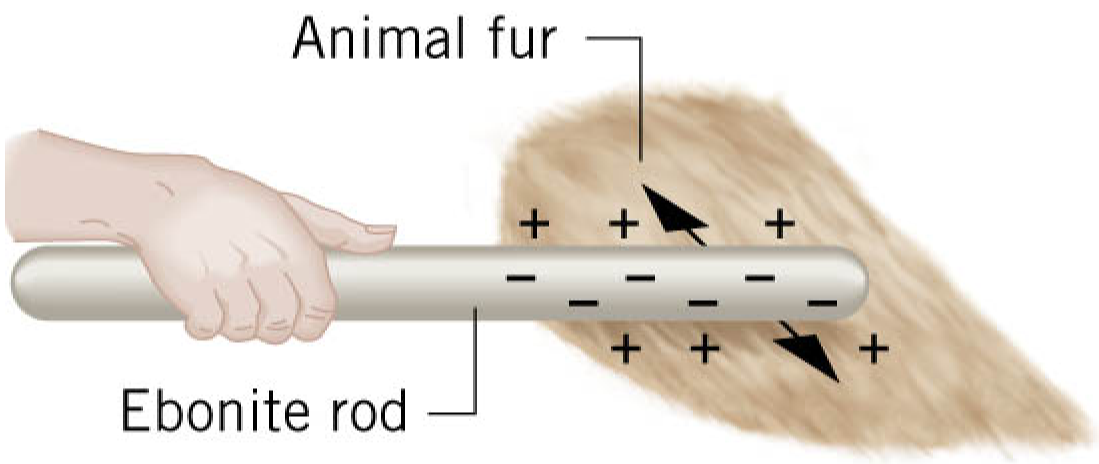
$$q = Ne$$

$$N = \frac{q}{e} = \frac{1.00\,\mathrm{C}}{1.60\times 10^{-19}\,\mathrm{C}} = 6.25\times 10^{18}$$



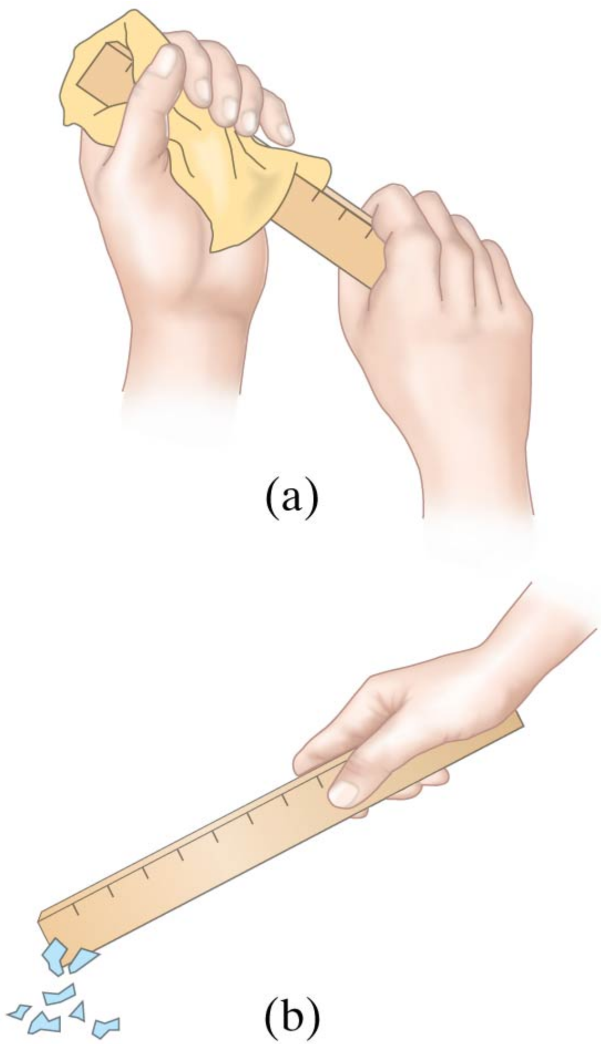
It is possible to transfer electric charge from one object to another.

The body that loses electrons has an excess of positive charge, while the body that gains electrons has an excess of negative charge.

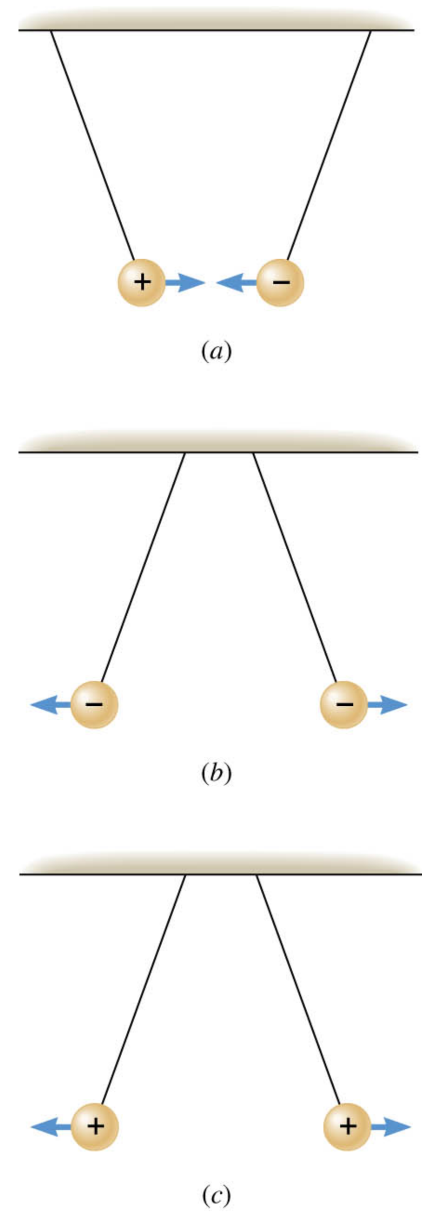


LAW OF CONSERVATION OF ELECTRIC CHARGE

During any process, the net electric charge of an isolated system remains constant (is conserved).

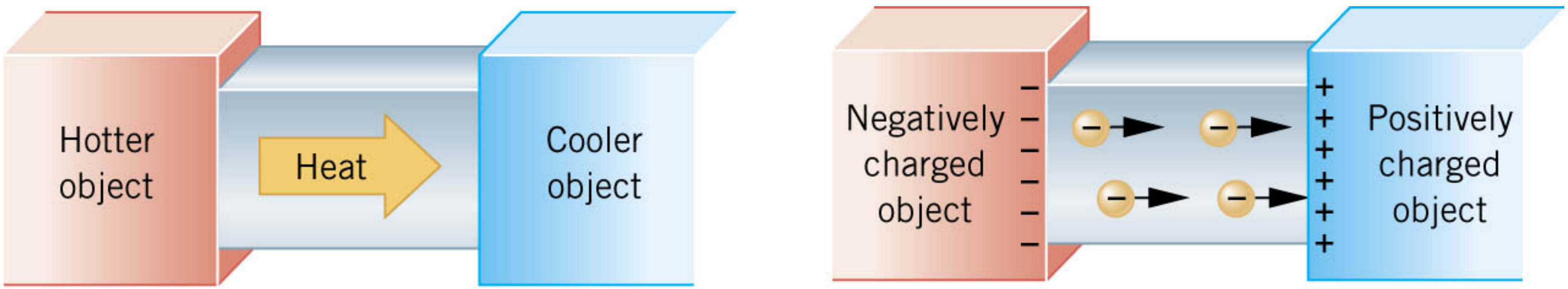

(a)
(b)

Objects can be charged by rubbing



Like charges repel and unlike charges attract each other.

18.3 Conductors and Insulators



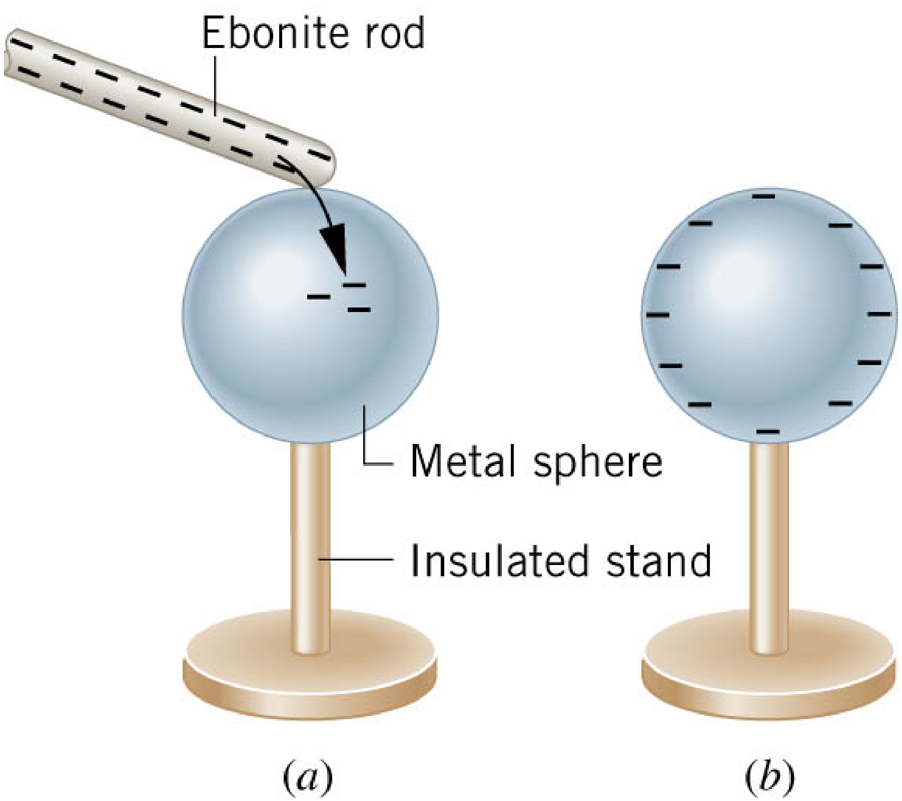
(a) (b)

Not only can electric charge exist *on an object,* but it can also move *through and object*.

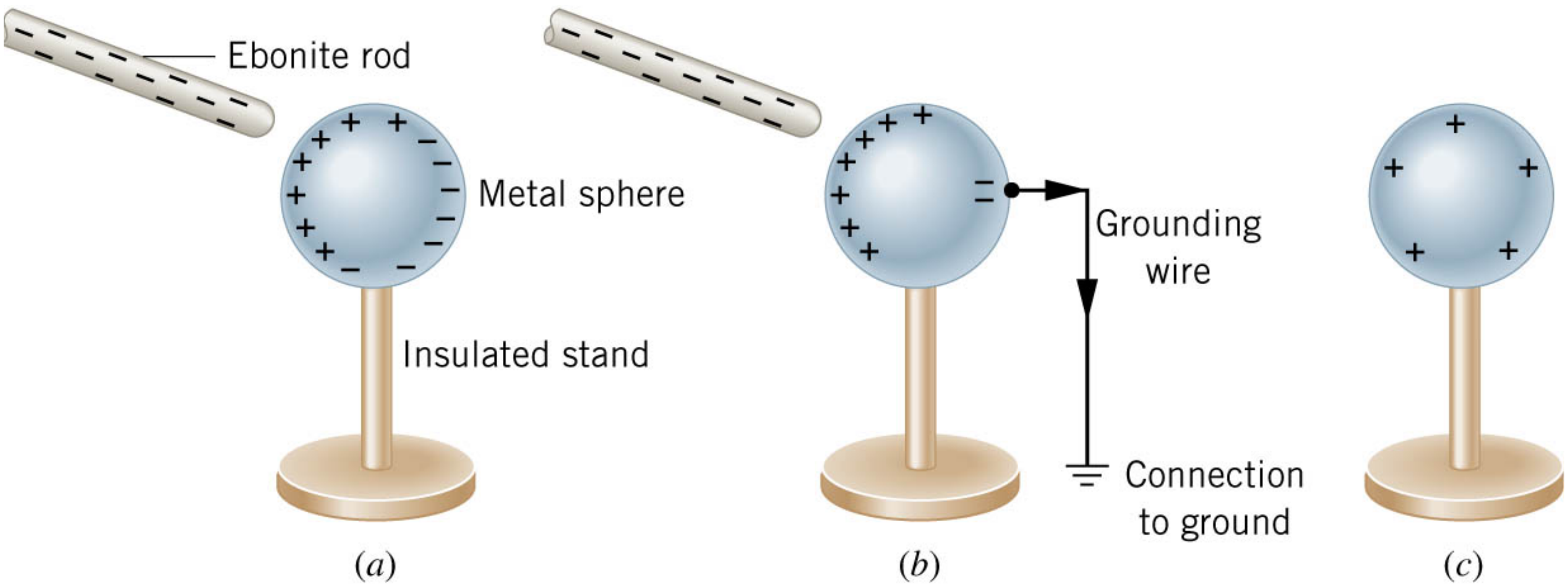
Substances that readily conduct electric charge are called ***electrical conductors***. Charges move from high level of potential energy to a low level Of potential energy. Positive charges flow from high potential to low potential (gnd).

Materials that conduct electric charge poorly are called ***electrical insulators.***

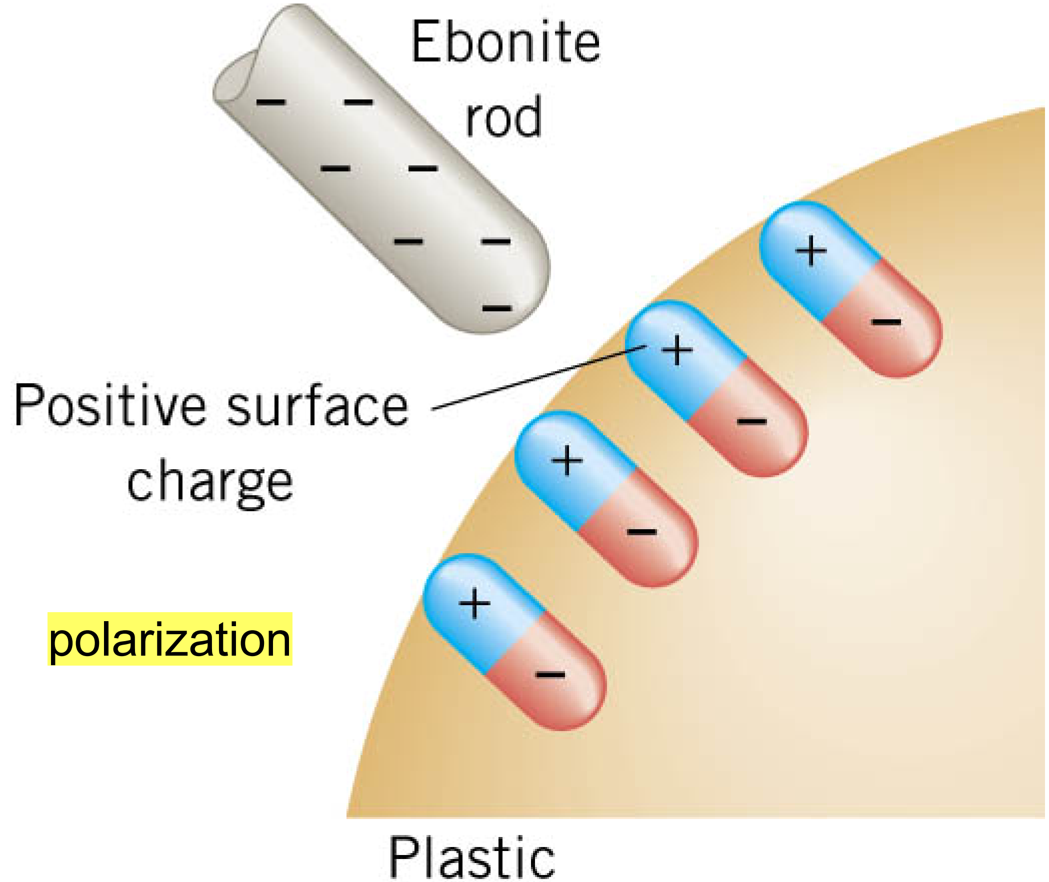
18.4 Charging by Contact and by Induction



Charging by contact.



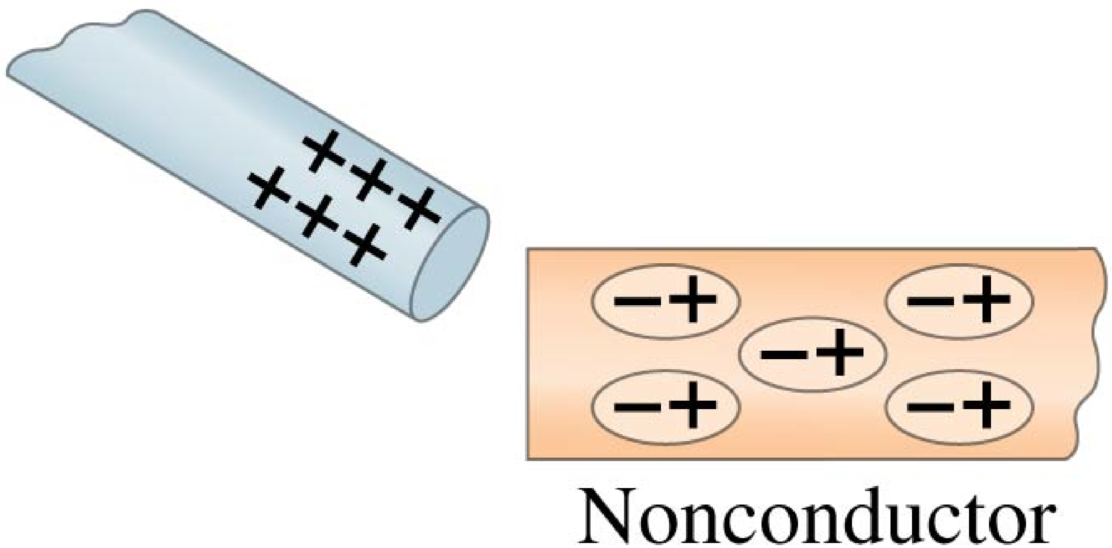
Charging by induction.



The negatively charged rod induces a slight positive surface charge on the plastic.

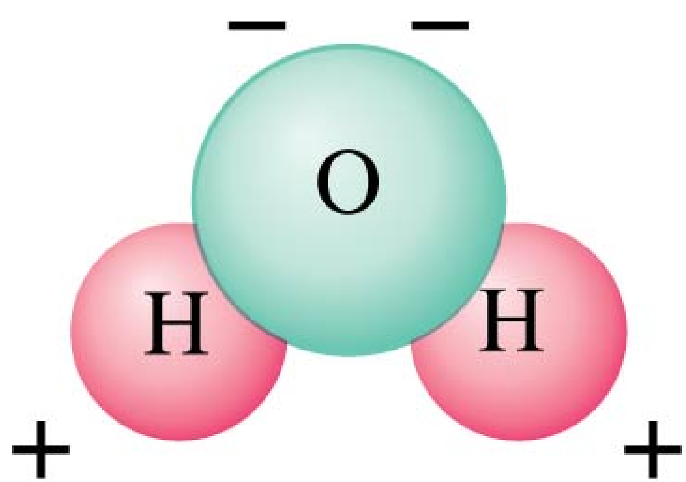
polarization

Nonconductors won't become charged by conduction or induction, but will experience charge separation:



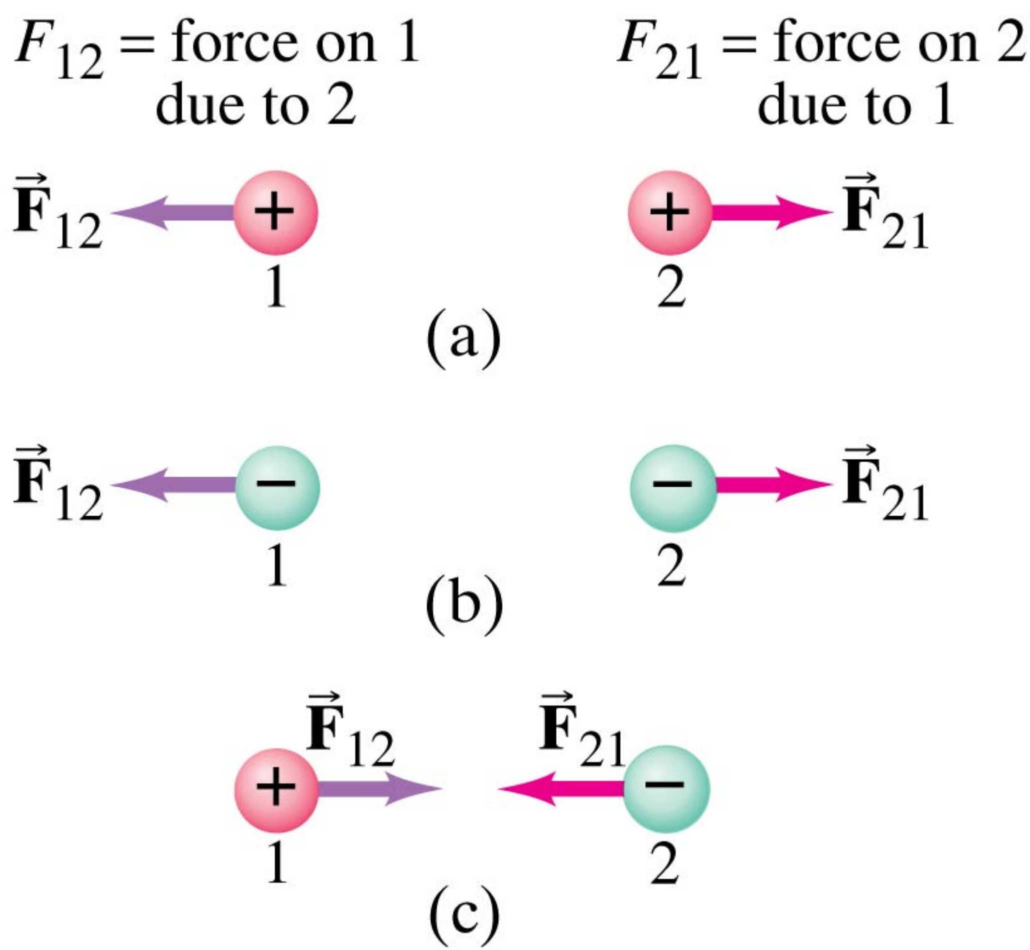
Water molecule is a polarized molecule
This is why it is the universal solvent

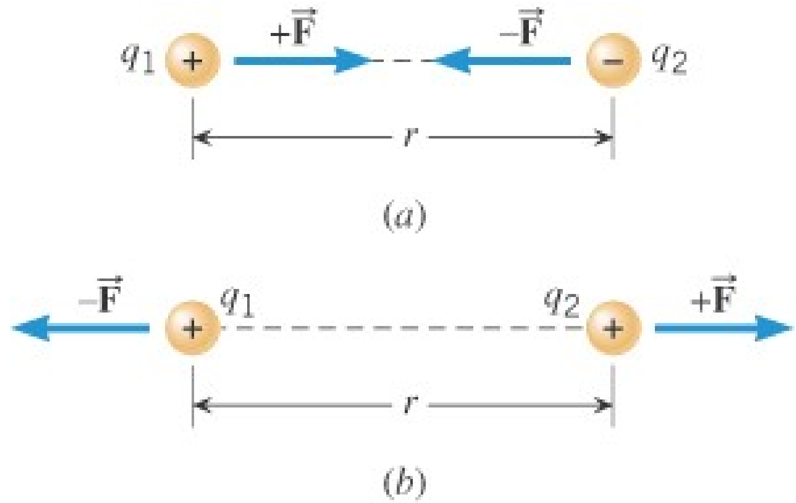
Polar molecule: neutral overall, but charge not evenly distributed



Coulomb's Law

The force is along the line connecting the charges, and is attractive if the charges are opposite, and repulsive if they are the same.





COULOMB'S LAW

The magnitude of the electrostatic force exerted by one point charge on another point charge is directly proportional to the magnitude of the charges and inversely proportional to the square of the distance between them.

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

$$\varepsilon_o = 8.85\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$$

$$k = 1/(4\pi\varepsilon_o) = 8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}$$

Unit of charge: coulomb, C

The proportionality constant in Coulomb's law is then:

$$k = 8.988 \times 10^9 \text{ N·m}^2/\text{C}^2$$

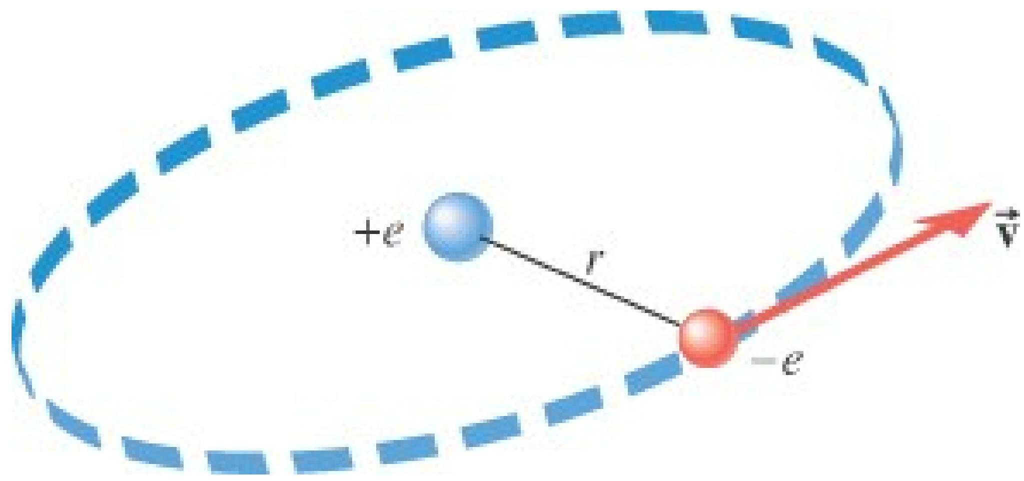
Charges produced by rubbing are typically around a microcoulomb:

$$1\ \mu\text{C} = 10^{-6}\ \text{C}$$

Charge on the electron:

$$e = 1.602 \times 10^{-19}\ \text{C}$$

Electric charge is quantized in units of the electron charge.

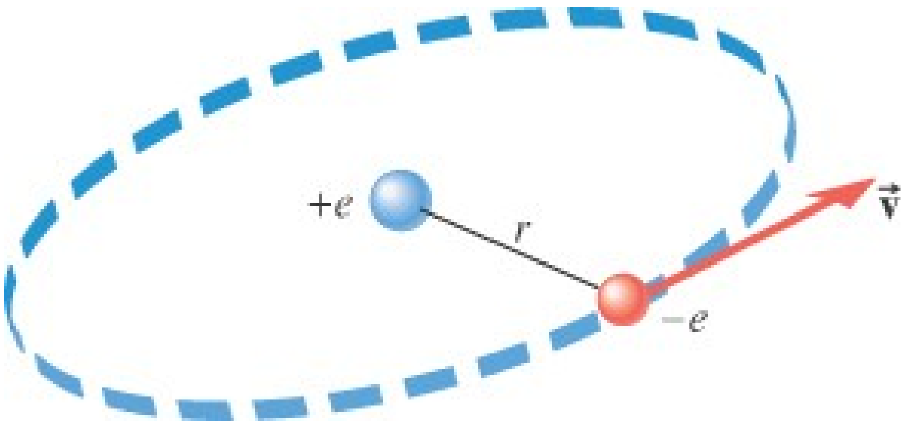


Example 3 **A Model of the Hydrogen Atom**

In the Bohr model of the hydrogen atom, the electron is in orbit about the nuclear proton at a radius of 5.29×10^{-11}m. Determine the force between The electron and the proton. (same charge 1,6 E-19C)

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

18.5 Coulomb's Law



$$F = k\frac{|q_1||q_2|}{r^2} = \frac{\left(8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}\right)\left(1.60\times10^{-19}\ \mathrm{C}\right)^2}{\left(5.29\times10^{-11}\ \mathrm{m}\right)^2} = 8.22\times10^{-8}\ \mathrm{N}$$

What is the force of attraction between two Ping-Pong balls whose centers are 10.0 centimeters apart if the charges on them are +12 nanocoulombs and –15 nanocoulombs, respectively?

Two small, equally conducting spheres are charged, touched together, and then separated until their centers are 12 centimeters apart. If they now repel each other with a force of 3.0×10^{-5} newtons, how much charge do they have?

Two graphite-coated Ping-Pong balls are charged, touched together, and then separated by 15 centimeters. If each exerts a repulsive force of 6.0×10^{-5} newtons on the other, how much charge is there on each ball?

Two conductive spheres are separated by 15 centimeters, measured center to center. Sphere A is charged to +25 nanocoulombs and sphere B to +15 nanocoulombs. (a) How much force does A exert on B? (b) How much force does B exert on A?

18.6 The Electric Field

DEFINITION OF ELECTRIC FIELD

The electric field is an " invisible aura" around charged object. A charge object (qo) Placed in an electric field experiences a force F:

$$\vec{E} = \frac{\vec{F}}{q_o}$$ Or F = qo E

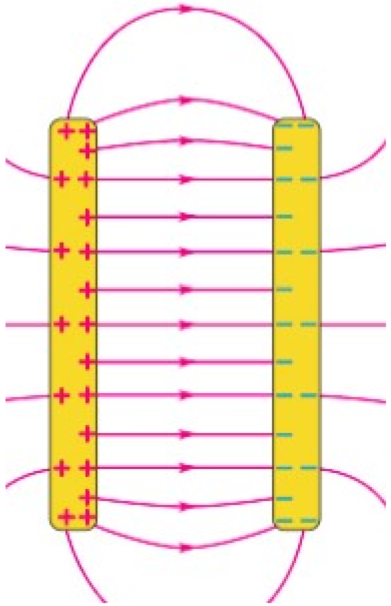
SI Units of Electric Field: newton per coulomb (N/C)

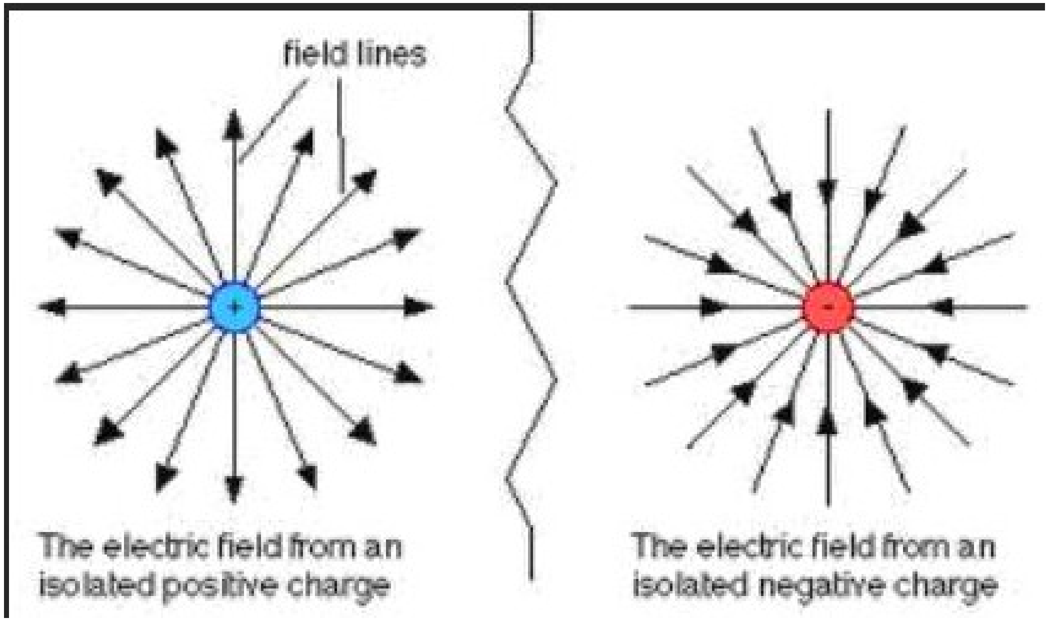
You have an electric field that acts on a positive charge to bring them to a lower level of Energy the same way you a gravitational field that acts on mass to bring them to a Lower level of energy. g = F/m or F = mg

A positive charge follows the electric field.

A negative charge goes Against the electric field.

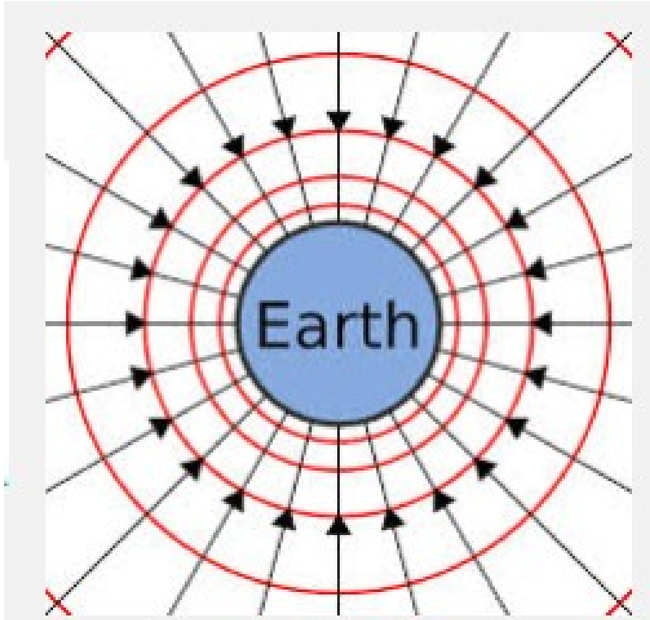
Examples of configuration of electric field:





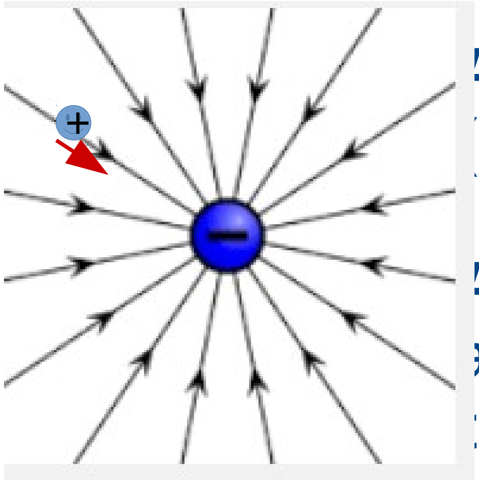
Electric field is away for positive charges
And inward negative charges.

What happens to a proton / electron in each case?



The Earth creates a gravitational field
In the space around.
A mass (like you) placed in that field acted upon by a “recoil “ force mg (weight) that wants to bring back the mass to the ground.

Gravity is like an invisible spring that pulls back masses to the ground.



A charge (+ or -) creates an electric field E (like an aura) in the space around.

A charge placed in this electric field is acted upon by a force qE that wants to move the charge to a lower energy level.

Acceleration of a Charged Drop of Gasoline

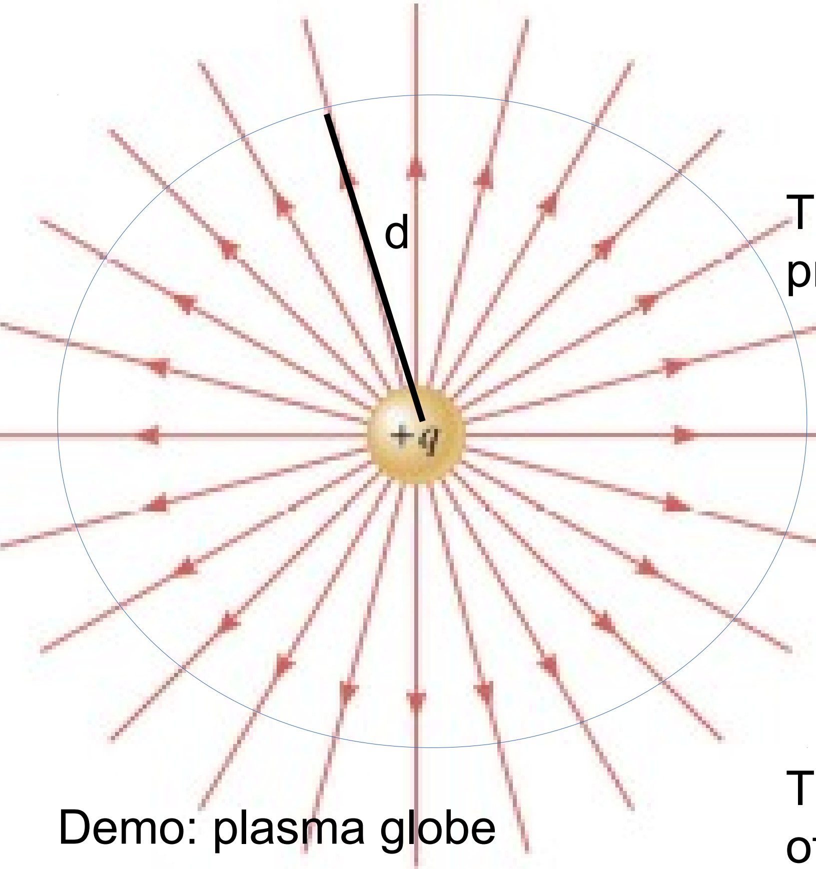
If steps are not taken to ground a gasoline pump, static electricity can be placed on gasoline when filling your car's tank. Suppose a tiny drop of gasoline has a mass of 4.00×10^{-15} kg and is given a positive charge of 3.20×10^{-19} C. (a) Find the weight of the drop. (b) Calculate the electric force on the drop if there is an upward electric field of strength 3.00×10^{5} N/C due to other static electricity in the vicinity. (c) Calculate the drop's acceleration.

2) If the distance between two spherical charged objects increases by a factor of two, then the electrical force between the objects
A. decreases by a factor of four.
B. is half as big.
C. does not change.
D. doubles.
E. increases by a factor of four.

3) Two equal charges repel one another with a force of 4.0×10^{-4} N when they are 10 cm apart. If they are moved until the separation is 5.0 cm, the repulsive force will be
A. 16.0×10^{-4}N.
B. 8.0×10^{-4}N.
C. 4.0×10^{-4}N.
D. 2.0×10^{-4}N.
E. 1.0×10^{-4}N.

4) A uniform electric field has a magnitude of 10 N/C and is directed upward. A charge brought into the field experiences a force of 5.0 N downward. The charge must be
A. +50 C.
B. -50 C.
C. +0.5 C.
D. -0.5 C.
E. -2.0 C.

Electric field lines or ***lines of force*** provide a map of the electric field in the space surrounding electric charges.

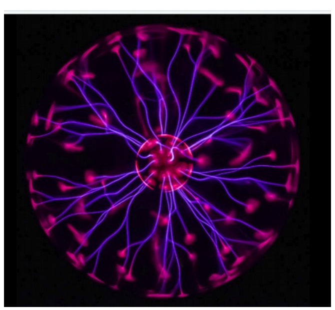


The magnitude of the electric field E produced by q at a distance d from the center of q is:

$$E=\frac{K\,q}{d^2}$$

Direction: outward for positive charge
Inward for negative charge.

Demo: plasma globe



The globe of an Van Graaf generator holds a charge of 5 uC. What is the electric field
At a distance of 10cm.

If the globe is charged negatively draw the electric field of the globe. There is no electric field inside ! Faraday's cage.

$$E=\frac{Kq}{d^2}$$

1mm = 10^{-3} m 1 uC = 10^{-6} C charge electron = 1.6 10^{-19}C

Calculate the strength and direction of the electric field E due to a point charge of 2.00 nC (nano-Coulombs) at a distance of 5.00 mm from the charge.

What force does the electric field found in the previous example exert on a point charge of $-0.250\ \mu\mathrm{C}$?

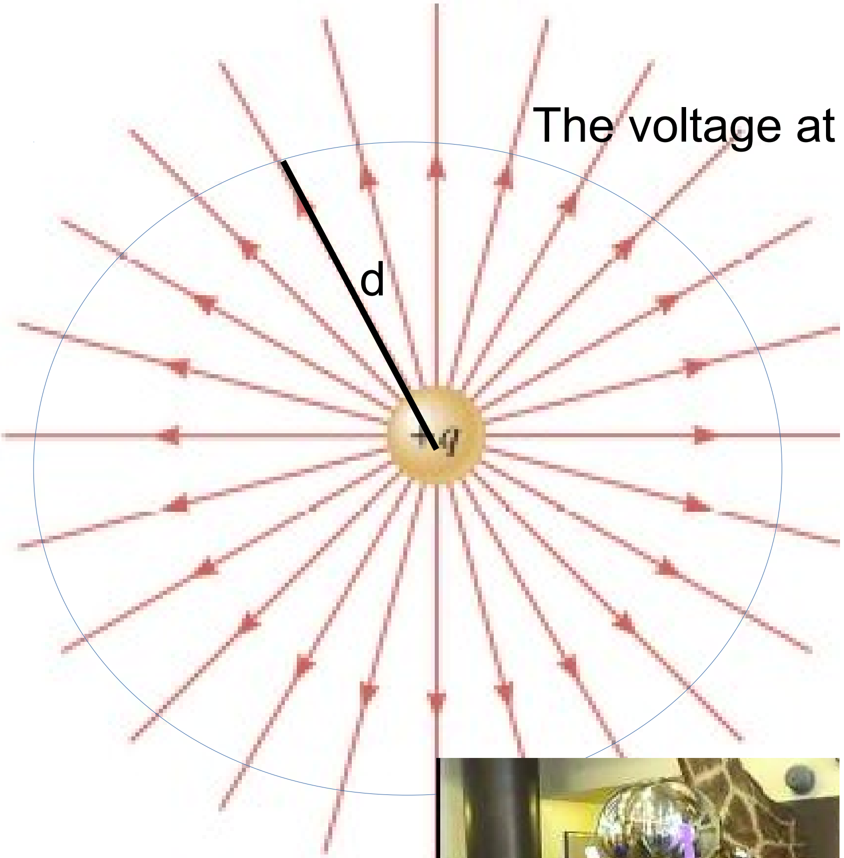
What is the magnitude and direction of an electric field that exerts a $2.00 \times 10^{-5}\ \mathrm{N}$ upward force on a $-1.75\ \mu\mathrm{C}$ charge?

What is the magnitude and direction of the force exerted on a $3.50\ \mu\mathrm{C}$ charge by a 250 N/C electric field that points due east?

Calculate the initial (from rest) acceleration of a proton in a $5.00 \times 10^{6}\ \mathrm{N/C}$ electric field (such as created by a research Van de Graaff). Explicitly show how you follow the steps in the Problem-Solving Strategy for electrostatics.

Use charge of proton. See slide 1

Electric field lines or ***lines of force*** provide a map of the electric field in the space surrounding electric charges.



The voltage at a distance d from the center of q is given by :

$V = 9\ 10^9\ q / d$

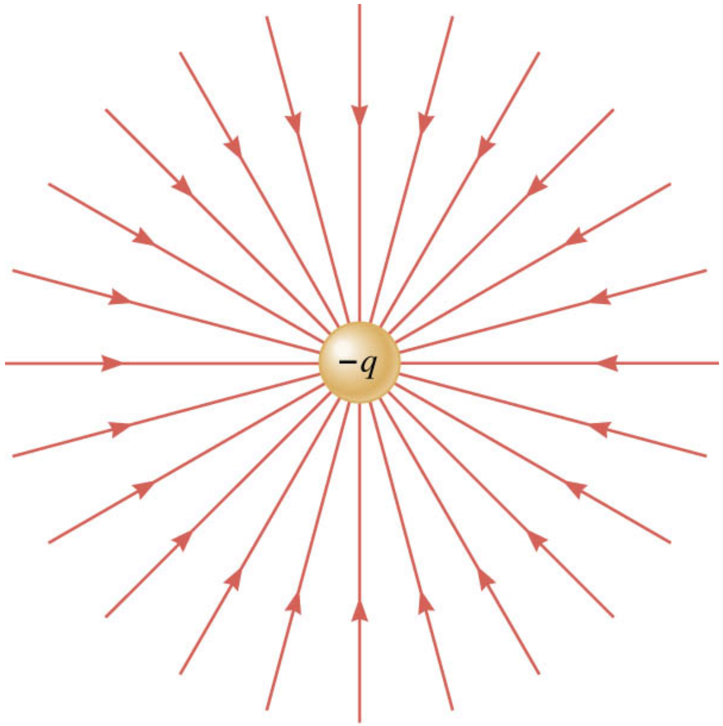
What is the voltage of globe at the surface ?
The radius is 20 cm (0.02m). d = 20cm

What is the voltage at a distance of 1 m ?

What is the voltage drop between the surface
And a distance of 1m

This is why a fluorescent can work if it touches
The globe.

18.7 Electric Field Lines



Electric field lines are always directed away from positive charges and toward negative charges.

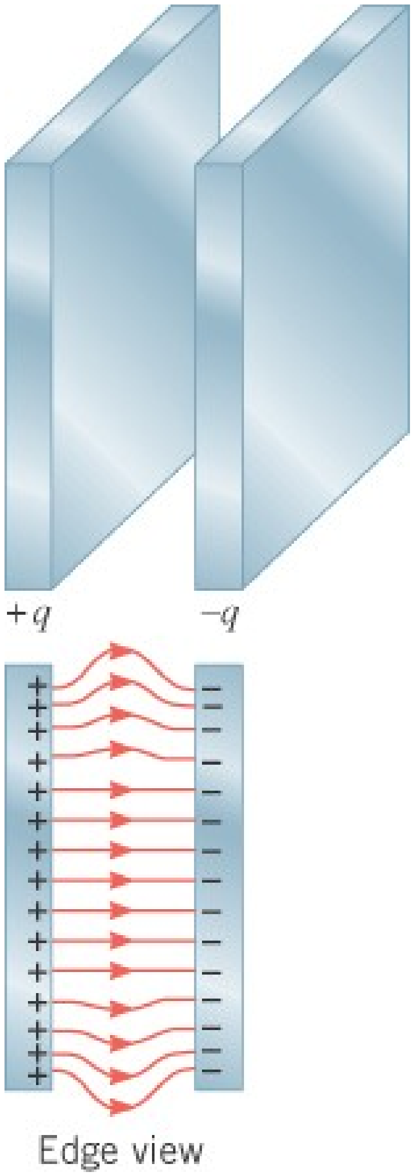
Electric Field Lines of a parallel plate capacitor

Electric field lines always begin on a positive charge and end on a negative charge and do not stop in midspace.

The electric field between the place has the same Direction and the same strength every where.

The electric field does not depend on the distance Between the 2 plates.

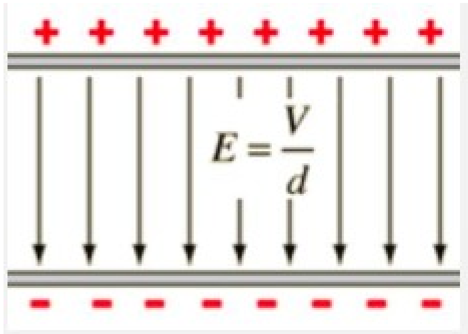
If the electric field between the plates is 1000N/C What is the force acting on 4uC of charge placed Between the plates. Draw the charge and show Which way it is going to accelerate.

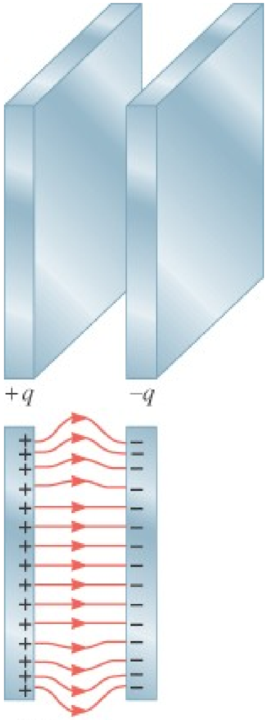


The electric field inside a capacitor is homogeneous. Same magnitude and direction. **d** is the distance between the plates.

V is the voltage drop across the capacitor.

E = V / d





Edge view

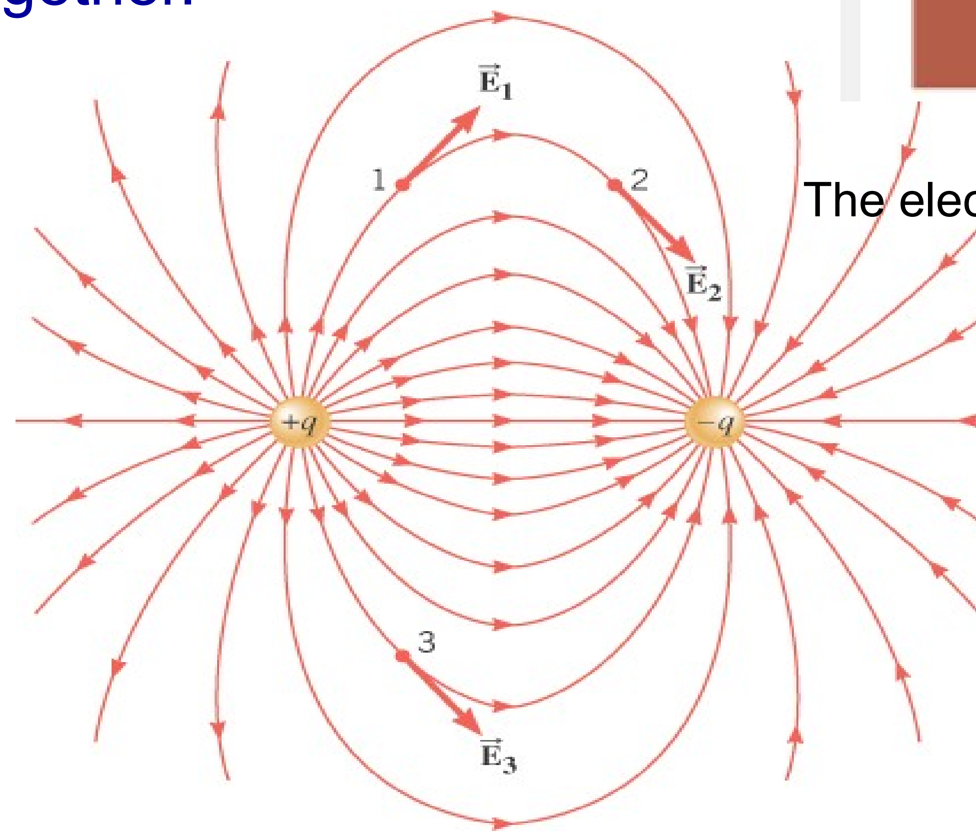
26. A capacitor consisting of two parallel plates separated by 2.0 cm has a potential of 100 V on the top plate and a potential of 0 V on the bottom plate. The value of the electric field in the middle is

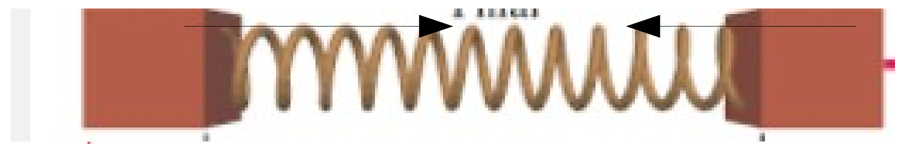
A. 5.0 N/C.
B. 50 N/C.
C. 500 N/C.
D. 5000 N/C.
E. 200 N/C.

Electric Field Lines of a dipole

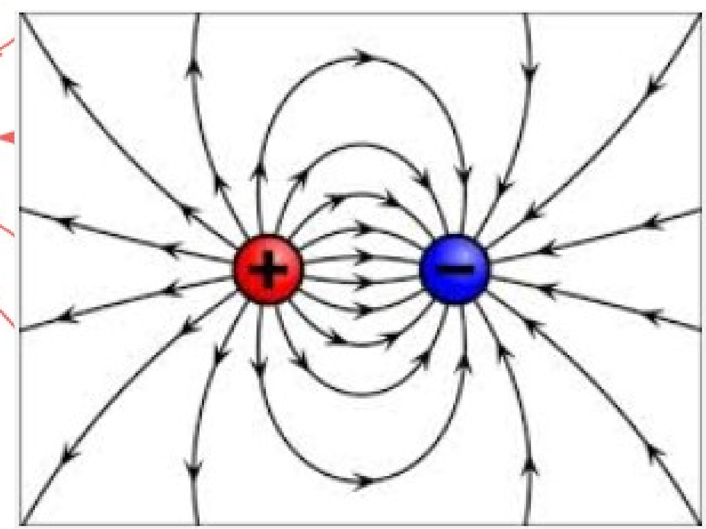
The number of lines leaving a positive charge or entering a negative charge is proportional to the magnitude of the charge.

2 like charges attract each other because the electric field pulling them together.

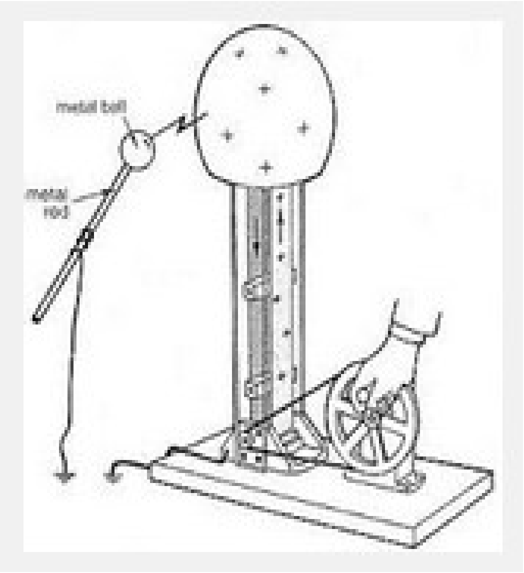


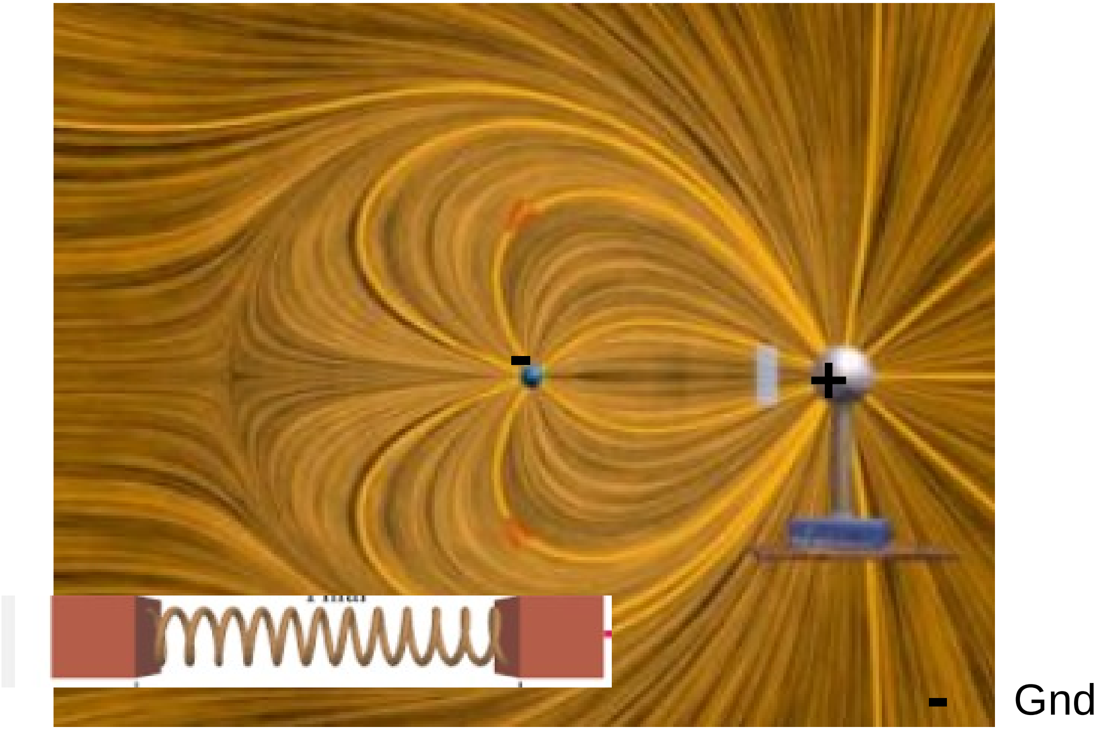


The electric field is like a stretched spring.



VAN GRAAF GENERATOR IS A CAPACITOR

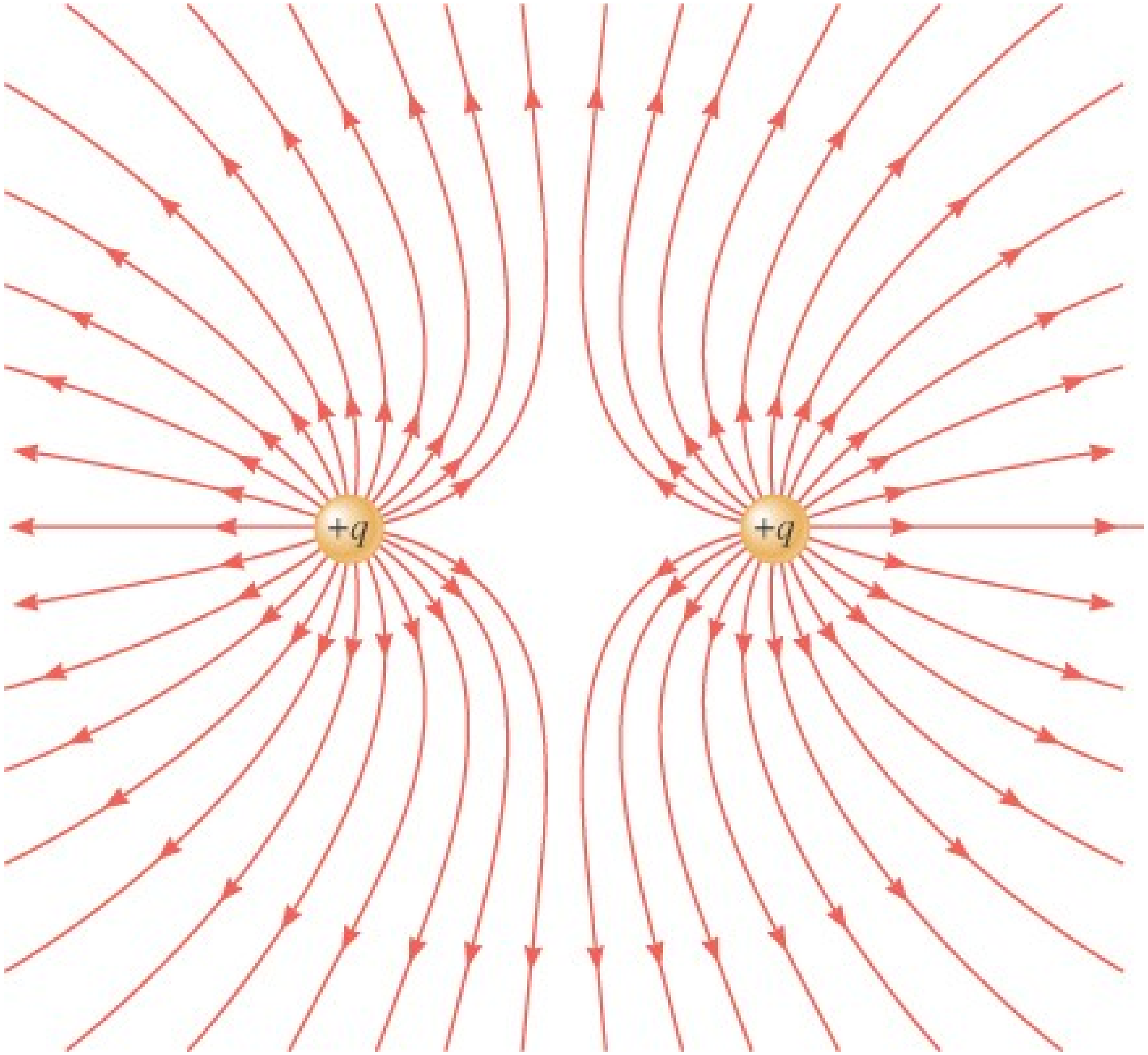




Demo. The Van de Graaf can be charged positively to 100,000 V.
It can hold on the charges for a long time. The electric field is pulling on the charge to bring them to the ground (to find -) or to another conductor (person, metallic rod). The energy is stored inside that electric field.
The electric field is like a stretched spring.

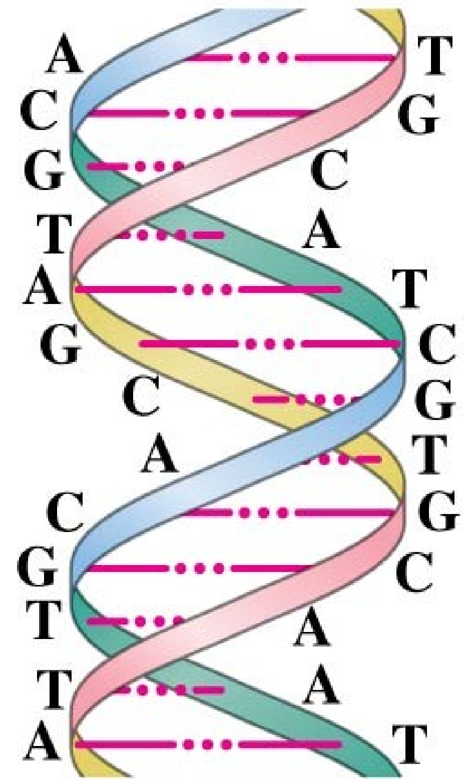
If the electric field is strong enough , there is a discharge. A spark. A break down of the electric field. This configuration is called a capacitor.

18.7 Electric Field Lines



16-10 Electric Forces in Molecular Biology: DNA Structure and Replication

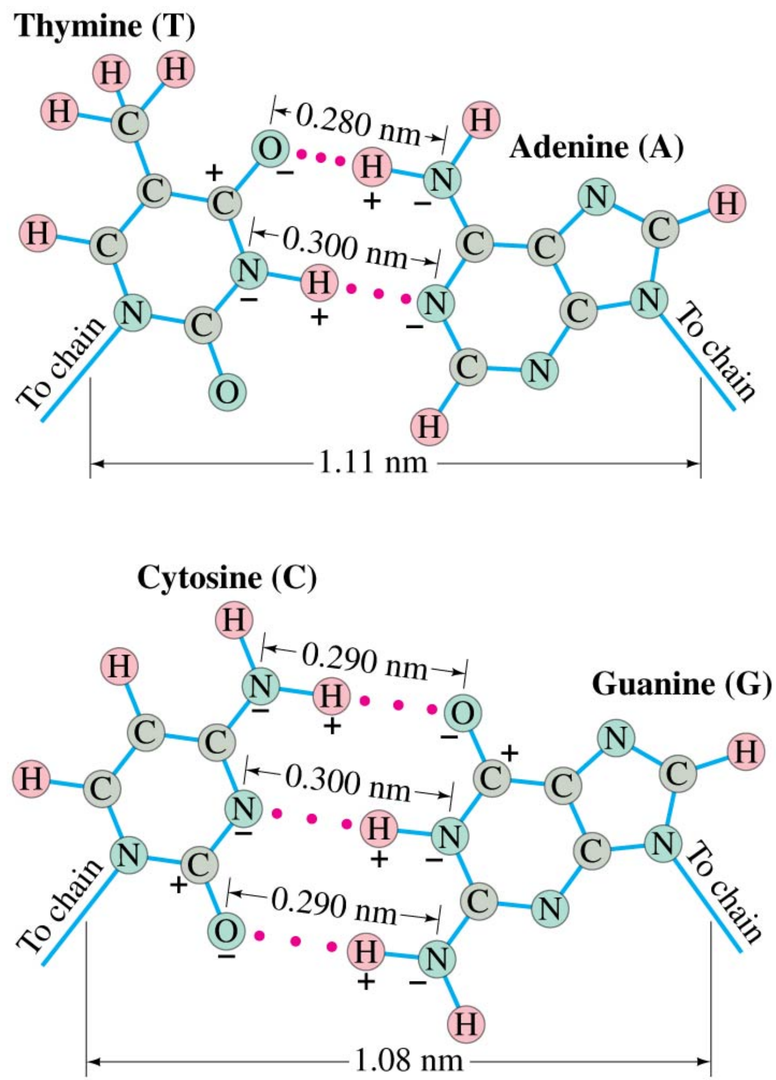
Molecular biology is the study of the structure and functioning of the living cell at the molecular level. The DNA molecule is a double helix:



(a)

16-10 Electric Forces in Molecular Biology: DNA Structure and Replication

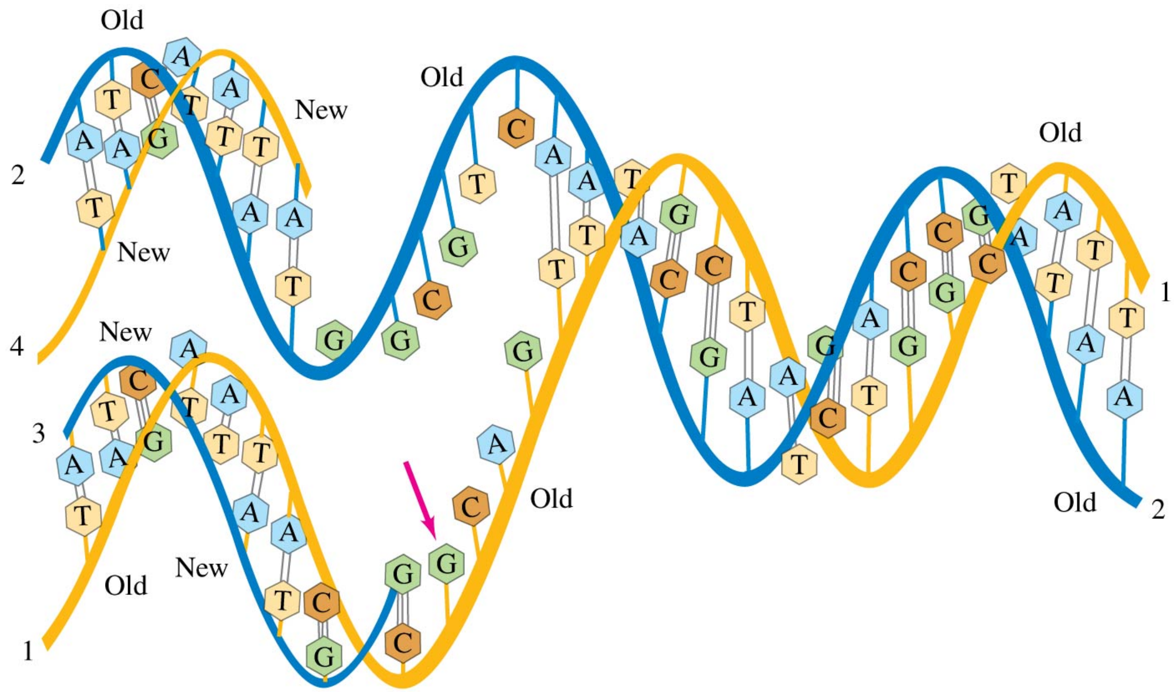
The A-T and G-C nucleotide bases attract each other through electrostatic forces.

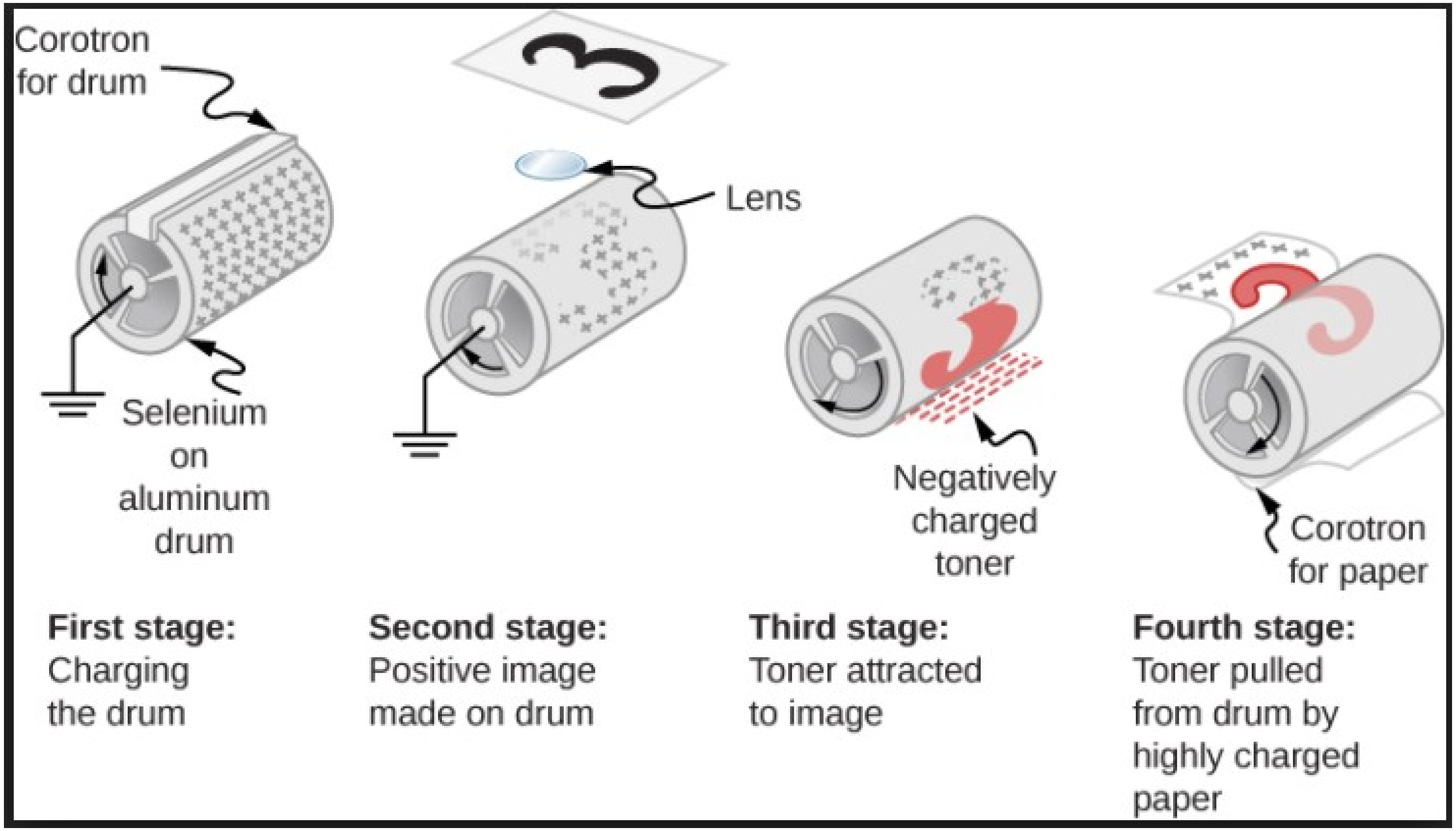


(b)

16-10 Electric Forces in Molecular Biology: DNA Structure and Replication

Replication: DNA is in a "soup" of A, C, G, and T in the cell. During random collisions, A and T will be attracted to each other, as will G and C; other combinations will not.




Corotron
for drum
Lens
Selenium
on
aluminum
drum
Negatively
charged
toner
Corotron
for paper
First stage:
Charging
the drum
Second stage:
Positive image
made on drum
Third stage:
Toner attracted
to image
Fourth stage:
Toner pulled
from drum by
highly charged
paper