Course Title: Applied Physics

Course Code: Phy 121

Credit Hours: 3 (2+1)

Instructor: Engr. S. Sufyan Syed

Textbook:

1) Physics Volume 2, by Halliday, Resnick and Krane, 5th/ 6th Edition.

Reference Books:

1) Fundamentals of Physics by Halliday, Resnick and Walker, 5th - 8th Edition.
2) Engineering Electromagnetics by William H Hayt and John A Buck, 6th Ed.

Physics:

Branch of science , which deals with matter and energy and their mutual relationships.

Matter: Any thing which occupies space and have mass called matter.

Energy: A property transferred to the matter for the purpose of doing work. For example potential energy, heat energy, Kinetic energy etc.

Physics has many subcategories:

Mechanics- the study of motion

Dynamics- the study of causes of motion

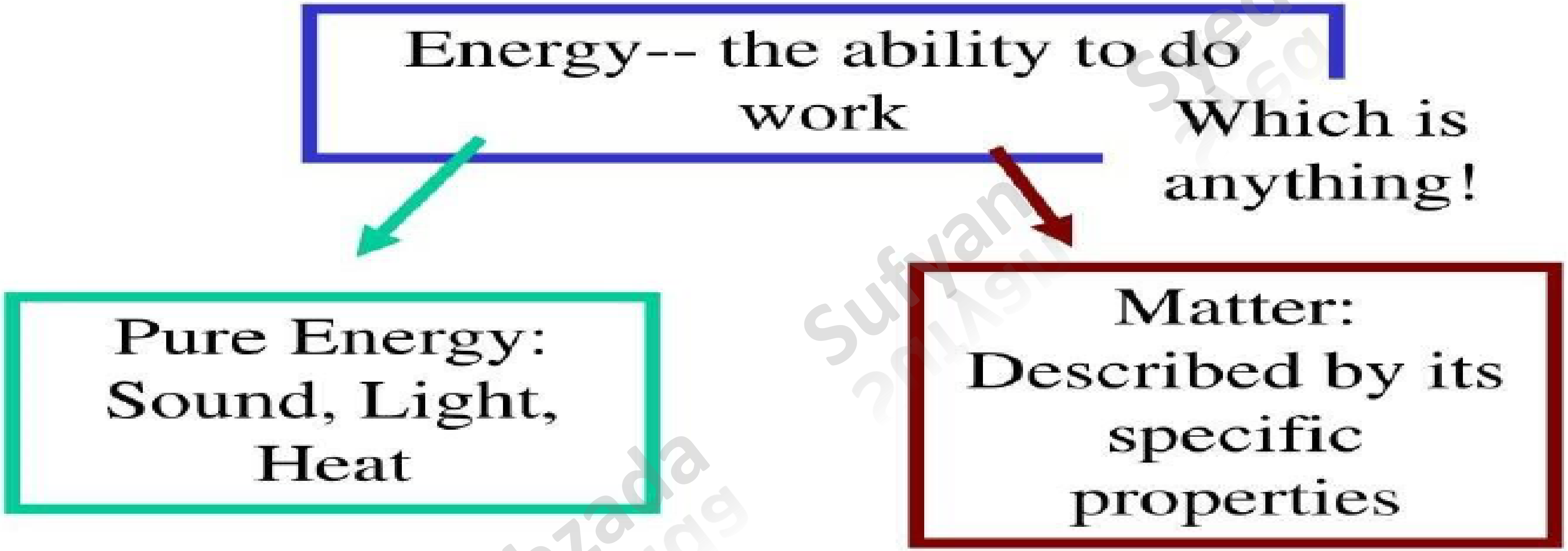
Thermodynamics- heat behaviors

Waves, Sound, Light, Optics

Modern Physics- nuclear physics, relativity, astrophysics, etc.

Physics is a science → an exploration into how things work and why

Physics--> the study of matter and energy



- Matter is anything that takes up space and can be weighed. In other words, matter has volume and mass.

Kinetic Energy

Kinetic energy is the energy that objects possess due to their motion.

$$KE = \frac{1}{2}mv^2$$

m = mass (kg)
v = velocity (m/s)
KE = Kinetic energy (J)

Gravitational Potential Energy

Gravitational potential energy is the energy stored in an object due to its position above the Earth's surface.

$$E_p = mgh$$

m = mass (kg)
g = gravitational field strength (N/kg)
h = height (m)
E_p = gravitational potential energy (J)

Properties of Matter

Mass: How much stuff - quantity of matter

Inertia: A resistance to a change in motion

Volume: How much space the matter takes up

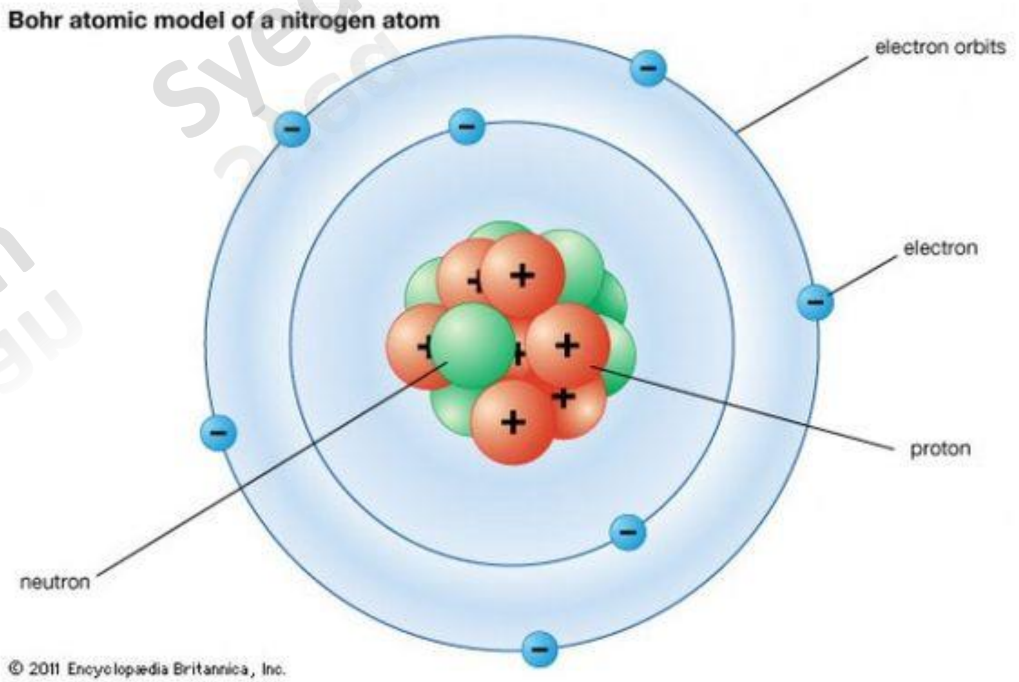
Mass Density: the ratio of mass to volume

Atom **Matter is composed of very small particles called atoms**

Atoms are made up of even smaller particles called electron, protons and neutrons.

Bohr's Atomic Model

According to Bohr's atomic model, the atom is composed of a nucleus and orbits. Proton and neutron resides in the nucleus and electrons revolve around the nucleus.



Proton: **Positively charged particles , found in the nucleus.**

Neutron : **Neutral particles also found in nucleus.**

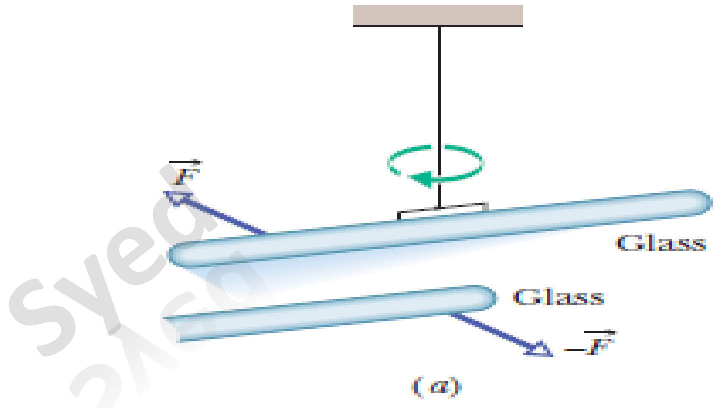
Electron: **Negatively charged particles revolve around the nucleus**

Charge : **Source of electric field is called the charge.**

Types:

Two types:

- **Positive Charge**
- **Negative charge**



Electric Charge:

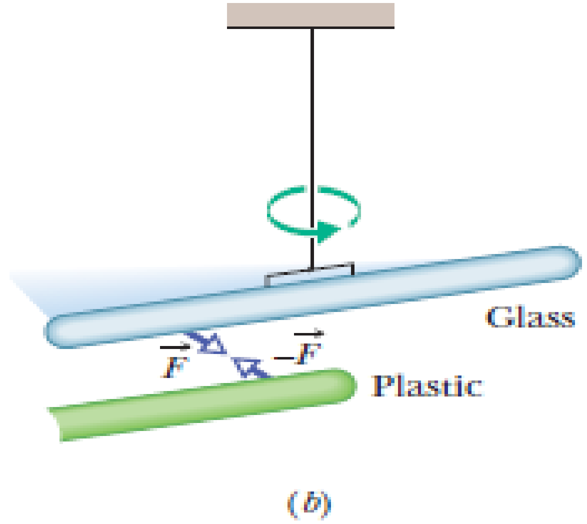
The charge produced due to the electron.

The charge produced by ionization process.

Unit of charge: Coulomb.
Symbol: C

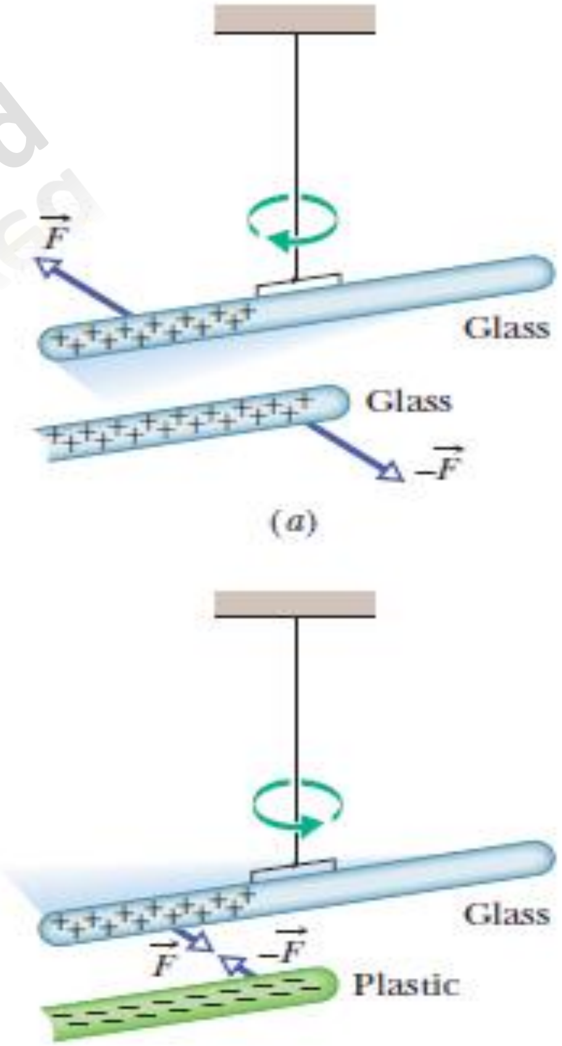
Property:

- **Scalar quantity**
- **Like charges repel each other and unlike charges attract each other**



(a) Two charged rods of the same sign repel each other.

(*b*) Two charged rods of opposite signs attract each other.



Conductors are materials through which charge can move rather freely; examples include metals (such as copper in common lamp wire), the human body, and tap water.

Nonconductors—also called **insulators**—are materials through which charge cannot move freely; examples include rubber (such as the insulation on common lamp wire), plastic, glass, and chemically pure water.

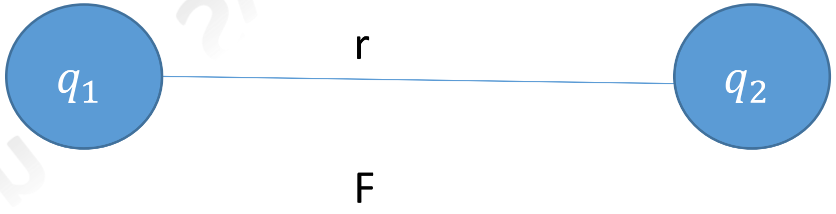
Semiconductors are materials that are intermediate between conductors and insulators; examples include silicon and germanium in computer chips.

Superconductors are materials that are *perfect* conductors, allowing charge to move without *any* hindrance..

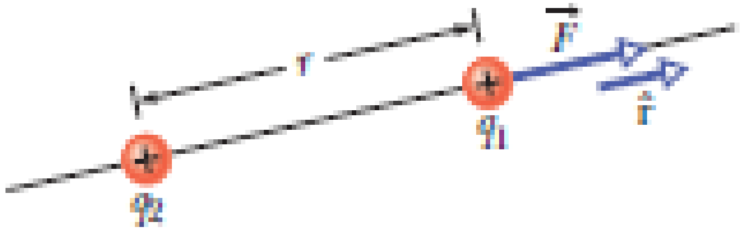
Coulombs Law:

If two charged particles are brought near each other, they each exert an electrostatic force on the other. The direction of the force vectors depends on the signs of the charges

$$F = K\frac{q_1 \times q_2}{r^2}$$



F: Coulomb 's Force or Electrostatic Force



q_1**: Electric Charge 1**
q_2**: Electric Charge 2**
$K = \frac{1}{4\pi\varepsilon_0}$ **: Electric Constant**
Where ε_0 **is the permittivity Of free Space**
The SI unit of charge is the **coulomb**

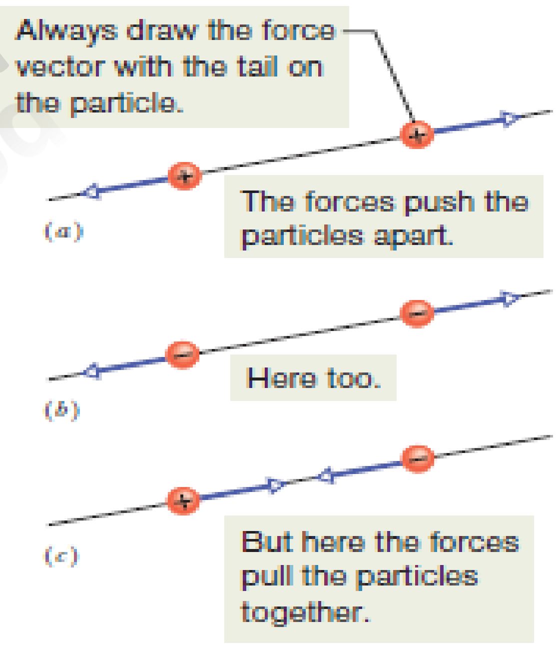
$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2} \quad \text{(Coulomb's law).} \tag{21-4}$$

The constants in Eqs. 21-1 and 21-4 have the value

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}. \tag{21-5}$$

The quantity ε_0, called the **permittivity constant**, sometimes appears separately in equations and is

$$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}. \tag{21-6}$$



Significance Of Coulomb's Law

1) The electrical force that bind the electrons of an atom to its nucleus
2) The force that bind atoms together to form molecules
3) The forces that bind atoms and molecules together to form the solids or liquids.

The smallest unit of charge known in nature is the charge on an electron or proton, which has an absolute value of

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

Therefore, 1C of charge is approximately equal to the charge of 6.24 x 1018electrons or protons.

Gravitational Force

$$F_g = G\frac{m_1 \times m_2}{r^2}$$

Particle	Charge (C)	Mass (kg)
Electron (e)	$-1.602\,191\,7 \times 10^{-19}$	$9.109\,5 \times 10^{-31}$
Proton (p)	$+1.602\,191\,7 \times 10^{-19}$	$1.672\,61 \times 10^{-27}$
Neutron (n)	0	$1.674\,92 \times 10^{-27}$

Object A has a charge of $+2\ \mu C$, and object B has a charge of $+6\ \mu C$. Which statement is true?

(a) $\mathbf{F}_{AB} = -3\mathbf{F}_{BA}$. (b) $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$. (c) $3\mathbf{F}_{AB} = -\mathbf{F}_{BA}$.

The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force between the two particles.

$$F_e = k_e \frac{|e|^2}{r^2} = \left(8.99 \times 10^9 \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right) \frac{(1.60 \times 10^{-19}\ \mathrm{C})^2}{(5.3 \times 10^{-11}\ \mathrm{m})^2}$$

$$= \boxed{8.2 \times 10^{-8}\ \mathrm{N}}$$

$$F_g = G \frac{m_e m_p}{r^2}$$

$$= \left(6.7 \times 10^{-11} \frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}\right)$$

$$= \times \frac{(9.11 \times 10^{-31}\ \mathrm{kg})(1.67 \times 10^{-27}\ \mathrm{kg})}{(5.3 \times 10^{-11}\ \mathrm{m})^2}$$

$$= \boxed{3.6 \times 10^{-47}\ \mathrm{N}}$$

Electric Charge is quantized means It is restricted to certain values).

The charge of a particle can be written as *ne*, where *n* is a positive or negative integer and *e* is the elementary charge,

Q = ne Where **E = $1.602\times 10^{-19} C$** **N = $0, \pm 1, \pm 2, \pm 3 \dots\dots\dots\dots\dots\dots.$**

Nucleus charge is not quantized

Charge on proton: 2/3e+2/3e-1/3e=1e

Quark Theory:
Nucleus particles are made up of fractional electric charged particles called Quarks

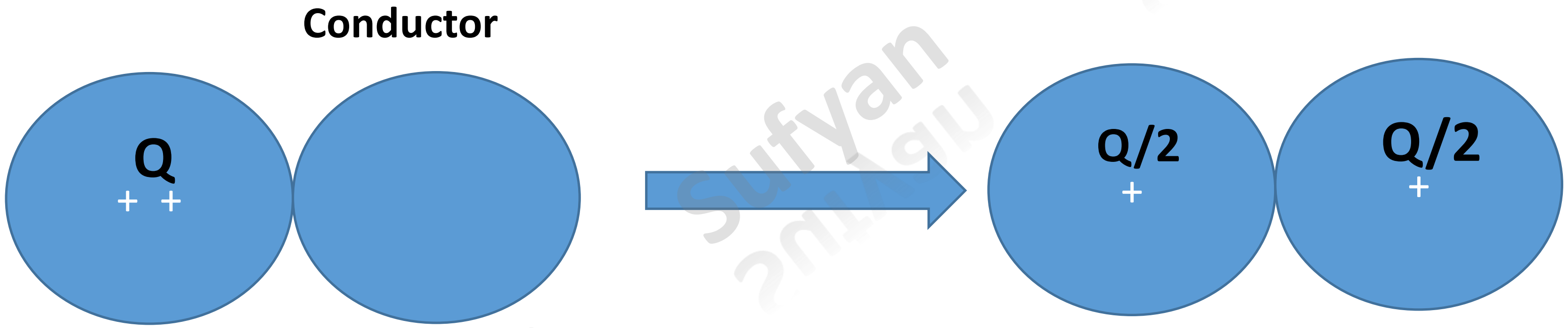
● (proton and neutron are made up of Quarks but electrons dont)

Charge on an neutron: -1/3e-1/3e+2/3e=0

Quarks Type:
Up Quarks : +(2/3) e
Down Quarks: -(1/3)e
Neutron is made up of three quarks: two down quarks, one up quark
Proton is made up of three quarks also: Two up Quarks, one down quark.

Charging Methods

1) Charging by Contact
2) Charging by Induction
3) Charging by Friction



- The process of giving one object a net electric charge by placing it in contact with another object that is already charged is known as charging by contact

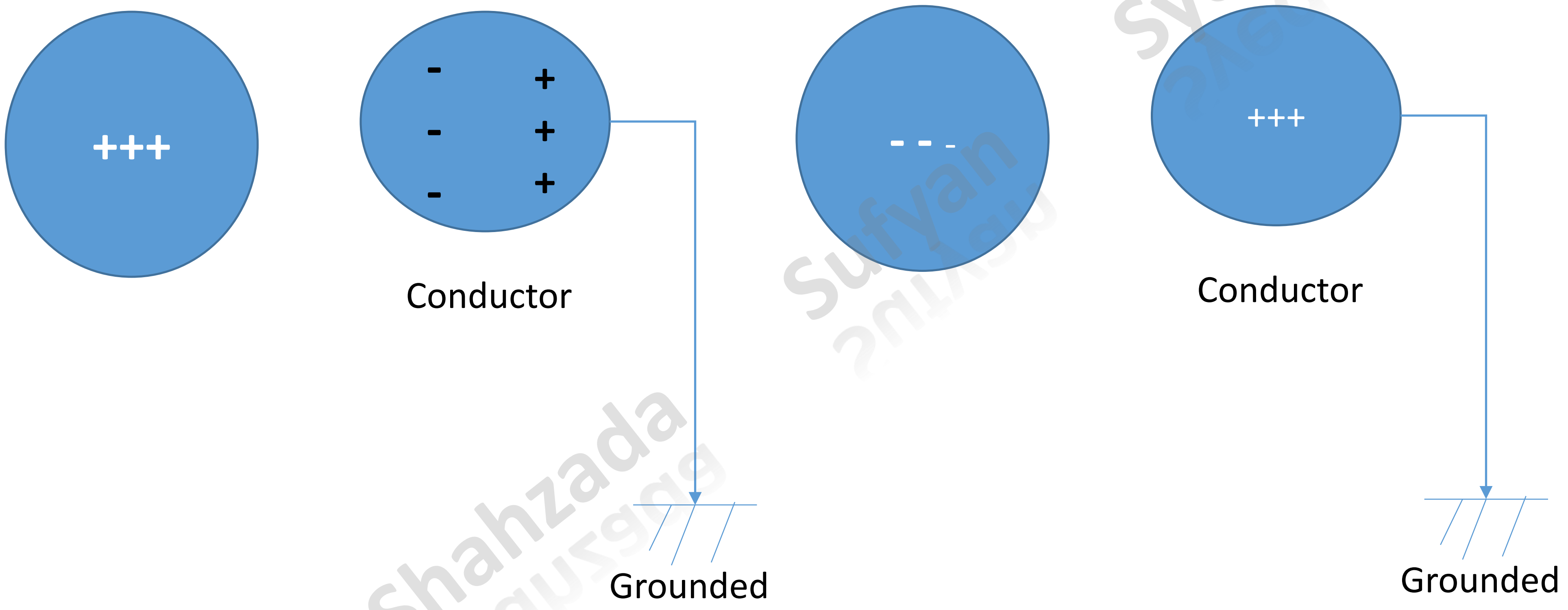
Positively Charged

Neutral

Charging by contact

Charging By Induction:

- Induction charging is a charging method that charges an object without actually touching the object to any other charged object. The charging by induction process is where the charged particle is held near an uncharged conductive material that is grounded on a neutrally charged material



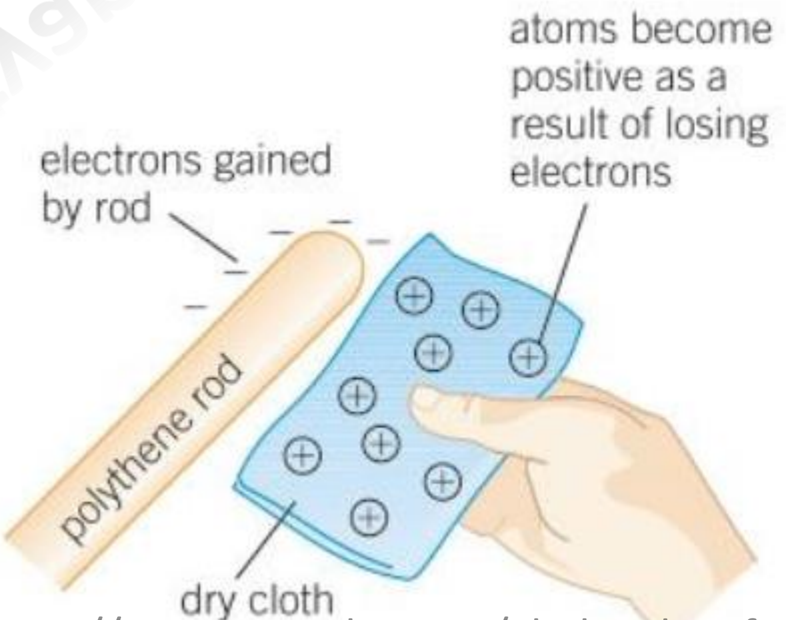
Charging By Friction

When insulating materials rub against each other, they may become electrically charged.

Electrons, which are negatively charged, may be ‘rubbed off’ one material and on to the other.

The material that gains electrons becomes negatively charged.

The material that loses electrons is left with a positive charge.



SAMPLE PROBLEM 25-2. In Sample Problem 25-1 we saw that a copper penny contains both positive and negative charges, each of a magnitude 1.37×10^5 C. Suppose that these charges could be concentrated into two separate bundles, held 100 m apart. What attractive force would act on each bundle?

SAMPLE PROBLEM 25-3. The average distance r between the electron and the proton in the hydrogen atom is 5.3×10^{-11} m. (*a*) What is the magnitude of the average electrostatic force that acts between these two particles? (*b*) What is the magnitude of the average gravitational force that acts between these particles?

Hints:

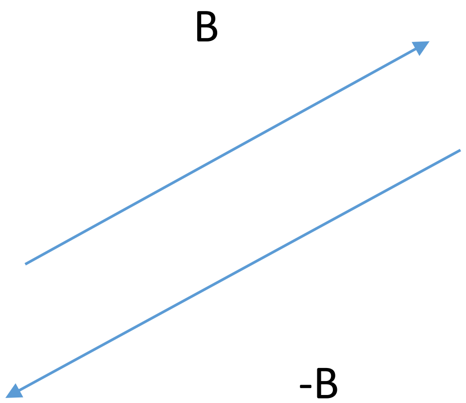
Electrical Force

$$F_e = K\frac{q_1 \times q_2}{r^2}$$

Gravitational Force

$$F_g = G\frac{m_1 \times m_2}{r^2}$$

Coulomb's Law: Vector Form



$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}.$$

Where

$$\hat{r}_{12} = \frac{\vec{r}_{12}}{r_{12}}.$$

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21}.$$

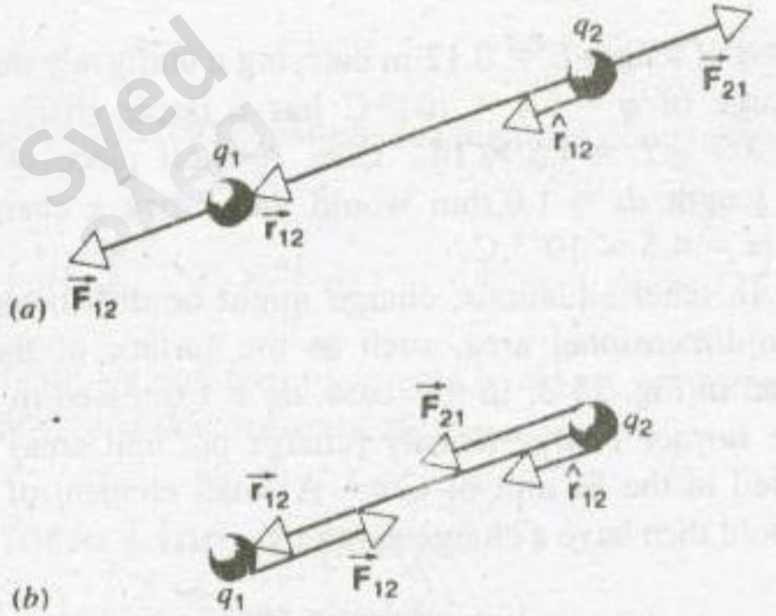
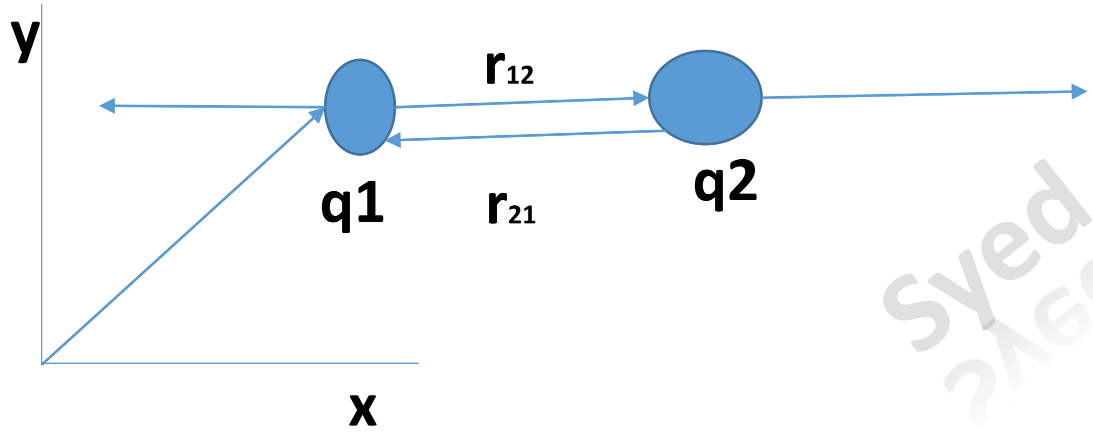
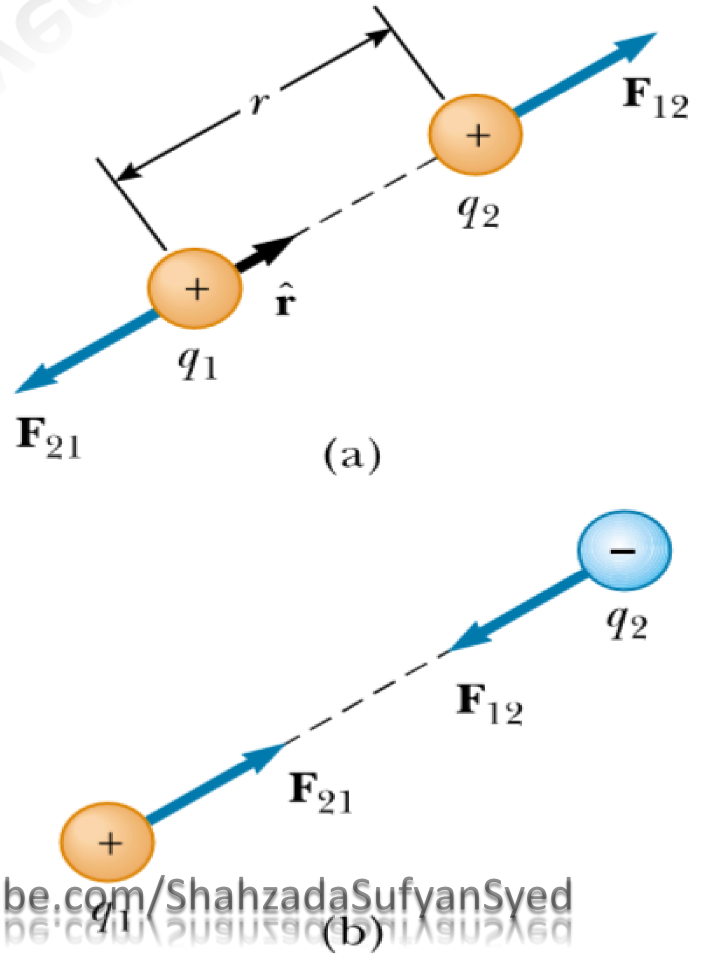


FIGURE 25-9. (*a*) Two point charges q_1 and q_2 of the same sign exert equal and opposite repulsive forces on one another. The vector $\vec{r}_{12}$ locates q_1 relative to q_2, and the unit vector $\hat{r}_{12}$ points in the direction of $\vec{r}_{12}$. Note that $\vec{F}_{12}$ is parallel to $\vec{r}_{12}$. (*b*) The two charges now have opposite signs, and the force is attractive. Note that $\vec{F}_{12}$ is antiparallel to $\vec{r}_{12}$.



$$r_{21} = |r_{21}|\hat{r}$$

$$F = K\frac{q_1 \times q_2}{r^2}$$



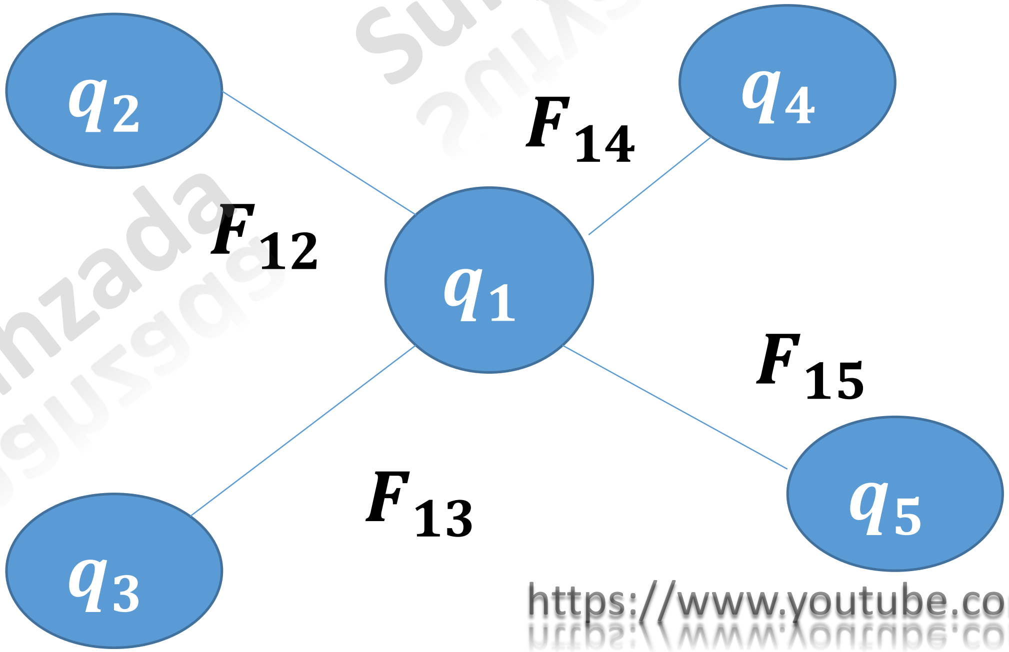
The electric force exerted by q2 on q1is equal in magnitude to the force exerted by q1on q2 and in opposite direction.

$$F_{21} = -F_{12}$$

Superposition Principle:

It states that force acting on one charge due to another is independent of whether or not other charges are present.

$$F_1 = F_{12} + F_{13} + F_{14} + \dots \dots \dots \dots \dots \dots \dots$$



What must be the distance between point charge $q_1 = 26.3\ \mu C$ and point charge $q_2 = -47.1\ \mu C$ for the attractive electrical force between them to have a magnitude of 5.66 N?

Solution:

Using

$$F = K\frac{q_1 \times q_2}{r^2}$$

The distance between the charges can be calculated as

$$r = \sqrt{\frac{(8.99\times 10^9 \text{N}\cdot\text{m}^2/\text{C}^2)(26.3\times 10^{-6}\text{C})(47.1\times 10^{-6}\text{C})}{(5.66\,\text{N})}} = 1.40\,\text{m}$$

A point charge of $+3.12 \times 10^{-6}$ C is 12.3 cm distant from a second point charge of -1.48×10^{-6} C. Calculate the magnitude of the force on each charge.

Solution:

Using

$$F = K\frac{q_1 \times q_2}{r^2}$$

$$F = \frac{(8.99\times10^{9}\,\mathrm{N\cdot m^2/C^2})(3.12\times10^{-6}\,\mathrm{C})(1.48\times10^{-6}\,\mathrm{C})}{(0.123\,\mathrm{m})^2} = 2.74\,\mathrm{N}.$$

Problem 3

Two equally charged particles, held 3.20 mm apart, are released from rest. The initial acceleration of the first particle is observed to be 7.22 m/s^2 and that of the second to be 9.16 m/s^2. The mass of the first particle is 6.31×10^{-7} kg. Find (*a*) the mass of the second particle and (*b*) the magnitude of the common charge.

(a) The forces are equal, so $m_1 a_1 = m_2 a_2$, or

$$m_2 = (6.31\times10^{-7}\text{kg})(7.22\,\text{m/s}^2)/(9.16\,\text{m/s}^2) = 4.97\times10^{-7}\text{kg}.$$

$$q = \sqrt{\frac{(6.31\times10^{-7}\text{kg})(7.22\,\text{m/s}^2)(3.20\times10^{-3}\text{m})^2}{(8.99\times10^9\text{N}\cdot\text{m}^2/\text{C}^2)}} = 7.20\times10^{-11}\text{C}$$