VIVEKANAND EDUCATION SOCIETY'S POLYTECHNIC

Vision

To be the centre of excellence in the field of technical education.

Program Code:- First Semester – All Program

Course Name:- Basic Science (PHYSICS)

Course Code : - BSC (22102)

Course coordinator: Mr. S. K. Rawat

Basic Science (PHYSICS)

Unit No 2: Electricity, magnetism & Semiconductors

Unit Name: Electric field, potential and potential difference

Unit Outcomes (UO2a): Calculate electric field, potential and potential difference of given static charge.

Learning Outcomes (LOs):

LO1: Student will be able to define charge and state Coulomb's inverse square law.

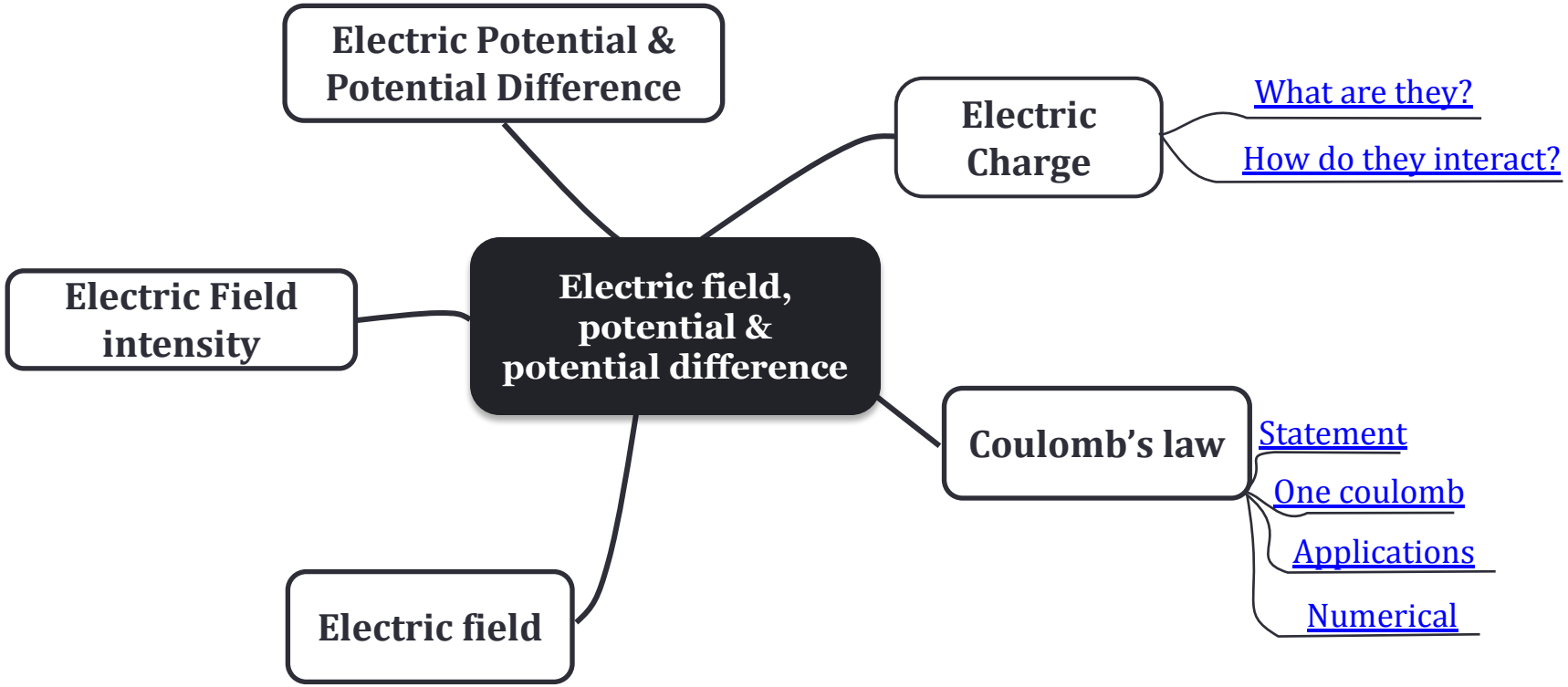
CONTENT

- Concept of charge
- Coulomb's inverse square law

LEARNING OBJECTIVES

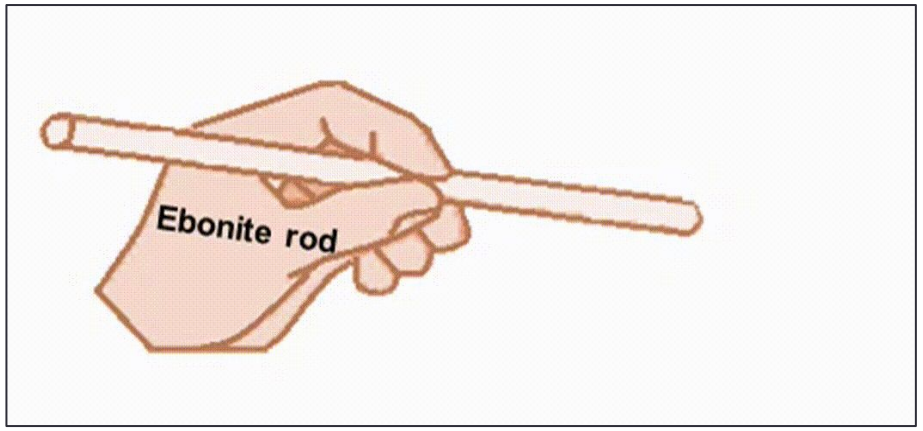
- Student will be able to define charge and state Coulomb's inverse square law.

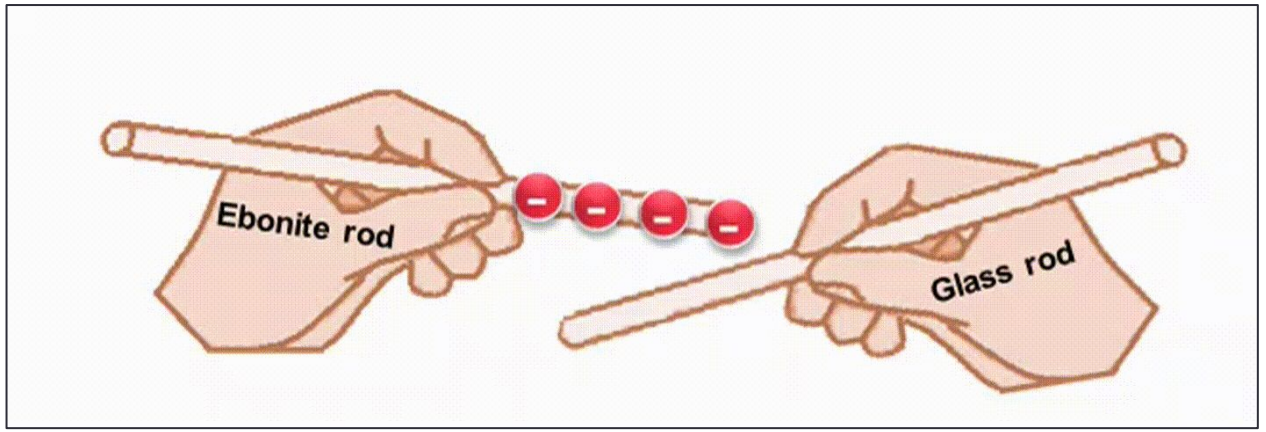
Concept Map


Electric Potential & Potential Difference
Electric Charge
What are they?
How do they interact?
Electric Field intensity
Electric field, potential & potential difference
Coulomb's law
Statement
One coulomb
Applications
Numerical
Electric field

ELECTRIC CHARGE

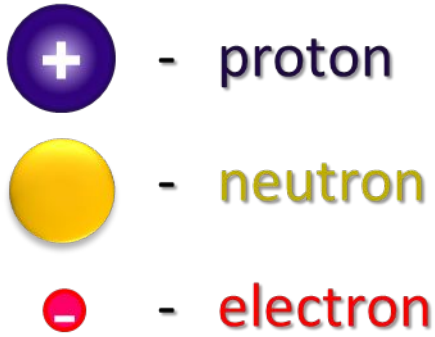
- **Key Question:**
  - What are electric charges ?
  - How do electric charges interact?

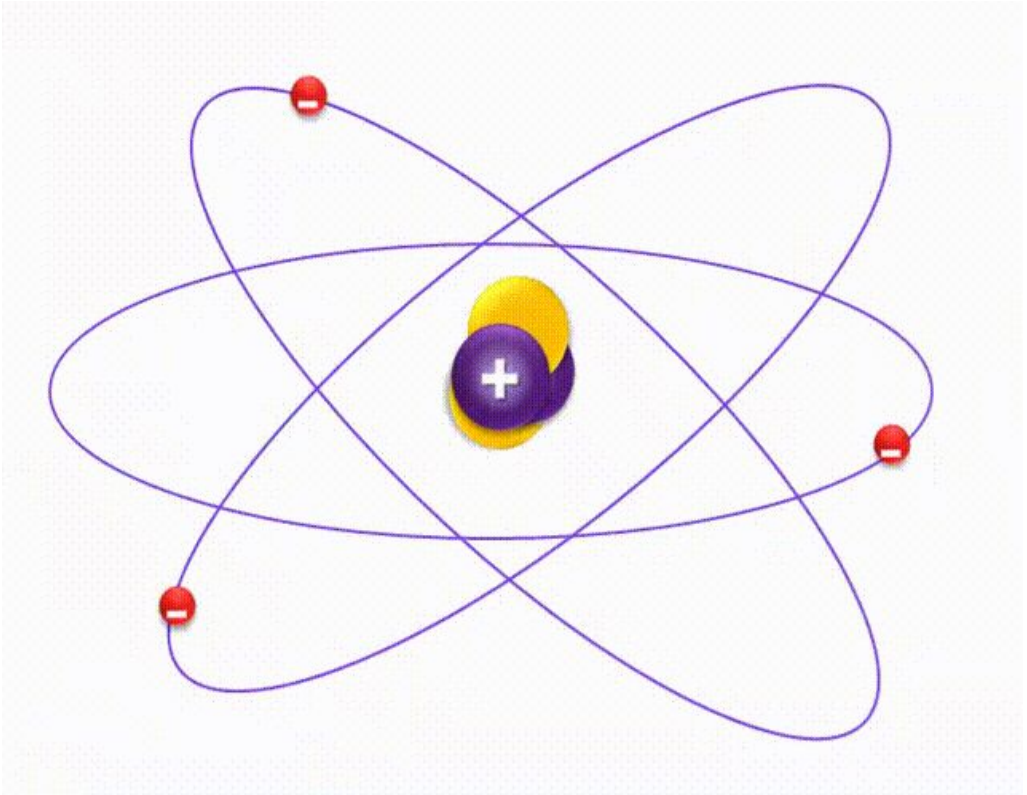




ELECTRIC CHARGE

- An Atom consists of protons, neutrons & electrons.

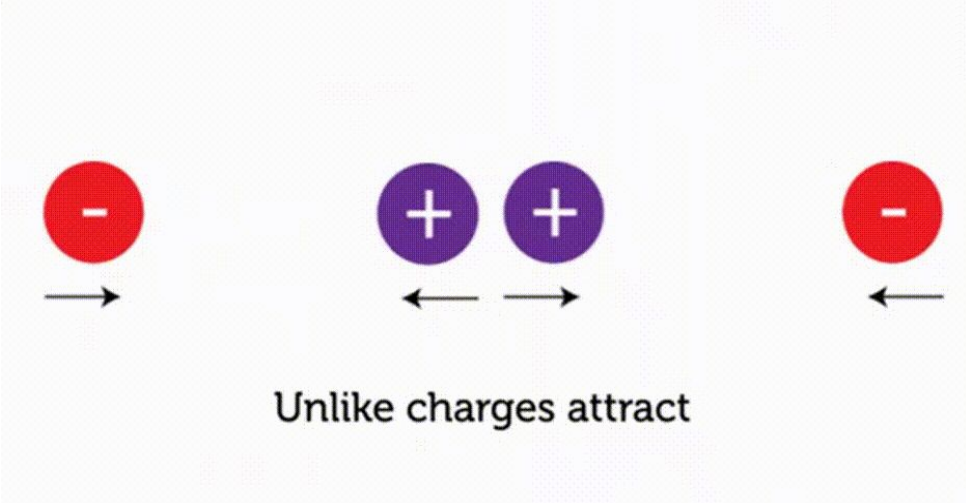


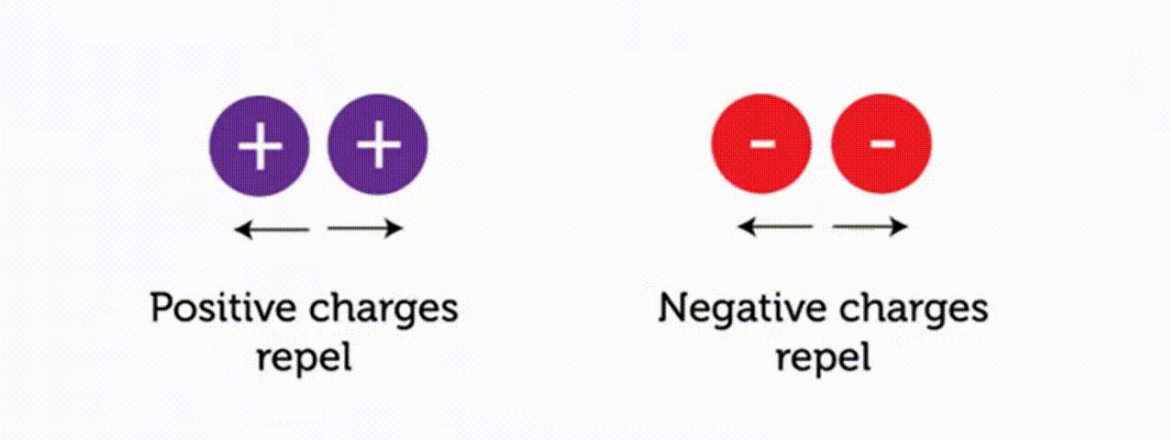


- Atom becomes positively charged when electron is taken away from it.
- Electric charge is a quantitative polarity of electrons & protons in an atom.

ELECTRIC CHARGE

- The unit of electric charge is the coulomb (C).
- A quantity of charge should always be identified with a positive or a negative sign
- We know unlike charges attract each other and like charges repel each other.





Attempt Set 1 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	In an atom, electric charge is a quantitative polarity of	In electricity, positive electric charge refers to	The force between the two electrically charged body is called
Level of Question	Remembering	Understanding	Understanding
Option (a)	electrons	protons	electromotive force
Option (b)	protons	neutrons	electrostatic force
Option (c)	electrons and protons	electrons	electromagnetic force
Option (d)	neutrons	atoms	magnetic force
Correct Option	**Option (c): electrons and protons**	**Option (a): protons**	**Option (b): electrostatic force**

START

COULOMB'S LAW

- In 1785, the French physicist Charles-Augustin de Coulomb published three papers on electricity and magnetism in which he described the electrostatic force.
- The law has become known as Coulomb's Law, and it states:
  1. Like charges repel each other, and unlike charges attract one another.
  2. The attraction or repulsion acts along a line between the two charges.
  3. The magnitude of the force is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

Charles-Augustin deCoulomb

COULOMB'S LAW

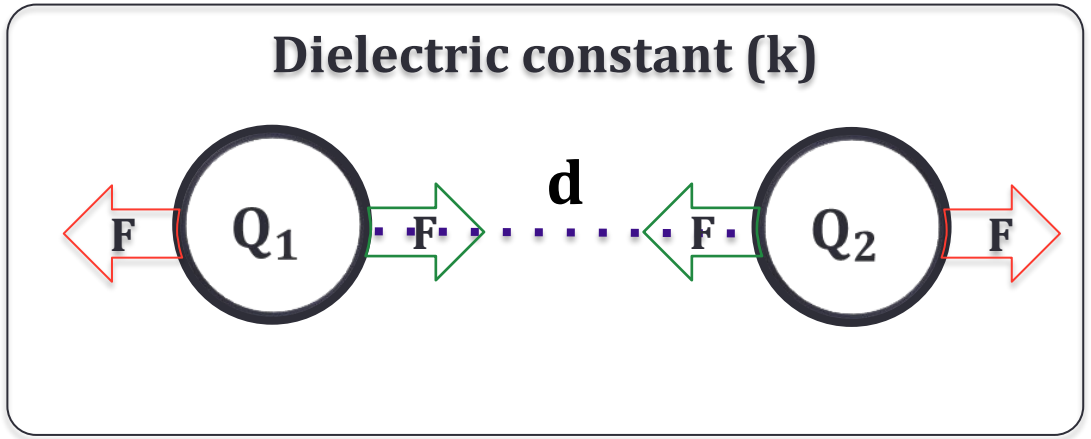
- To understand Coulomb's law, let us consider two electric charges having magnitude $\mathbf{Q_1}$ and $\mathbf{Q_2}$ placed at a distance $\mathbf{d}$ from each other in a medium with dielectric constant $\mathbf{k}$.
- According to Coulomb's law, the force (F) of attraction or repulsion between two electric charges is
  i. directly proportional to product of magnitude of each charge, i.e.,$\mathbf{F \propto Q_1 \times Q_2}$ &
  ii. inversely proportional to square of distance between them, i.e., $\mathbf{F \propto \frac{1}{d^2}}$
- From equation (i) and (ii) we get,

$$\mathbf{F \propto \frac{Q_1 \times Q_2}{d^2}}$$

$$\therefore \mathbf{F = C \times \frac{Q_1 \times Q_2}{d^2}} \quad (\mathbf{C} \text{ is Coulomb's constant})$$

$$\therefore \mathbf{F = \frac{1}{4\pi\epsilon} \times \frac{Q_1 \times Q_2}{d^2}}$$

$$\therefore \mathbf{F = \frac{1}{4\pi\epsilon_0 k} \times \frac{Q_1 \times Q_2}{d^2}} \quad (\text{where } \boldsymbol{\epsilon = \epsilon_0 k} \text{ is called the permittivity of medium})$$



UNIT CHARGE: ONE COULOMB

- From coulomb's law, we know $\mathbf{F} = \frac{1}{4\pi\epsilon} \times \frac{Q_1 \times Q_2}{d^2} = \frac{1}{4\pi\epsilon_0 k} \times \frac{Q_1 \times Q_2}{d^2}$

(where $\epsilon = \epsilon_0 k$ is called the permittivity of medium

$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2 , is called the permittivity of free space

k = relative permittivity or dielectric constant of medium)

NOTE: If we substitute valve of π and ϵ_0 in $\frac{1}{4\pi\epsilon_0 k}$, we get

$$\mathbf{F} = 9 \times 10^9 \times \frac{Q_1 \times Q_2}{k d^2}$$

This is simplified equation of electrostatic force by coulomb's law and normally used to solve numerical examples.

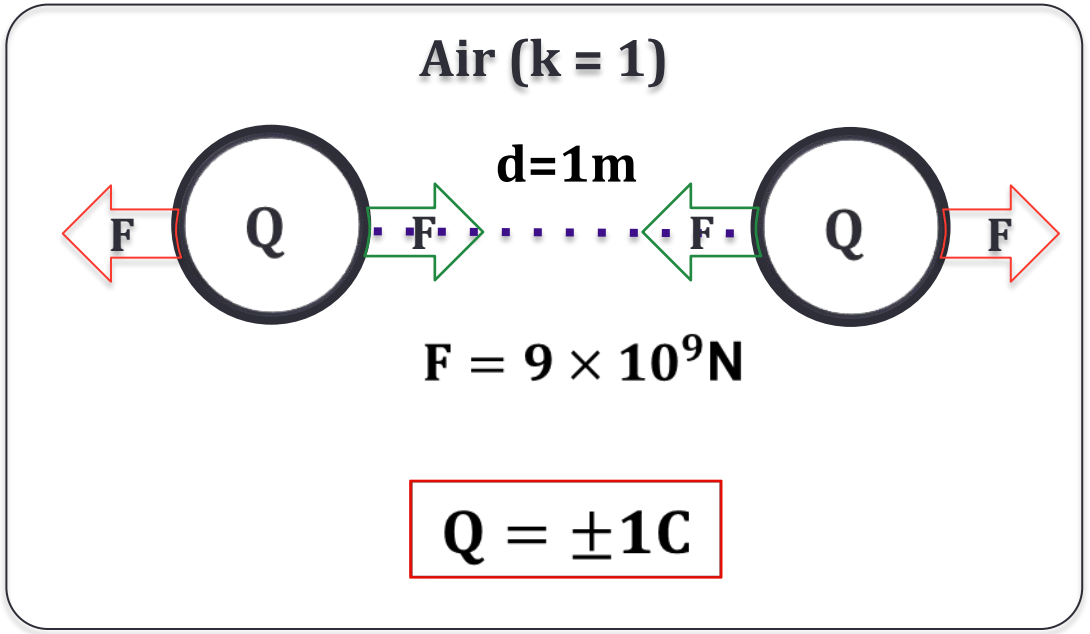
UNIT CHARGE: ONE COULOMB

- According to Coulomb's law, we know

$$F = 9 \times 10^9 \times \frac{Q_1 \times Q_2}{kd^2}$$

- Now if we consider $Q_1 = Q_2 = Q, k = 1, d = 1$ and $F = 9 \times 10^9$
- Then, $F = 9 \times 10^9 \times \frac{Q_1 \times Q_2}{kd^2} \Rightarrow$
- $9 \times 10^9 = 9 \times 10^9 \times \frac{Q \times Q}{1 \times (1)^2} \Rightarrow Q^2 = 1$

$$\Rightarrow Q = \pm 1C$$

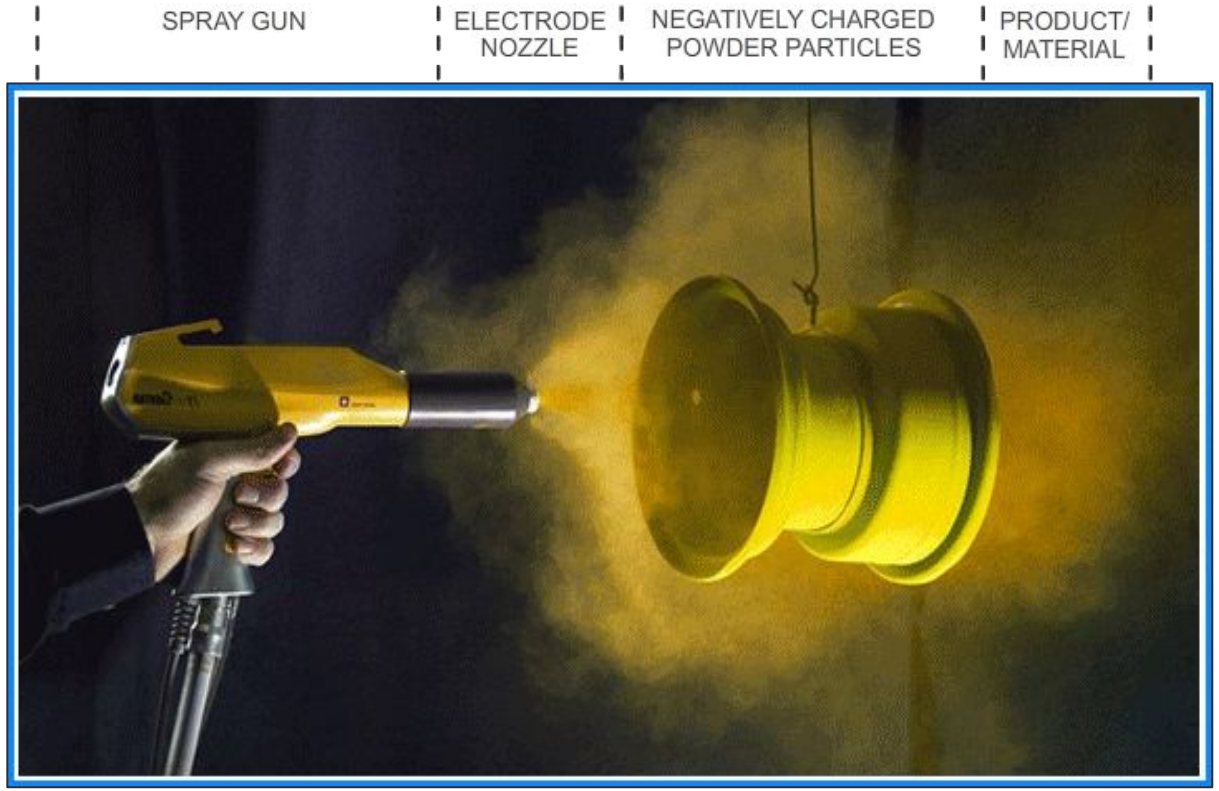


- **Unit Charge:** If two equal charges are placed in air at a distance of 1 meter from each other & if they exert a force of 9 x 10^9 N on each other, then each charge is said to be of **unit charge** *or* **one coulomb**.

Application of Coulomb law in real life

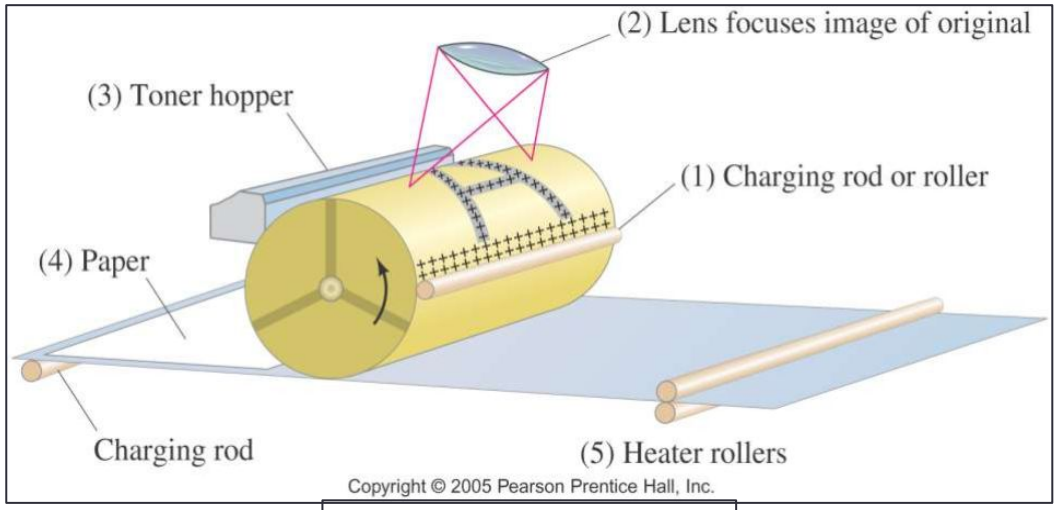
- **Coulomb's Law** has a great many applications to modern life, from powder coating to xerox machines to printers, to life sciences.

- **Powder Coating**
- **Electrostatic process used** is electrostatic painting or coating, also known as "powder coating."
- The process uses a high voltage electrostatic charge which is applied to both the object to be coated and the sprayer mechanism.

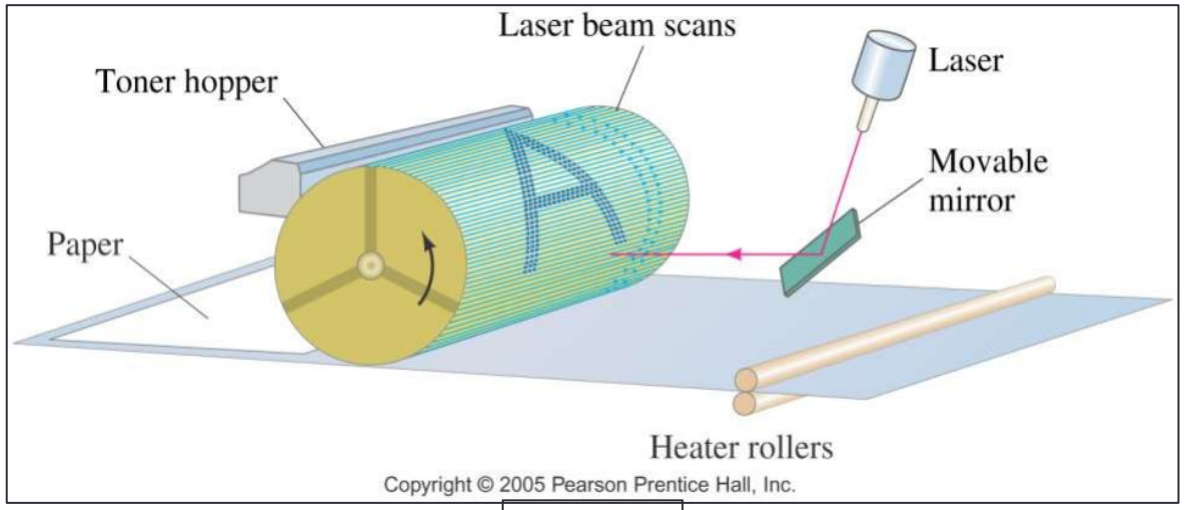


Application of Coulomb law in real life

- **Xeror Machines, Photocopiers and Printers** uses concept of **Electrostatics**
- **Xeror Machines, Photocopiers:** Drum is charged positively and image is focused on drum. Here only black areas stay charged and attract toner particles. Then finally image is transferred to paper and sealed by heat.
- **Printers** is similar, except a computer controls the laser intensity is used to form the image on the drum.



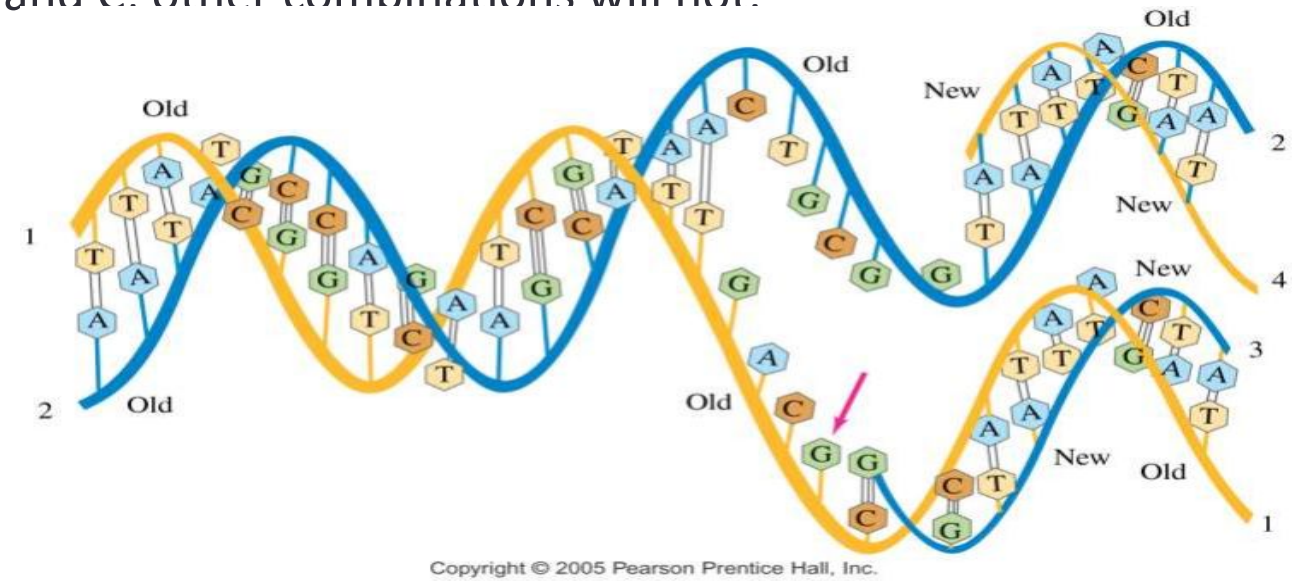
Photocopy Machines



Printers

Application of Coulomb law in real life

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



Important Formulas/ Points to Remember

- The numerical value of electron e = 1.6 x 10^{-19} C
- Permittivity of free space ϵ_0 = 8.85 x 10^{-12} C^2/Nm^2
- Force between two charges $F = 9 \times 10^9 \times \frac{Q_1 \times Q_2}{kd^2}$
- One unit charge = Q = ± 1 Coulomb
- One coulomb charge = 1 C = 6.24×10^{16} electrons

Word Problem

PROBLEM 1

Two point charges of +8 µC and -5 µC, are separated by a distance of 10 cm. What is the magnitude of the electric force if the dielectric constant k = 9 Nm^2/C^2

- Given: Q_1 = +8 µC = +8 x 10^{-6} C, Q_2 = - 5 µC = -5 x 10^{-6} C, d = 10 cm = 0.1 m, k = 9 Nm^2/C^2
- Find: The magnitude of the electric force (F)
- Solution:

Formula of Coulomb's law : $\mathbf{F = 9 \times 10^9 \times \frac{Q_1 \times Q_2}{kd^2}}$

$$F = 9 \times 10^9 \times \frac{8 \times 10^{-6} \times -5 \times 10^{-6}}{9 \times (0.1)^2}$$

$\mathbf{F = -\ \ \ 4\ N}$ (negative sign indicates force of attraction)

- An attractive force of – 4 N acts between two unlike charges.

Attempt Set 2 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	According to Coulomb's law, the force between two charges separated by a distance is	The relation between $\epsilon 0$, k and ϵ is given by	Determine the force in Newton between 4μC charges separated by 0.1 meter in air.
Level of Question	Remembering	Understanding	Application
Option (a)	$F \propto Q1Q2$	$\epsilon \times \epsilon 0 = k$	1.44 N
Option (b)	$F \propto 1/d2$	$\epsilon 0/\epsilon = k$	14.4 N
Option (c)	Both (a) and (b)	$\epsilon = \epsilon 0 \times k$	144 N
Option (d)	None of the above	$\epsilon 0 = \epsilon \times k$	1440 N
Correct Option	**Both (A) and (B)**	$\epsilon = \epsilon 0 \times k$	**14.4 N**

START