

Introduction to Electrostatic Fields

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Introduction

- *Electrostatic fields* are also called as static electric fields or steady electric fields. These fields are time invariant.
- They are produced by static charges or charge distributions.
- These fields have wide range of applications.

APPLICATIONS OF ELECTROSTATIC FIELDS

- The *Electrostatic Fields* are used
 - in Ink-jet printers to obtain the speed of printing and quality of print
 - In LCDs
 - in Touch pads
 - in Capacitance keyboards /Electrical Switchboards
 - in ECGs, EEGs, ERG, EMG, EOG
 - in X-ray machines
 - in Spray Painting
 - in Electrodeposition

APPLICATIONS OF ELECTROSTATIC FIELDS (Cont'd.)

- The *Electrostatic Fields* are used
 - in Cathode ray oscilloscopes to obtain the electron beam deflection
 - in ore separators to sort out minerals, to sort out seeds in agriculture and for spraying plants and trees
 - in Electrostatic generators
 - to produce Potential
 - to produce Force on charges for their mobility
 - in Electric Power Transmission
 - in Lightning Protection

APPLICATIONS OF ELECTROSTATIC FIELDS (Cont'd.)

- The *Electrostatic Fields* are used
 - to measure Moisture content
 - to Spin cotton
 - in Field Effect Transistors
 - in Capacitors
 - in Electrochemical machining

Fundamental laws for electrostatic fields

Two fundamental laws for electrostatic fields:

- **Coulomb's Law**: useful in finding field due to any charge configuration
- **Gauss's Law**: applied for symmetrical charge distribution

Both laws are based on experimental studies and are interdependent.

Coulomb's law of force

$$\mathbf{F}_{12} = K \frac{Q_1 Q_2}{R^2} \mathbf{a}_{R_{12}}$$

where the constant of proportionality K in SI units is $\frac{1}{4\pi\epsilon_0}$,
 ϵ_0 being the permittivity of the free space ($\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$)

Fundamental laws for electrostatic fields (Cont'd.)

- study on electric fields in free space or in vacuum
- From figure 1, $\mathbf{a}_{R_{12}} = -\mathbf{a}_{R_{21}}$, $\mathbf{F}_{21} = -\mathbf{F}_{12}$

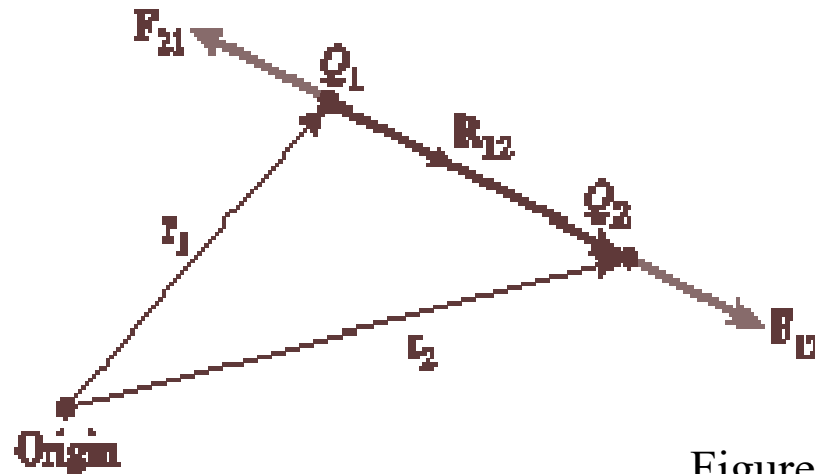


Figure 1

$$\mathbf{F}_{12} = \frac{Q_1 Q_2}{4 \pi \epsilon_0 R^2} \mathbf{a}_{R_{12}} = \frac{Q_1 Q_2}{4 \pi \epsilon_0 R^3} \mathbf{R}_{12} = \frac{Q_1 Q_2 (\mathbf{r}_2 - \mathbf{r}_1)}{4 \pi \epsilon_0 |\mathbf{r}_2 - \mathbf{r}_1|^3}$$

Fundamental laws for electrostatic fields (Cont'd.)

- Like charges repel each other while unlike charges attract

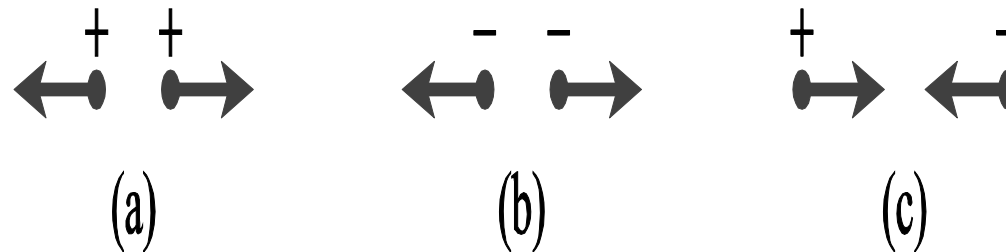


Figure 2

- The principle of superposition can be applied to determine the resultant force on a point charge Q due to other charges Q_1, Q_2, \dots, Q_N

$$\mathbf{F} = \frac{Q}{4\pi\epsilon_0} \sum_{k=1}^N \frac{Q_k (\mathbf{r} - \mathbf{r}_k)}{|\mathbf{r} - \mathbf{r}_k|^3}$$

Fundamental laws for electrostatic fields (Cont'd.)

Electric field intensity

- Electric field can be defined as the force per unit charge from Coulomb's law

$$\mathbf{E} = \frac{Q}{4\pi\epsilon_0 R^2} \mathbf{a}_R = \frac{Q(\mathbf{r} - \mathbf{r}')}{4\pi\epsilon_0 |\mathbf{r} - \mathbf{r}'|^3}$$

Electric field at point \mathbf{r} due to a point charge located at \mathbf{r}'

- \mathbf{E} at point \mathbf{r} due to N point charges Q_1, Q_2, \dots, Q_N located at $\mathbf{r}_1, \mathbf{r}_2, \dots, \mathbf{r}_N$ is obtained by the principle of superposition.

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0} \sum_{k=1}^N \frac{Q_k (\mathbf{r} - \mathbf{r}_k)}{|\mathbf{r} - \mathbf{r}_k|^3}$$

Electric fields due to continuous charge distributions

- For a continuous charge distribution:

$$Q = \int_L \rho_L dl \quad \text{for line charge}$$

$$Q = \int_S \rho_S dS \quad \text{for surface charge}$$

$$Q = \int_V \rho_V dv \quad \text{for volume charge}$$

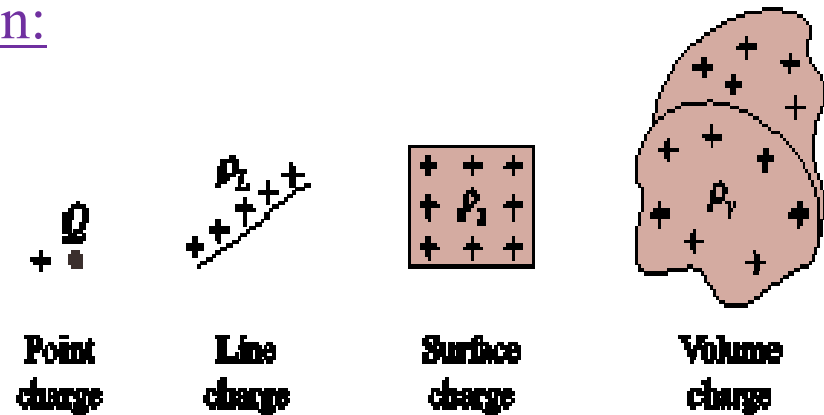


Figure 3

- Electric field due to continuous charge distributions

An infinite line charge

$$\mathbf{E} = \frac{\rho_L}{2\pi\epsilon_0\rho} \mathbf{a}_\rho$$

An infinite sheet of charge

$$\mathbf{E} = \frac{\rho_S}{2\epsilon_0} \mathbf{a}_n$$

Electric fields due to continuous charge distributions (Cont'd.)

A spherical charge distribution :

$$\mathbf{E} = \frac{Q}{4\pi\epsilon_0 r^2} \mathbf{a}_r$$

where $Q = \int \rho_v dv = \rho_v \int dv = \rho_v \frac{4\pi a^3}{3}$ (a : sphere radius)

The expression is identical to that of \mathbf{E} at the same point (\mathbf{r}) due to an effective charge Q located at the center of the spherical charge distribution.