Physics

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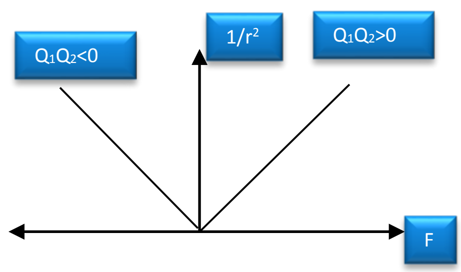
(Unit 1)(Electrostatics)

(Class 12)

Key Points and Revision Notes

- Electrostatics is the study of charges at rest.
- Charging a body can be done by friction, induction and conduction.
- Properties of charges:
    - ✓ Like charges repel and unlike charges attract.
    - ✓ Charges are additive in nature i.e., Q=$\sum_{i=1}^{n} q_i$
    - ✓ Charges are quantized. i.e., Q= ± ne [n=1,2,3,... & e=1.602 X10^{-19} C]
    - ✓ Charge in a body is independent of its velocity.
    - ✓ Charge is conserved.
- To measure charge electroscopes are used.
- Coulomb's law: $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$ k=$\frac{1}{4\pi\varepsilon_0}$ = 9X10^9 Nm^2c^{-2}

  Where, ε_0= permittivity of free space



$F_{total} = F_{12} + F_{13} + ...$

- Principle of superposition: $Ftotal = \sum_{i=1}^{n} \vec{F_i}$ [vector sum of individual forces]

$$= \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r_{12}^2}\hat{r}_{12} + \frac{1}{4\pi\varepsilon_o}\frac{q_1q_3}{r_{13}^2}\hat{r}_{13} + ...$$

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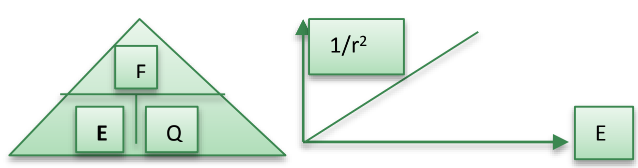
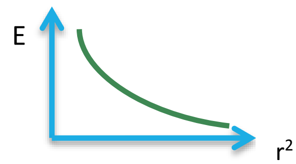
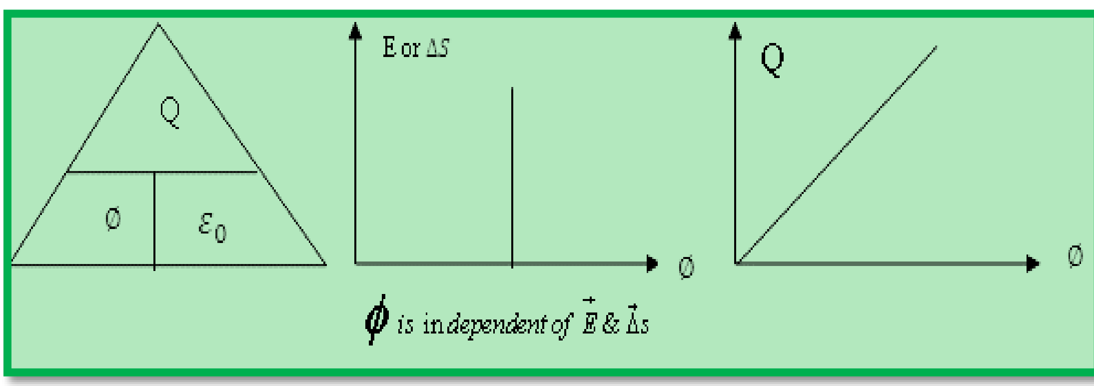


Note: *In the above triangle the quantity shown at the vertex, could be arrived by multiplying the quantities shown at the base, ie F=E X Q. Any one of the quantity shown at the base is given by the ratio of the quantities shown at vertex & the other quantity shown at the base, ie E=F/Q or Q= F/E*

- Electric field: Force experienced by a unit positive (or test) charge. It is a vector. SI unit NC^{-1}.
- $\vec{E} = \frac{kQ}{r^2}\hat{r}$
- $\vec{E} = \lim_{q_o \to 0} \frac{\vec{F}}{q_o}$



- Field due to a point charge: $\vec{E} = \frac{kQ}{r^2}\hat{r}$
- Principle of superposition: $\vec{E}_{total} = \sum_{i=1}^{n} \vec{E}_r$ [vector sum of individual fields]
- Dipole: Two equal and opposite charges separated by a small distance.
- Dipole moment: Product of magnitude of charge and distance of separation between them. It is a vector. SI unit: Cm, $\vec{p}$=Q.2$\vec{a}$; direction of $\vec{p}$ is negative to positive charge.
- Dipole in a uniform electric field experiences no net force and instead experiences a torque. $\vec{\tau}=\vec{p} \times \vec{E} \Rightarrow \vec{\tau}=|\vec{p}||\vec{E}|\sin\theta\,\hat{n}$
- If θ= 0° ⇒ stable equilibrium; If θ= 180° ⇒ unstable equilibrium.
- Electric field due to a dipole
  - ✓ **At a point on the axial line** : $\frac{2k\vec{p}}{r^3}$ along the direction of dipole moment
  - ✓ **At a point on the equatorial line**: $\frac{k\vec{p}}{r^3}$ opposite to the direction of dipole moment.
- Electric flux: $\emptyset=\overrightarrow{\Delta S}.\vec{E} = |\vec{E}||\overrightarrow{\Delta S}|\cos\theta$; It is a scalar; SI unit: $NC^{-1}m^2$ or Vm.
- Gauss' theorem in electrostatics: $\emptyset_{total} = \frac{q_{total}}{\varepsilon_0}$



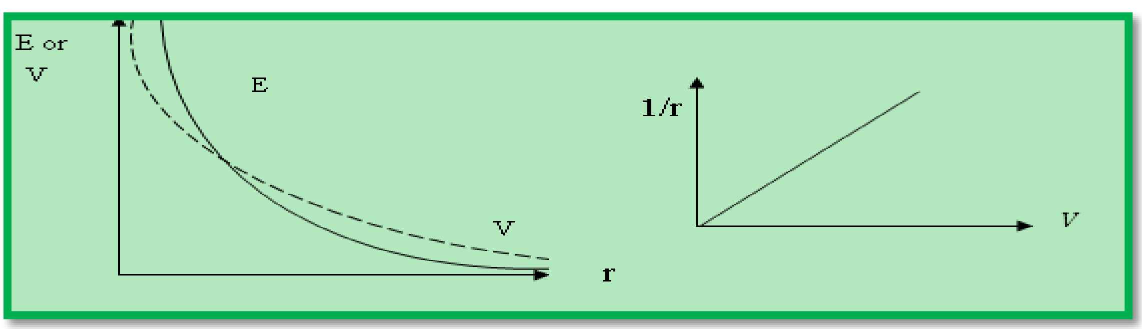
- Uniform Charge distribution:
  - Linear charge distribution: $\lambda = \frac{\Delta q}{\Delta l}$ [$\lambda \Rightarrow$ linear charge density Unit Cm^{-1}]
  - Surface charge distribution: $\sigma = \frac{\Delta q}{\Delta S}$ [$\sigma \Rightarrow$ surface charge density Unit Cm^{-2}]
  - Volume charge distribution: $\rho = \frac{\Delta q}{\Delta V}$ [$\rho \Rightarrow$ Volume charge density Unit Cm^{-3}]
- Applications of Gauss' theorem for uniform charge distribution:

Expression for	Infinite Linear	Infinite plane sheet	Thin spherical shell
Flux Ø	$\frac{\lambda l}{\varepsilon_0}$	$\frac{\sigma s}{\varepsilon_0}$	$\frac{\sigma 4\pi r^2}{\varepsilon_0}$
Magnitude of Field E	$\frac{\lambda}{2\pi r\varepsilon_0}$	$\frac{\sigma}{\varepsilon_0}$	$\frac{Q}{4\pi r^2\varepsilon_0}$ [for points on/outside the shell] =0 [for points inside the shell]
Charge density	$\lambda = \frac{\Delta q}{\Delta l}$	$\sigma = \frac{\Delta q}{\Delta S}$	$\frac{\sigma}{4\pi r^2}$

- Properties of electric field lines:
  - ✓ Arbitrarily starts from +ve charge and end at –ve charge
  - ✓ Continuous, but never form closed loops
  - ✓ Never intersect
  - ✓ Relative closeness of the field lines represents the magnitude of the field strength.
  - ✓ For a set of two like charges – lateral pressure in between
  - ✓ For a set of two unlike charges – longitudinal contraction in between.
- Electrostatic Potential: Work done per unit positive Test charge to move it from infinity to that point in an electric field. It is a scalar. SI unit: J/C or V

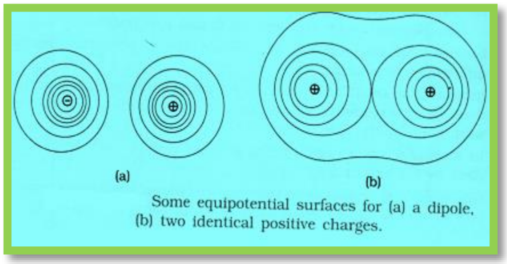
  $V = W / q_o$

  Electric potential for a point charge: $V = \frac{kq}{r}$



- Electric field is conservative. This means that the work done is independent of the path followed and the total work done in a closed path is zero.
- Potential due to a system of charges: $V_{total} = \sum_{i=1}^{n} \frac{kq_i}{r_i}$
- Potential due to a dipole at a point
    - ✓ **On its axial line:** $V_{axial} = \frac{k\,|\vec{p}|}{r^2}$ [or] $\frac{k|\vec{p}|}{r^2} cos\theta$
    - ✓ **On its equatorial line:** $V_{eq} = 0$

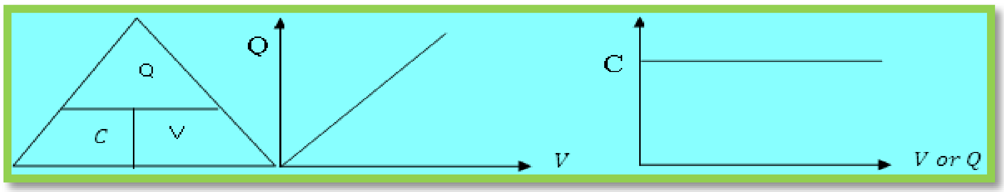
- Potential difference $V_A - V_B = kq\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$
- Potential energy of two charges: $U = \frac{kq_1q_2}{r}$
- Potential energy of a dipole : $U = \vec{p}.\vec{E}$ = p E $[cos\theta_0 - cos\theta_1]$
- Electrostatics of conductors
    - **(i)** Inside a conductor Electrostatic field is zero
    - **(ii)** On the surface E is always Normal
    - **(iii)** No charge inside the conductor but gets distributed on the surface
    - **(iv)** Charge distribution on the surface is uniform if the surface is smooth
    - **(v)** Charge distribution is inversely proportional to '*r*' if the surface is uneven
    - **(vi)** Potential is constant inside and on the surface
- Equipotential surfaces: The surfaces on which the potential is same everywhere.
    - ✓ Work done in moving a charge over an equipotential surface is zero.
    - ✓ No two equipotential surfaces intersect.
    - ✓ Electric field lines are always perpendicular to the equipotential surfaces.



Some equipotential surfaces for (a) a dipole, (b) two identical positive charges.

As $E = -\frac{dV}{dr}$ If Vis constant, $E \propto \frac{1}{r}$ **and if E is constant, V**$\propto r$

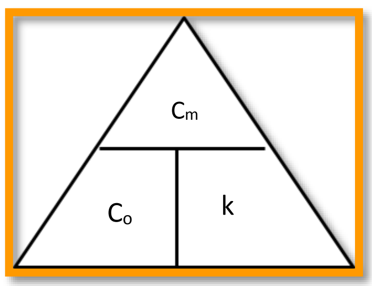
- Capacitor: A device to store charges and electrostatic potential energy.
- Capacitance: $C = \frac{Q}{V}$, Ratio of charge and potential difference. Scalar,
- SI unit: farad [F]



Capacitance of a parallel plate capacitor: $C = \frac{\varepsilon_0 \times A}{d}$

Capacitance of a parallel plate capacitor with a dielectric medium in between:

- $C_m = \frac{\epsilon_o A}{\left(d - t + \frac{t}{k}\right)}$
- If t=0 =>$C_0 = \frac{\epsilon_o A}{(d)}$
- If t=d =>$C_0 = k \frac{\epsilon_o A}{(d)}$ =>$C_m = k\, C_0$

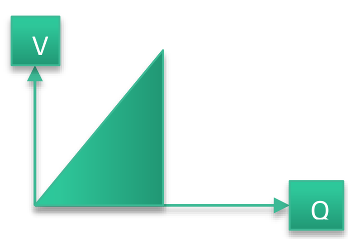


- Combination of capacitors:

  Capacitors in series: $\frac{1}{c} = \sum_{i=1}^{n} \frac{1}{c_i}$

  Capacitors in parallel: $c = \sum_{i=1}^{n} c_i$

- Energy stored in capacitors: $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$
- Area shaded in the graph = U $= \frac{1}{2}QV$



- Energy density : $U_d = \frac{1}{2}\varepsilon_0 E^2 = \frac{\sigma^2}{2\varepsilon_0}$
- Introducing dielectric slab between the plates of the charged capacitor with:

Property↓	Battery connected	Battery disconnected
Charge	K Q_0	Q_0
Potential difference	V_0	V_0/K
Electric field	E_0	E_0/K
Capacitance	KC_0	KC_0
Energy	K times $\frac{1}{2}\varepsilon_0 E^2$ [Energy is supplied By battery]	1/K times $\frac{1}{2}\varepsilon_0 E^2$ [Energy used for Polarization]

- On connecting two charged capacitors:
  - Common Potential: $V = \frac{C_1V_1 + C_2V_2}{V_1+V_2}$
  - Loss of energy: $\Delta U = \frac{1}{2}\frac{C_1 \times C_2}{C_1+C_2}(V_1 - V_2)^2$

- Van de Graff generator:-

a) is an electrostatic machine to build very high voltages.

b) works on the Principle $V(r) - V(R) = kq\left(\frac{1}{r} - \frac{1}{R}\right)$;

c) Corona discharge is the electrical discharge through the defected part of the spherical conductor, where the surface is not smooth. Hence, the hollow spherical conductor in the Van de Graff generator should have a smooth outer surface.