ELECTRIC FIELD AND POTENTIAL
Part - I

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Charges

- All matter is made up of atoms and molecules;
  - contain charged particles,
  - the proton and electron.
- The charges on each are equal;
  - but opposite in sign.

Charges

- The quantity of charge is measured coulombs (C).
- 1C = charge carried by 6.25 x 10^{18} e
- The charge on one electron = -1.6 x
- The charge on one proton = +1.6 x

Coulomb's Law

Coulomb's law:

$$F = k\frac{Q_1 Q_2}{r^2}, \qquad \text{[magnitudes]}$$

This equation gives the magnitude of the force.

The proportionality constant *k* can also be written in terms of ε_0, the permittivity of free space:

$$F = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{r^2},$$

$$\epsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}.$$

The Electric Field

For a point charge:

$$E = \frac{F}{q} = \frac{kqQ/r^2}{q}$$

$$E = k\frac{Q}{r^2}; \qquad \text{[single point charge]}$$

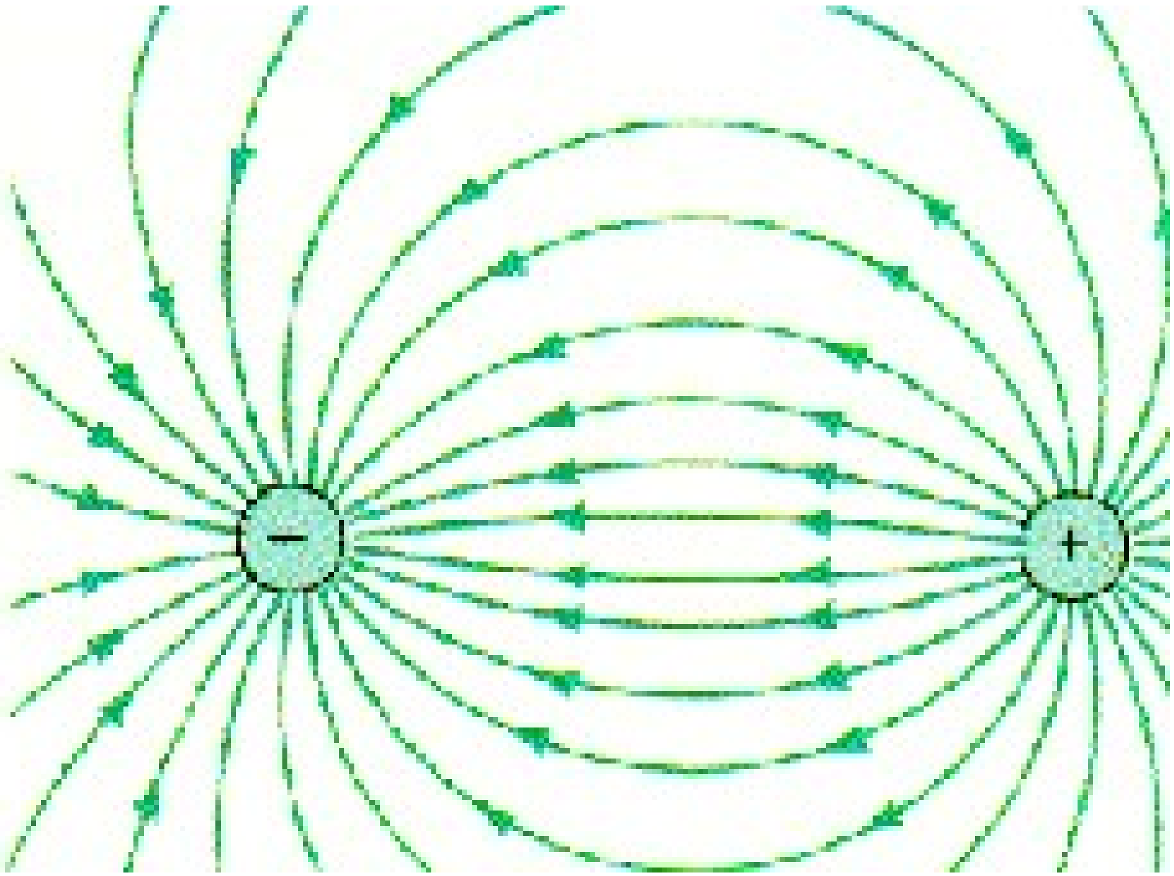
$$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}. \qquad \text{[single point charge]}$$

Electric Field Vector, E

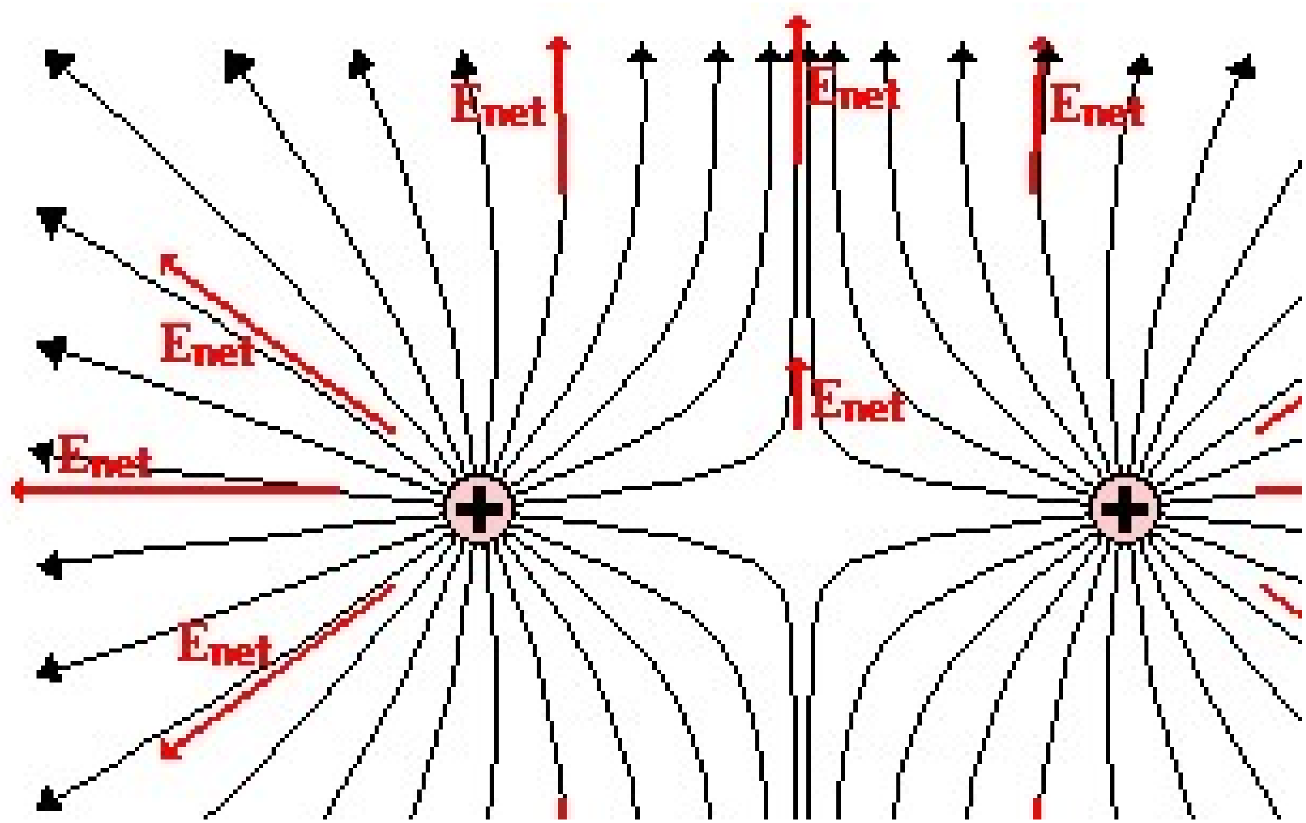
Electric Field is designed as follows –

- **$E = F/ q_o$** where q_o , positive test charge
- **E is a vector quantity**
  - **Direction indicated by small + test charge**
- **Unit: N/C**

Electric Field Lines



Electric Field Lines of two Positive Charges



FLUX OF AN ELECTRIC FIEL

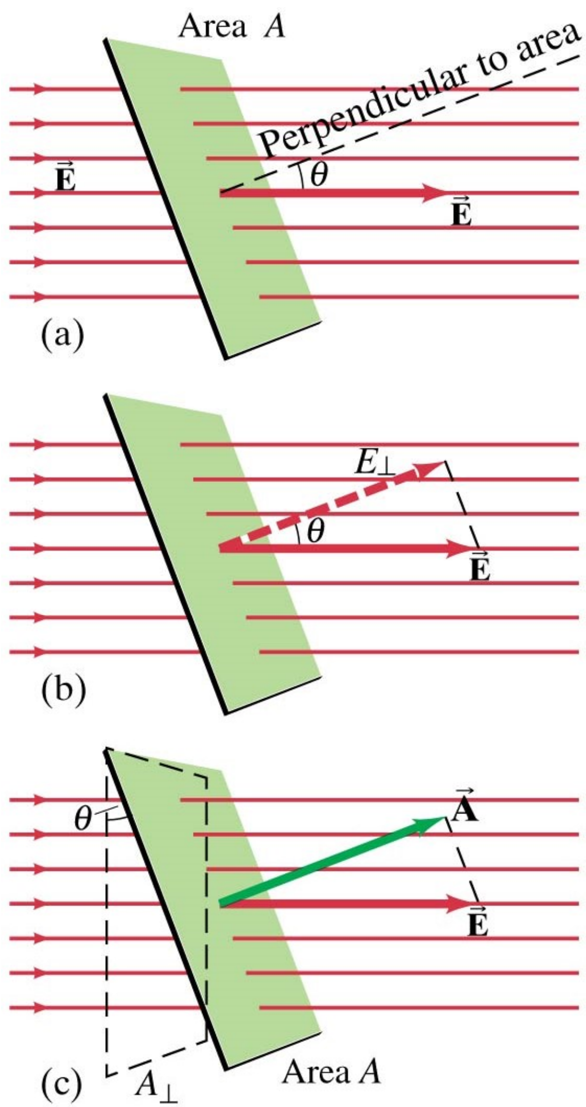
- Electric flux is the total number of lines of forc passing through a surface.

- In physical sense, electric flux is defined as:

  "The total number of lines of force passing tl the unit area of a surface held *perpendicularly*."

- Mathematically the electric flux is defined as:

  "The dot product of electric field intensity



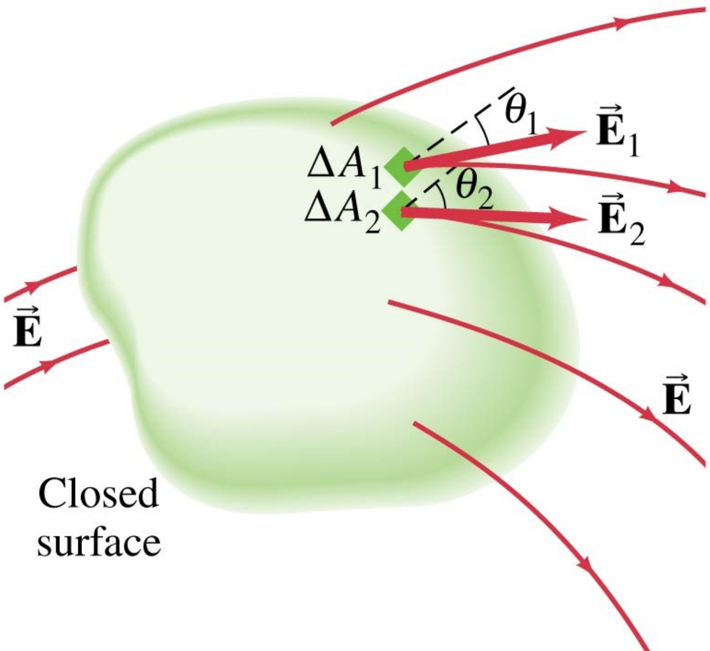
Electric flux:

$$\Phi_E = E_\perp A = E A_\perp = E A \cos\theta,$$

* Electric flux through an area is proportional to the total number of field lines crossing the area.

Gauss's Law

Flux through a closed surface:



$$\Phi_E = E_1 \Delta A_1 \cos\theta_1 + E_2 \Delta A_2 \cos\theta_2 + \cdots$$
$$= \sum E \Delta A \cos\theta = \sum E_\perp \Delta A,$$

The net number of field lines through the surface is proportional to the charge enclosed, and also to the flux, giving Gauss's law:

$$\sum_{\substack{\text{closed}\\ \text{surface}}} E_\perp \Delta A = \frac{Q_{\text{encl}}}{\epsilon_0},$$

Statement Of Gauss's Law

The total electric flux through a closed su
is proportional to the enclosed charg

$$\oint \underline{E} \bullet \underline{dA} = \frac{\sum_{inside} q}{\varepsilon_0}$$

Where:

E	=	Electric Field
dA	=	Area Vector
Σq	=	Sum of all charges

[illegible]…

Gauss' Law Summary

The electric field coming through a certain area is proportional to the charge enclosed.

$$\Phi_E = \int E dA = \frac{Q}{\varepsilon_o}$$

Φ_E = Electric Flux (Field through an Are

E = Electric Field

A = Area

q = charge in object (inside Gaussian sur

Electrostatic Potential

- The work done is given by:

  $\Delta W = Fx\ \Delta x$

- The force *F* and the electric field *E* a
  oppositely directed, and we know th

  $F = -q \times E$

- Therefore $\mathbf{E = -\Delta V / \Delta x}$
- This is the ***potential gradient.***

Potential Due to a Point Charge

- Start with (set V_f=0 at ∞ and V_i=V at R)

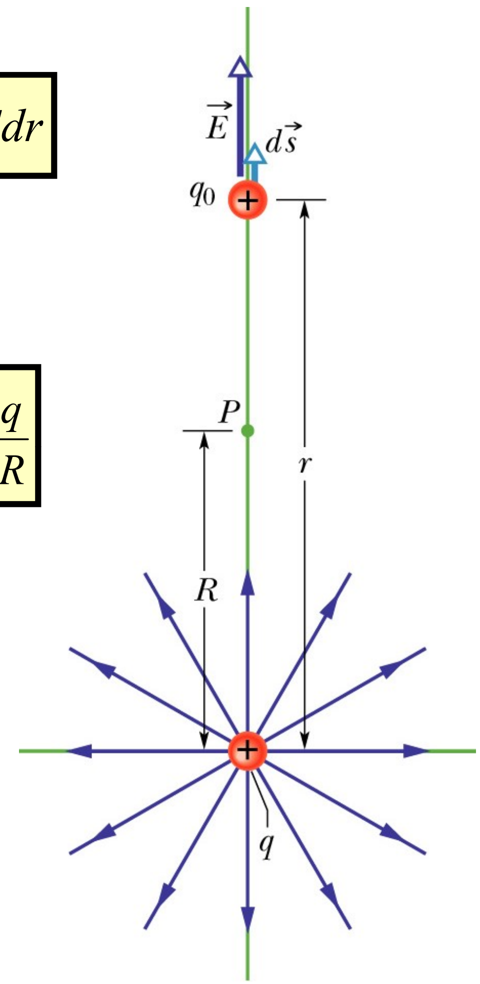
$$\Delta V = V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s} = -\int_i^f (E\cos 0^\circ)ds = -\int_R^\infty E dr$$

- We have $$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

- Then $$0 - V = -\frac{q}{4\pi\varepsilon_0}\int_R^\infty \frac{1}{r^2}dr = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\right]_R^\infty = -\frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

- So $$V(r) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

- A positively charged particle produces a positive electric potential.
- A negatively charged particle produces a negative electric potential



Potential due to a group of point charges

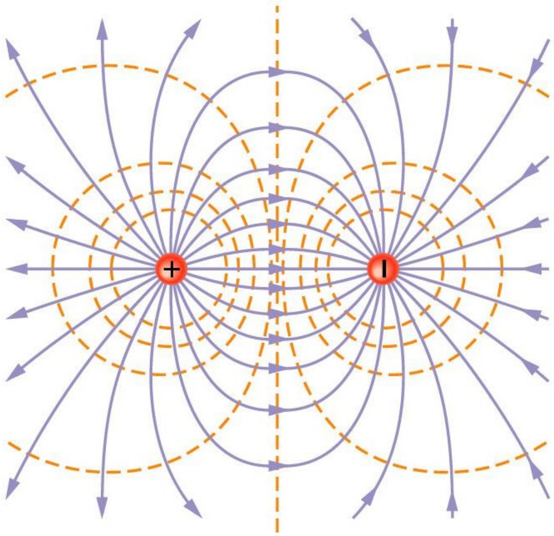
- Use superposition

$$V = -\int_{\infty}^{r} \vec{E} \cdot d\vec{s} = -\sum_{i=1}^{n} \int_{\infty}^{r} \vec{E}_i \cdot d\vec{s} = \sum_{i=1}^{n} V_i$$

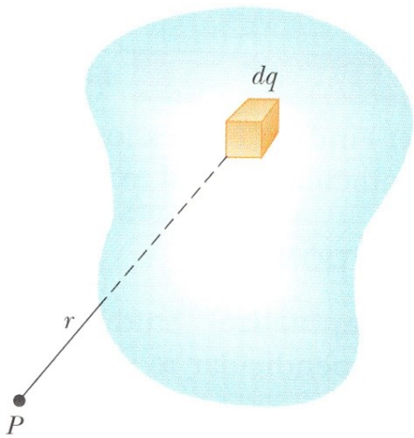
- For point charges

$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i}$$

- The sum is an algebraic sum, not a vector sum.



Potential due to a Continuous Charge Distribution



- Find an expression for dq:
  - dq = λdl for a line distribution
  - dq = σdA for a surface distribution
  - dq = ρdV for a volume distribution

- Represent field contributions at P due to point charges dq located in the distribution.

$$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r}$$

- Integrate the contributions over the whole distribution, varying the displacement as needed,

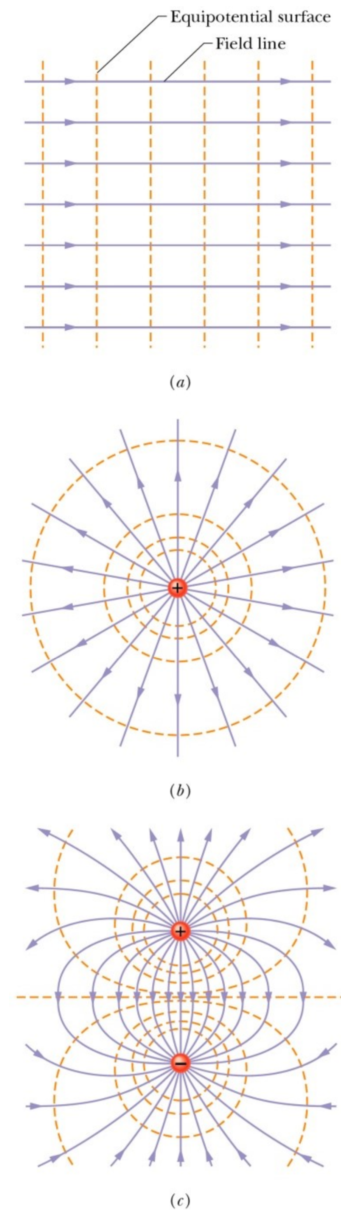
$$V = \int dV = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}$$

Equipotential Surface

- The name equipotential surface is given to any surface consisting of a continuous distribution of points having the same electric potential.

- Equipotential surfaces are always perpendicular to electric field lines.

- No work is done by the electric field on a charged particle while moving the particle along an equipotential surface.



Thanks