**REVIEW OF ELECTROMAGNETICS**

**Coulomb's Law:**

\[ F = \frac{q_1 q_2}{4\pi \varepsilon_0 y^2} \]

- \( q_1, q_2 \) \( \rightarrow \) Charges (in Coulombs)
- \( \varepsilon \) \( \rightarrow \) Permittivity of the medium
- \( y \) \( \rightarrow \) Distance between charges

**Direction of** \( F \) **\( \rightarrow \)** Along the line joining \( q_1 \) & \( q_2 \).

**The Force of attraction or repulsion between charges is a vector** \( \vec{F} \).

\[ \vec{F} = F \hat{y} \]

\( \hat{y} \) \( \rightarrow \) Unit vector in the direction \( \vec{F} \).

**Electric Field Intensity** \( E \):

**Let** \( q_1 = q \), \( q_2 = +1 \) C

\[ E = F = \frac{q_1 q_2}{4\pi \varepsilon_0 y^2} = \frac{q(1)}{4\pi \varepsilon_0 y^2} \]

**The force on the unit charge is called Electric Field Intensity** \( E \).

\[ E = \frac{q}{4\pi \varepsilon_0 y} \]

**Electric Field Intensity is a vector**.

\[ \vec{E} = E \hat{y} = \frac{q}{4\pi \varepsilon_0 y} \hat{y} \]

**The advantage of using** \( E \) **is that it can be used to find a force on a charge in a region** \( E \) **is known, regardless of the charge causing that** \( E \) **is unknown. For example,**
There is a charge $q$, leading to $E$ around it,

$$ E = \frac{q_1}{4\pi \varepsilon_0} $$

If we place a charge $q$ near $q_1$, the force of attraction or repulsion between $q_1$ and $q$ is

$$ F = \frac{q_1 q}{4\pi \varepsilon_0 r^2} = qE $$

or

$$ F = qE \quad \rightarrow \quad (3) $$

or

$$ E = \frac{F}{q} \quad \rightarrow \quad (4) $$

**Electric field intensity = force per unit charge**

Eq. (3) may be used to find the force on $q$ in a region for which $E$ is known, even if the charge or charge distribution causing this $E$ is unknown.

**Electric flux density, $D$:**

For historic reasons, electric flux density is defined as

$$ D = \varepsilon E \quad \rightarrow \quad (5) $$

For a point charge, we have

$$ E = \frac{q}{4\pi \varepsilon_0 r^2}, \quad \text{so} \quad D = \frac{q}{4\pi \varepsilon_0 r^2} = \frac{q}{4\pi \varepsilon_0}.$$
\[ \mathbf{D} = \mathbf{D} \]

\[ \mathbf{E} \cdot \mathbf{y} = \mathbf{E} \rightarrow \mathbf{G} \]

**Electric Flux, \( \psi = \text{Flux Density} \times \text{Area} \)**

**Flux Flow**

\[ \psi = \mathbf{D} \cdot \mathbf{A}, \quad \mathbf{A} = \text{Area Normal To Flux} \]

**Gauss’s Law (Integral Form):**

Consider a charge distribution with total charge \( q \) shown below.

Imagine a spherical surface \( S \) at a distance \( r \) from the center of charge distribution.

According to Gauss’s Law:

\[ \int_{S} \mathbf{D} \cdot d\mathbf{s} = q \rightarrow \mathbf{G} \]

\[ \psi = \mathbf{D} \cdot ds = \text{Flux crossing the elemental surface } ds \]

If we sum up all the elemental fluxes (\( d\psi \)) crossing the surface \( S \), according to Gauss’s Law, it is equal to charge \( q \).
SO, GAUSS'S LAW MAY BE STATED AS FOLLOWS:

TOTAL FLUX CROSSING ANY CLOSED SURFACE IS EQUAL TO THE CHARGE ENCLOSLED.

GAUSS'S LAW (DIFFERENTIAL FORM):

EQ. (7) MAY BE REWRITTEN AS

\[ \text{DIV} \mathbf{D} = \nabla \cdot \mathbf{D} = \rho \]

\[ \rho = \text{CHARGE DENSITY} = \text{d}q/\text{d}V \]

INTERPRETATION:

IMAGINE A GUNMAN SHOOTING RANDOMLY IN ALL DIRECTIONS.

LED \( \mathbf{D} \) DENOTE THE BULLET FLUX DENSITY.

INSIDE THE SURFACE \( S_1 \):

- NO. OF BULLETS ENTERING = NO. OF BULLETS LEAVING THE SURFACE \( S_1 \),

\[ \therefore \text{NET FLUX CROSSING THE SURFACE} \ S_1 = 0 \]

\[ \text{DIV} \mathbf{D} = 0 \text{ FOR THE POINTS INSIDE } S_1 \]

INSIDE THE SURFACE \( S_2 \):

- NO. OF BULLETS ENTERING THE SURFACE = 0

- NO. OF BULLETS LEAVING THE SURFACE ≠ 0

\[ \therefore \text{NET FLUX CROSSING THE SURFACE} \neq 0 \]

\[ \text{DIV} \mathbf{D} \neq 0 \]

GUNMAN IS THE SOURCE OF BULLET FLUX.
Inside the surface $S_3$: Suppose the gunman shot a person & the bullet is stuck inside the surface $S_3$.

No. of bullets entering the surface $\neq$ No. of bullets leaving the surface

\[ \text{Net flux crossing the surface } S_3 \neq 0 \]

\[ \text{Div } \neq 0 \neq 0 \]

Dead man is the sink of bullet flux.
When there are two charges closely, there is electric flux density, \( \mathbf{D} \).

**Inside the surface** \( S_1 \): \( \text{flux lines entering the surface } S_1 \) = \( \text{flux lines leaving the surface } \)

\[
\text{Div } \mathbf{D} = 0
\]

**Inside the surface** \( S_2 \): net flux crossing the surface \( \neq 0 \)

\[
\text{Div } \mathbf{D} \neq 0
\]

'\( +q \)' is the source of electric flux.

**Inside the surface** \( S_3 \): net flux crossing the surface \( \neq 0 \)

\[
\text{Div } \mathbf{D} \neq 0
\]

'\( -q \)' is the sink of electric flux.

**Magnetic field:**