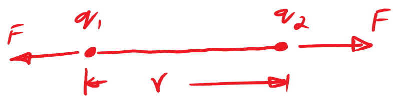
REVIEW OF ELECTROMAGNETICS

COULOMB'S LAW :



$$\boxed{F = \frac{q_1 q_2}{4\pi \epsilon r^2}} \longrightarrow (1)$$

$q_1, q_2 \Rightarrow$ CHARGES (IN COULOMBS)

$\epsilon \Rightarrow$ PERMITTIVITY OF THE MEDIUM

$r \Rightarrow$ 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 $\vec{F}$.

$\vec{F} = F\,\vec{r}$, $\quad F$ = MAGNITUDE OF FORCE

$\vec{r}$ = UNIT VECTOR IN THE DIRECTION OF r.

ELECTRIC FIELD INTENSITY, E :

LET $q_1 = q$, $q_2 = +1\,C$ (COULOMB)

$$E = F = \frac{q_1 q_2}{4\pi \epsilon r^2} = \frac{q.(+1)}{4\pi \epsilon r^2}$$

THE FORCE ON THE UNIT +VE CHARGE IS CALLED ELECTRIC FIELD INTENSITY, E.

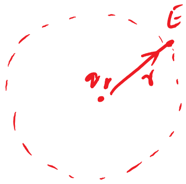
$$\boxed{E = \frac{q}{4\pi \epsilon r^2}} \longrightarrow (2)$$

ELECTRIC FIELD INTENSITY IS A VECTOR.

$$\vec{E} = E\,\vec{r} = \frac{q}{4\pi \epsilon r^2}\vec{r}$$

THE ADVANTAGE OF USING E IS THAT IT CAN BE USED TO FIND A FORCE ON A CHARGE IN A REGION AT WHICH E IS KNOWN, BUT THE CHARGE CAUSING THAT E IS UNKNOWN. FOR EXAMPLE,

THERE IS A CHARGE q_1 LEADING TO E AROUND IT,



$$E = \frac{q_1}{4\pi\epsilon r^2}$$

IF WE BRING A CHARGE q NEAR q_1, THE FORCE OF ATTRACTION OR REPULSION BETWEEN q_1 & q IS

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

E

$$\boxed{F = qE} \longrightarrow (3)$$

or

$$\boxed{E = \frac{F}{q}} \longrightarrow (4)$$

$\therefore$ 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

$$D = \epsilon E \longrightarrow (5)$$

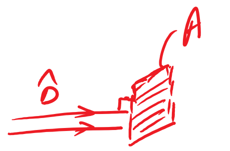
FOR A POINT CHARGE, WE HAVE

$$E = \frac{q}{4\pi\epsilon r^2}, \quad \text{SO} \quad D = \cancel{\epsilon} \cdot \frac{q}{4\pi\cancel{\epsilon} r^2} = \frac{q}{4\pi r^2}$$

$$\vec{D} = D\,\vec{r}$$

$$= \epsilon E\, r = \epsilon \vec{E} \longrightarrow (6)$$

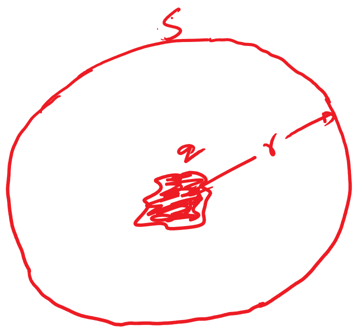
ELECTRIC FLUX, ψ = FLUX DENSITY × AREA ⊥ʳ TO FLUX FLOW



$$\psi = D \times A,$$ A = 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:

$$\oiint_S \vec{D} \cdot \vec{ds} = q \longrightarrow (7)$$

$d\psi = \vec{D} \cdot \vec{ds}$ = 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 ENCLOSED.

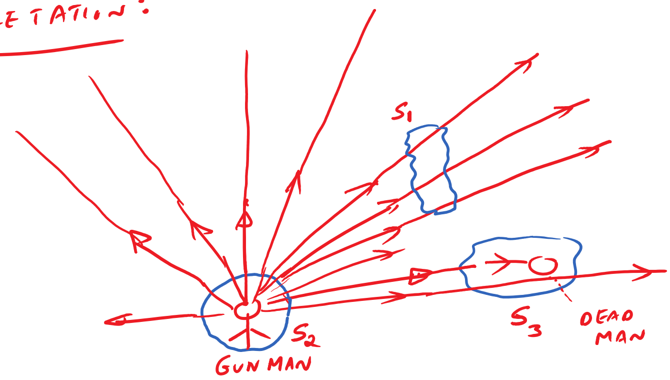
GAUSS'S LAW (DIFFERENTIAL FORM):

EQ. (7) MAY BE REWRITTEN AS

$$\text{DIV } \vec{D} = \nabla \cdot \vec{D} = \rho \longrightarrow (8)$$

ρ = CHARGE DENSITY = dq/dV

INTERPRETATION:



IMAGINE A GUNMAN SHOOTING RANDOMLY IN ALL DIRECTIONS.

LET D DENOTE THE BULLET FLUX DENSITY.

INSIDE THE SURFACE S_1: NO. OF BULLETS ENTERING THE SURFACE S_1 = NO. OF BULLETS LEAVING THE SURFACE S_1

$\therefore$ NET FLUX CROSSING THE SURFACE $S_1 = 0$

$\text{DIV } \vec{D} = 0$ FOR THE POINTS INSIDE S_1

INSIDE THE SURFACE S_2: NO. OF BULLETS ENTERING THE SURFACE = 0

NO. OF BULLETS LEAVING THE SURFACE $\neq 0$

$\therefore$ NET FLUX CROSSING THE SURFACE $\neq 0$

$\text{DIV } \vec{D} \neq 0$

GUN MAN IS THE SOURCE OF BULLET FLUX

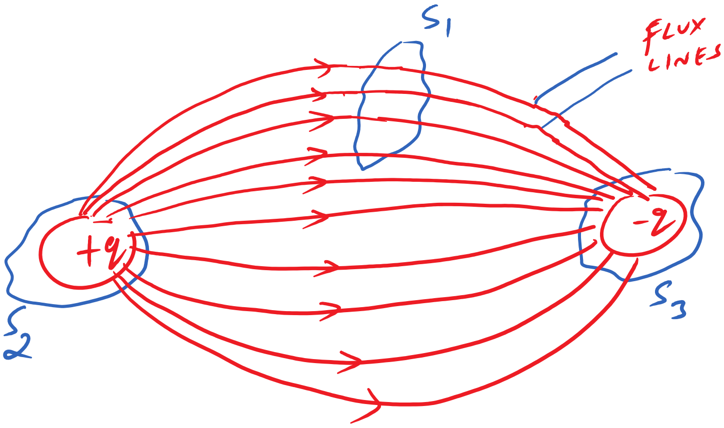
INSIDE THE SURFACE S_3: SUPPOSE THE GUNMAN SHOT A PERSON & THE BULLET IS STUCK INSIDE THE SURFACE S_3.

NO. OF BULLETS ENTERING THE SURFACE $\neq$ NO. OF BULLETS LEAVING THE SURFACE

$\therefore$ NET FLUX CROSSING THE SURFACE S_3 $\neq 0$

$$\operatorname{DIV} \vec{D} \neq 0$$

DEAD MAN IS THE SINK OF BULLET FLUX.



WHEN THERE ARE TWO CHARGES CLOSEBY, THERE IS ELECTRIC FLUXDENSITY, D.

INSIDE THE SURFACE S_1 : NUMBER OF FLUX LINES ENTERING THE SURFACE S_1 = NUMBER OF FLUXLINES LEAVING THE SURFACE

$$\mathrm{DIV}\ \vec{D} = 0$$

INSIDE THE SURFACE S_2 : NET FLUX CROSSING THE SURFACE $\neq 0$

$$\mathrm{DIV}\ \vec{D} \neq 0$$

'+q' IS THE SOURCE OF ELECTRIC FLUX.

INSIDE THE SURFACE S_3 : NET FLUX CROSSING THE SURFACE $\neq 0$

$$\mathrm{DIV}\ \vec{D} \neq 0$$

'-q' IS THE SINK OF ELECTRIC FLUX.

MAGNETIC FIELD :