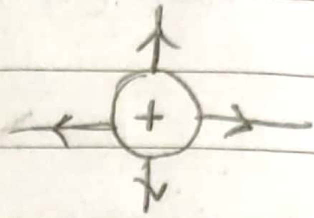
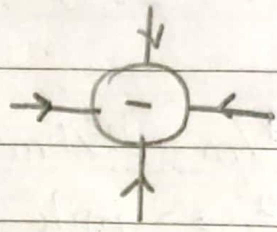
ELECTRIC FEILD

Around a positive charge



Around a negative charge

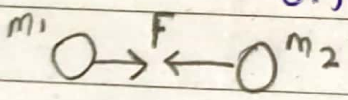


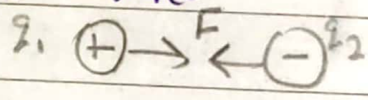
Fields and forces

Charge creates an electric field that creates forces on other charges

Mass creates a gravitational field that exerts forces on other masses.

G. force << E. force

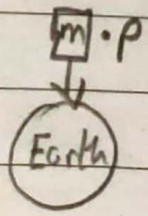




$= 6.7 \times 10^{-11}$ N $\quad\quad = 1.8 \times 10^{25}$ N

→ Concept of a field

A field is defined as a property of space in which a material /object experiences a force



At point (P) we say g. field exists because mass (m) experiences a force.

* The direction of field is determined by force

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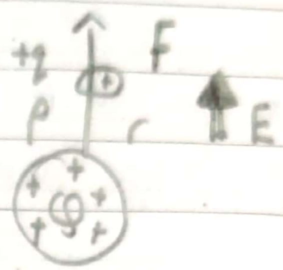
→ Gravitational field

$\boxed{g = F/m}$ ~~magnitude and direction of g is dependant on~~

→ Electric field

① r is dist of P from Q'

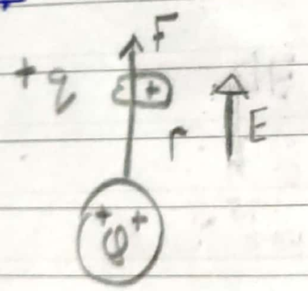
② E. field E exists at P if a test charge ^+q has force F at this point.



③ E has same direction as F on ^+q

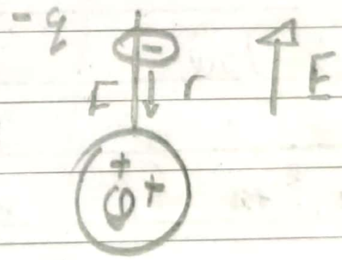
④ magnitude of E ⇒ $\boxed{E = F/q}$ Units = N/C.

$\underline{+q}$



force is in direction of E

$\underline{-q}$



F is opposite to direction of E.

· Same for around a negative charge, only direction of E. feild E is reversed.

→ Magnitude of electric field.

Magnitude of electric field intensity at a point in space is defined as force per unit charge (N/C) that any test charge would experience at that point.

$$\boxed{E = F/q}$$

* The direction of E at a point is same as the direction a +ve charge would move if placed at that point.

→ F and E relationship.

$F_e = qE$

- For point charges, if q is +ve field and force same direction
  " -ve " opp. "

→ Vector form.

Using Coloumb's Law,

$$\cancel{F_e = k_e \frac{q q_0}{r^2} \hat{r}}$$

$$\boxed{F_e = k_e \frac{q_1 q_2}{r^2} \hat{r}}$$

F_e = Force

k_e = Coloumb's const.

r = dist b/w q_1 q_2

$k = 1/4\pi\epsilon_0$

→ $k = \cancel{8.8}\ 8.99 \times 10^9\ Nm^2/C^2$

ϵ_0 (permitivity const)

→ $\epsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$

Using $E = F/q_2$

$$\boxed{E = k_e\, q/r^2\, \hat{r}}$$

→ Superposition.

At any point P, the total electric field due to a group of source charges equal the vector sum of the electric fields of all the charges.

$$\boxed{E = k_e \sum_i q_i/r_i^2 \ \hat{r}_i}$$

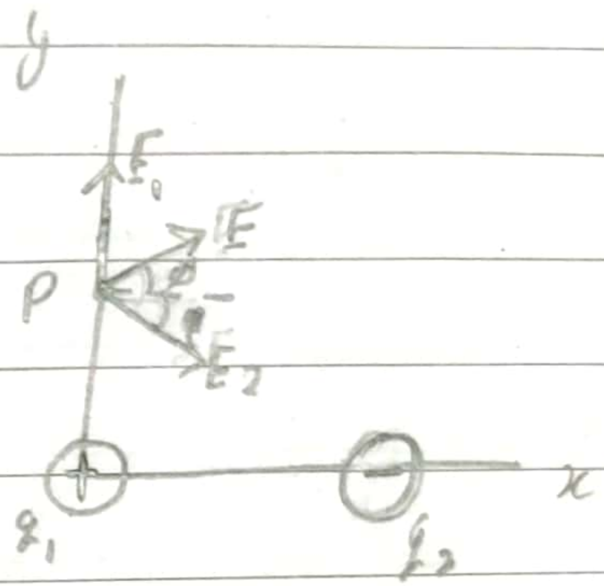
→ Due to two charges.

find E_1 and E_2

find compts

sum of compts

$E = E_1 + E_2$



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GAUSS' LAW

Gauss' Law relates the electric field at points on a closed Gaussian surface to the net charge ~~on~~ enclosed by that surface.

Electric Flux.

The amount of field, material or other physical quantity passing through a surface.

$$\boxed{\Phi = \int \vec{E} \cdot d\vec{A}} \quad \text{(total flux.)}$$

This is for Flat surface, uniform field.

$$\boxed{\Phi = (E\cos\theta)A}$$

An inward ~~stream~~ piercing field is negative flux

An outward piercing field is positive flux

A skimming field is zero flux.

→ Net flux

$$\boxed{\Phi = \oint \vec{E} \cdot d\vec{A}}$$

* if $\theta < 90°$, +ve flux

* if $\theta > 90°$, -ve flux.

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Guass' Law

$$\boxed{\varepsilon_0 \Phi = q_{enc}}$$

or

$$\boxed{\varepsilon_0 \oint \vec{E} \cdot \vec{dA} = q_{enc}}$$

ε_0 = permitivity const.
q_{enc} = Net charge enclose by that surface.

→ and C's Law.

$$\varepsilon_0 \oint \vec{E} \cdot \vec{dA} = q_{enc}$$

here $q_{enc} = q$ as E is same at every patch element.

$$\therefore \ \varepsilon_0 E \oint dA = q$$

Substituting $4\pi r^2$ for ~~dA~~ total Area.

$$\varepsilon_0 E (4\pi r^2) = q$$

which can be written as

$$E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \quad \text{(C's Law)}.$$

→ E. field due to point charge.

$$\phi_e = q/\varepsilon_0$$

$$E(4\pi r^2) = q/\varepsilon_0$$

$$\therefore E = q/4\pi\varepsilon_0 r^2 = k\, q/r^2$$

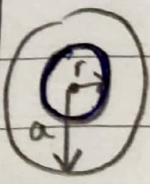
Charge Distribution

→ Spherically symmetric

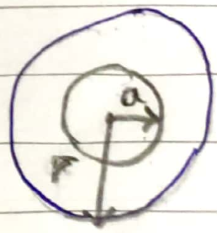
$EA = q_{in}/\varepsilon_0$ → $A = 4\pi r^2$ → $q_{in} = \rho V' = \rho(4/3\, \pi r^3)$

$$\text{so, } E = q_{in}/4\pi\varepsilon_0 r^2 = \rho\, \tfrac{4}{3}\pi r^3 / 4\pi\varepsilon_0 r^2 = \boxed{\frac{\rho}{3\varepsilon_0}(r)}$$

$$\boxed{E = \frac{k_e Q}{a^3}(r) \quad r < a}$$



$$\boxed{E = \frac{k_e Q}{r^2} \quad r > a}$$



* r is for gaussian sphere (in blue)

→ Cylindrically symmetric charge distribution.

$\phi_E = EA = q_{in}/\varepsilon_0$

q_{in} is replaced by linear density $= \lambda l$

$\therefore E(2\pi r l) = \lambda l/\varepsilon_0$

$E = \lambda/2\pi\varepsilon_0 r = \boxed{2k_e \lambda/r}$

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CAPACITANCE

Capacitors:

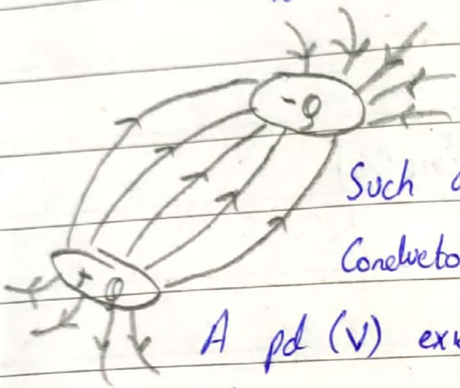
Devices that store electric charge.

Used to: 1) tune the frequency of radio recievers.

2) as filters in power supplies.

3) eliminate sparking in automobile ignition systems.

4) energy-storing devices in electronic flash units:



equal magnitude . opposite sign.

Such a combination is called capicitor.

Conductors $(-Q, +Q)$ are plates.

A pd (V) exists b/w them due to presence of charges.

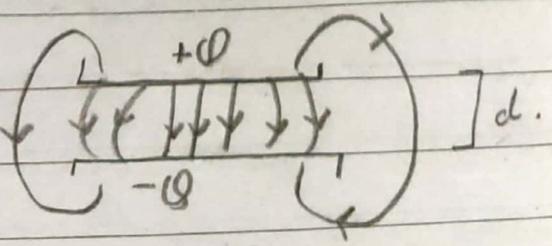
$\boxed{C = Q/\Delta V}$ Q = mag. of charge on either conductor.

ΔV = diff of pd b/w them.

Unit = farad (F)

Calculating capacitance:

→ Parallel plates:



$E = \sigma/\varepsilon_0 = Q/\varepsilon_0 A$

$\Delta V = Ed = Qd/\varepsilon_0 A$

$C = Q/\Delta V = \dfrac{Q}{Qd/\varepsilon_0 A}$

$\therefore \boxed{C = \dfrac{\varepsilon_0 A}{d}}$ A = Area of plate

d = dist b/w them.

$C \propto A$, $C \propto 1/d$

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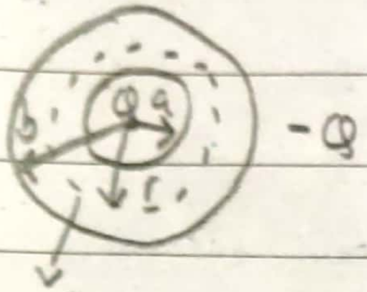
→ Cylindrical Capacitor:

A solid cylindrical conductor of radius (a) and charge (Q) is coaxial with a cyl. shell of negligible thickness. Radius b > a. Charge (−Q)



Guassian surface.

$$\boxed{\frac{C}{\ell} = \frac{1}{2k_e \ln(b/a)}}$$

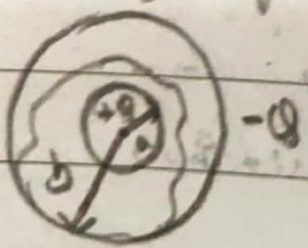
Capacitance per unit length.

OR.

$$C = 2\pi\varepsilon_0 \frac{L}{\ln(b/a)}$$

→ Spherical.

Consists of a spherical conducting shell of radius b, and charge Q⁻ concentric with a smaller conducting sphere of radius a, charge Q.



$$\boxed{C = 4\pi\varepsilon_0 \frac{ab}{b-a}}$$

OR.

$$\boxed{C = ab/k_e(b-a)}$$

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Combination of Capacitors :

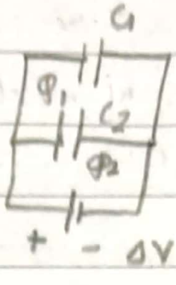
→ Parallel.

Total charge => $Q = Q_1 + Q_2$

$Q_1 = C_1 \Delta V \quad Q_2 = C_2 \Delta V$

$C_T = C_1 + C_2 + C_3 \cdots$

(parallel).



$\Delta V_1 = \Delta V_2 = \Delta V$

$C_T =$ total.

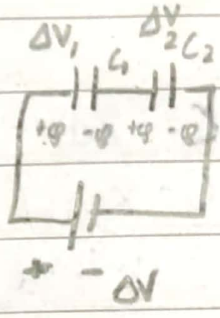
→ Series.

$\Delta V_1 = Q/C_1 \quad \Delta V_2 = Q/C_2$

$\Delta V = Q/C_T$

$1/C_T = 1/C_1 + 1/C_2 \cdots$

(series).



$\Delta V = \Delta V_1 + \Delta V_2$

The equivalent capacitance < individual capacitance.

ENERGY stored in a charged capacitor.

Suppose, q is charge on capacitor at any instant during charging process. At this instant $\Delta V = q/C$

$$\boxed{U = Q^2/2C = \frac{1}{2} Q \Delta V = \frac{1}{2} C (\Delta V)^2}$$

parallel-plate: $\boxed{U = \frac{1}{2} (\varepsilon_0 A d) E^2}$

energy-density (U_E) $\boxed{u_E = \frac{1}{2} \varepsilon_0 E^2}$

$u_E \propto E^2$

$u_E \propto$ square of mag. of elec. feild (E^2).

Date:

Di Electrics

A di-electric is a non-conducting material.

When a di-electric is inserted b/w plates of a capacitor $C \uparrow$.

If di-electric fills the space b/w ~~capacitor~~ plates (d) completely, $C \uparrow$ by a dimensionless factor K, called dielectric const.

$$\Delta V = \Delta V_0 / K \qquad C = Q_0/\Delta V = K\, Q_0/\Delta V_0$$

$$\boxed{C = K C_0}$$

$$\boxed{C = K\, \varepsilon_0 A/d}$$

→ ~~Advnts~~ Advantages: ① Capacitance increases ($\uparrow$)

② $\uparrow$ in max. operating Voltage

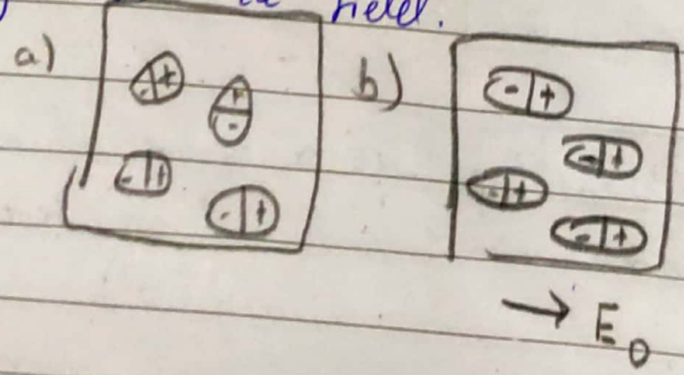
③ $\downarrow d$ and $\uparrow C$.

→ Atomic description:

$$E = E_0/K$$

a) Polar molecules are randomly oriented in the absence of an external elec. field.

b) When external elec. field is applied, molecules partially allign with the field.



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CURRENT AND RESISTANCE

Electric Current

A current is said to exist, whenever there is a net flow of charge through some region.

$\boxed{I_{avg} = \Delta Q/\Delta t}$ → The avg current is equal to the charge that passes through A. per unit time.

$\boxed{I = dQ/dt}$ → The Inst. current I is differential of avg. current.

Unit : 1 Ampere = ~~Cs~~ (Cs^{-1}) Coulomb per second.

→ Direction :

* A current arrow is drawn in the direction in which +ve charge carriers would move, even if the charge carriers are -ve and move in opposite direction. (electrons.)

→ Density:

* Current (I a scalar quantity) is related to ~~J~~ Current density (J a vector) by $i = \int \vec{J} \cdot d\vec{A}$

$\boxed{* \; J = I/A = nqv_d}$

$\boxed{J = (nq)\vec{v_d}}$ ~~n=number e=Reps charge~~ e. ~~v_d = Drift speed~~.

ne (C/m^3) is the carrier charge density.

For +ve, ne is +ve and predicts J and v_d direction is same.

For -ve, ne is -ve and " " direction is opp.

→ In a Conductor:

$\Delta q = (nA\Delta x)q$ ⇒ no. of charge carriers is a section $(nA\Delta x)$ × charge per carrier (q).

$\Delta x = v_d \Delta t$ ⇒ v_d is drift speed (Avg. of charge carriers speed)

$\therefore \Delta Q = (nAv_d\Delta t)q$

$$\boxed{I_{avg} = \Delta Q/\Delta t = nqv_dA}$$

Resistance $(R = V/I)$

→ Ohm's LAW:

$\Delta V = E\ell$ $\qquad J = \sigma E = \sigma \Delta V/\ell$

$\Delta V = \ell/\sigma J = (\ell/\sigma A)I$

The quantity $\cancel{(\ell/\sigma A)}$ $(\ell/\sigma A)$ is called the resistance of a conductor.

$$\boxed{R = \ell/\sigma A = \Delta V/I}$$ Units = Ohm Ω

Materials that obey Ohm's law demonstrate this relationship b/w J and E.

→ Resistivity:

$\rho = 1/\sigma = E/J$

so, for a uniform block

$$\boxed{R = \rho \ell/A = \ell/\sigma A = \Delta V/I}$$

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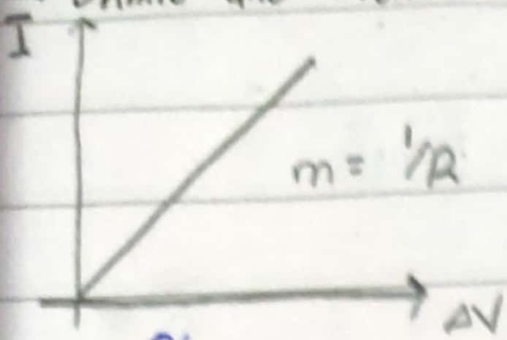
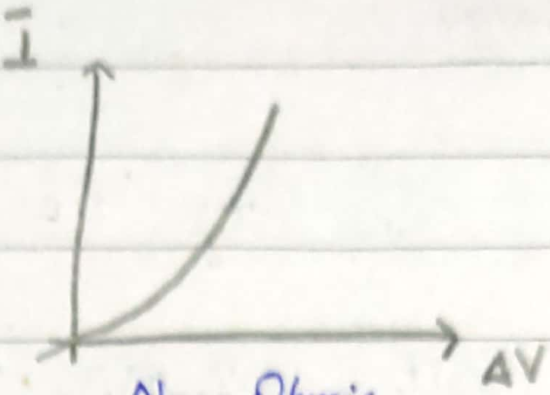
→ Ohmic and Non-Ohmic.



Ohmic



Non-Ohmic.

→ Resistance is a property of an object.

→ Resistivity is a property of a material.

→ Temperature.

$$\boxed{\rho = \rho_0 \left[1 + \alpha \left(T - T_0 \right) \right]}$$

α is the temperature coefficient of resistivity.

For Resistivity versus time, curve is linear ~~for~~ over a wide range. $\uparrow \rho$ as $\uparrow T$

As T approaches absolute zero, ρ approaches a finite value of $\underline{\underline{0}}$.

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Power and Energy

Rate of charge ΔQ losing P.E going through a resistor.

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t}\Delta V = I\Delta V$$

∴ as Power is energy over time

$$\boxed{P = I\Delta V = I^2 R = (\Delta V)^2/R}$$

Q1) $J = 440\ A/cm^3$ $I = 0.552$

Area $= \pi r^2$

$$\therefore J = I/A \Rightarrow 440 = \frac{0.552}{\pi r^2}$$

$$r = \sqrt{I/\pi J}$$ so, $r = 0.019\ cm$

$d = 2r = 0.039\ cm$