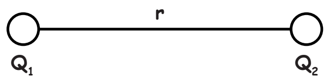
ELECTROSTATIC POTENTIAL ENERGY

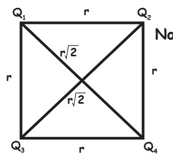
2 point charges



$\Delta U = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r}$ <
- like charges - positive (repulsive energy)
- Unlike charges - negative (attractive energy)

System of charges

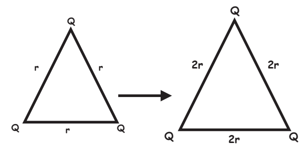
$\Delta U_{system} = \sum \Delta U_{pair}$ No. of pairs $= \frac{n(n-1)}{2}$



No. of pairs $= \frac{4 \times 3}{2} = 6$

Total P.E $= \frac{KQ_1Q_2}{r} + \frac{KQ_1Q_4}{r\sqrt{2}} + \frac{KQ_2Q_3}{r\sqrt{2}} + \frac{KQ_2Q_4}{r} + \frac{KQ_3Q_4}{r} + \frac{KQ_1Q_3}{r}$

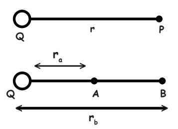
WORK DONE IN REARRANGEMENT OF THE SYSTEM



$W = U_f - U_i = \frac{3kQ^2}{2r} - \frac{3kQ^2}{r}$
$= -\frac{3kQ^2}{2r}$

$U_i = \frac{3kQ^2}{r}$ $U_f = \frac{3kQ^2}{2r}$

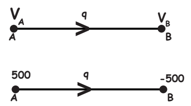
ELECTROSTATIC POTENTIAL



$V_p = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

$V_{AB} = V_B - V_A = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_b} - \frac{1}{r_a}\right]$

WORK DONE



$w = q[V_B - V_A]$

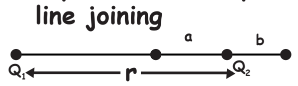
$w = 1 \times (-500-500) = -1000J$

Superposition of potential - Algebraic sum of all potentials

ZERO POTENTIAL

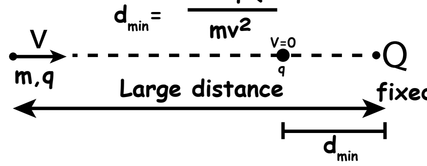
a) Like charge-no zero potential point

b) Unlike charge- 2 points of zero potential on line joining

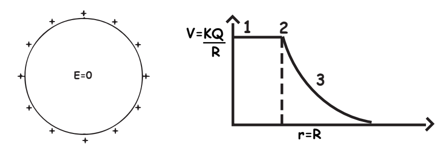


Inside point = $a = \frac{Q_2 r}{Q_1+Q_2}$ Outside point = $b = \frac{Q_1 r}{Q_1-Q_2}$

$d_{min} = \frac{2kqQ}{mv^2}$

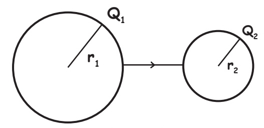


POTENTIAL OF CHARGED CONDUCTING SPHERE



case 1: V_{inside} = Const $= V_{surface} = \frac{KQ}{R}$ case 2: $V_{surface} = \frac{kQ}{R}$ case 3: $V_{outside} = \frac{kQ}{r}$

Redistribution of Charge when two Conducting sphere are connected



→ Charge flow from higher potential to lower potential
Final potentials of spheres are equal

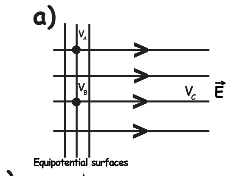
$\frac{1}{4\pi\varepsilon_0}\frac{Q_1'}{r_1} = \frac{1}{4\pi\varepsilon_0}\frac{Q_2'}{r_2}$

$Q_1' = \frac{(Q_1+Q_2)\,r_1}{r_1+r_2}$ $Q_2' = \frac{(Q_1+Q_2)\,r_2}{r_1+r_2}$

$\boxed{\frac{Q_1'}{Q_2'} = \frac{r_1}{r_2},\ \frac{E_1}{E_2} = \frac{r_2}{r_1},\ \frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1}}$

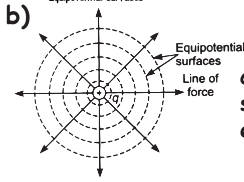
EQUIPOTENTIAL SURFACE

a)



$V_A = V_B > V_C$

b)



c) Field lines and equipotential surface are perpendicular to each other at every location.

d) work done in moving a charge on equipotential surface is 0

ELECTRIC FIELD & POTENTIAL

$E = \frac{-dV}{dr}$ $E_x = \frac{-\partial V}{\partial x}$ $E_y = \frac{-\partial V}{\partial y}$ $E_z = -\frac{\partial V}{\partial z}$

$\Delta V = -\int \vec{E}.\vec{dr}$

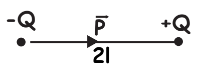
ELECTROSTATICS-02

PHYSICS WALLAH

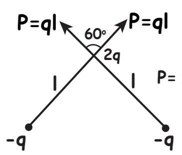
DIPOLE

Dipole moment

$\vec{P} = q\ 2\vec{l}$



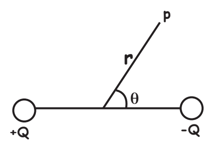
Direction is from -Q to +Q



$P = 2ql\cos30° = 2\sqrt{3}ql(\uparrow)$

Q. Fine net dipole moment

ELECTRIC FIELD

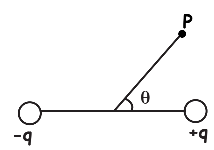


$E_p = \frac{Kp}{r^3}\sqrt{3\cos^2\theta+1}$

$E_{axial} = \frac{Kp}{r^3}\sqrt{3+1} = \frac{2Kp}{r^3}$ 0° with dipole moment, E_{net} from -Q to +Q

$E_{equitorial} = \frac{Kp}{r^3}\sqrt{0+1} = \frac{Kp}{r^3}$ 180° with dipole moment, E_{net} from +Q to -Q

ELECTRIC POTENTIAL

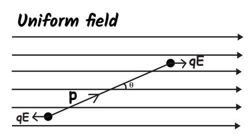


$V_p = \frac{kp\cos\theta}{r^2}$

$V_{axial} = \frac{Kp}{r^2}$ $V_{equitorial} = 0$

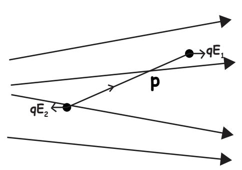
TORQUE

Uniform field



- Rotational motion only
- No translatory motion

$\vec{\tau} = \vec{P} \times \vec{E}$
$\tau = PE\sin\theta$



- Both rotatory and translatory motion

Non - Uniform field

$\tau_{max} = pE\sin\theta = pE,\ (\theta = 90°)$

$\tau_{min} = pE\sin\theta = 0, (\theta = 0°)$

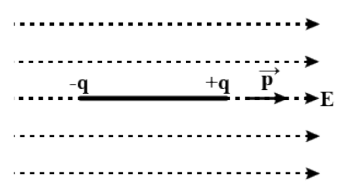
WORK DONE

$W = pE(\cos\theta_1 - \cos\theta_2)$

POTENTIAL ENERGY

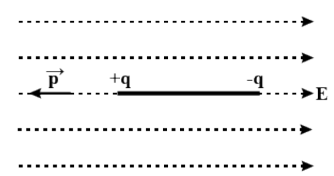
$U = -pE\cos\theta$

1) $U_{minimum}$ (stable equilibrium)



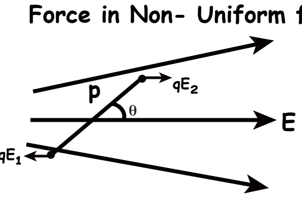
$\theta = 0°$
$\cos\theta = 1$
$U = -pE$

2) $U_{maximum}$ (Unstable equilibrium)



$\theta = 180$
$\cos\theta = -1$
$U = +pE$

Force in Non- Uniform field



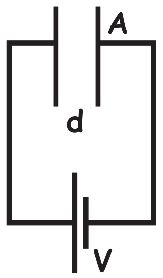
$F_x = p\frac{dE}{dx}\cos\theta$

where, dE= small change in field at the two locations of the charges

CAPACITANCE

PHYSICS WALLAH

CAPACITANCE



$Q=CV$

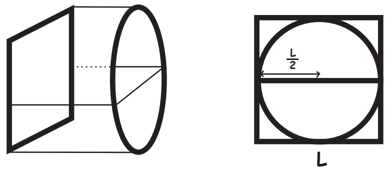
$C=\frac{Q}{V}$

$C=\frac{\varepsilon_0 A}{d}$

Capacitance Depends on
1. Distance between plates
2. Area of plates
3. Medium b/w plates

Capacitance is Independent of
1. Charge
2. Potential difference

Unit Of Capacitance = Farad



$A_{eff}=\pi\left(\frac{L}{2}\right)^2=\pi\frac{L^2}{4}$

$C=\frac{\varepsilon_0 A_{eff}}{d}=\frac{\pi\varepsilon_0 L^2}{4d}$

ENERGY STORED

Work done by battery $=QV$ (100%)

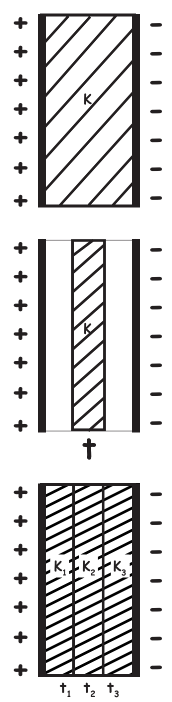
- 50% Energy stored in capacitor $=\frac{1}{2}QV=\frac{CV^2}{2}=\frac{Q^2}{2C}$
- 50% Energy dissipated $=\frac{1}{2}QV=\frac{CV^2}{2}=\frac{Q^2}{2C}$

Variation with plate seperation

1. $Q=CV=\frac{\varepsilon_0 AV}{d}$
2. $C=\frac{\varepsilon_0 A}{d}$ $\quad C\propto\frac{1}{d}$
3. $V=\frac{Q}{C}=\frac{Qd}{\varepsilon_0 A}$ $\quad$ 4. $E=\frac{Q}{A\varepsilon_0}=\frac{V}{d}$
5. $F=\frac{Q^2}{2A\varepsilon_0}=\frac{CV^2}{2d}$
6. $U=\frac{CV^2}{2}$ OR $U=\frac{Q^2}{2C}=\frac{Q^2 d}{2\varepsilon_0 A}$

$=\frac{\varepsilon_0 AV^2}{2d}$

DIELECTRIC IN CAPACITOR



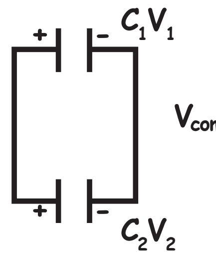
$C'=\frac{k\varepsilon_0 A}{d}$

$C'=KC$

$C'=\frac{\varepsilon_0 A}{d-t+\frac{t}{K}}$

$C'=\frac{\varepsilon_0 A}{\frac{t_1}{K_1}+\frac{t_2}{K_2}+\frac{t_3}{K_3}}$

Connecting two charged capacitors - Case 1



$V_{common}=\frac{C_1V_1+C_2V_2}{C_1+C_2}$

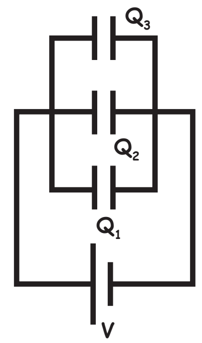
Initial Energy → Heat loss → Final Energy

$U_i=\frac{C_1V_1^2}{2}+\frac{C_2V_2^2}{2}$

$U_f=\frac{1}{2}(C_1+C_2)\left(\frac{C_1V_1+C_2V_2}{C_1+C_2}\right)^2$

Energy loss $=\frac{C_1C_2}{2(C_1+C_2)}(V_1-V_2)^2$

2. Parallel combination



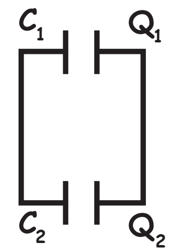
$C_{eq}=C_1+C_2+C_3$

$C_{eq}=nC$

[if $C_1=C_2=.......=C_n=C$]

Charge divider rule

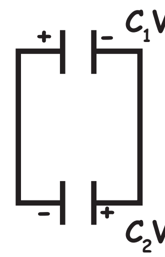
$Q\propto C$



$Q_1=\left(\frac{C_1}{C_1+C_2}\right)Q$

$Q_2=\left(\frac{C_2}{C_1+C_2}\right)Q$

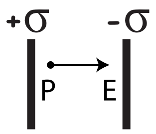
Connecting two charged capacitors - Case 2



$V_{common}=\frac{C_1V_1-C_2V_2}{C_1+C_2}$

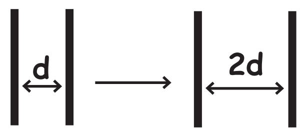
Energy loss $=\frac{C_1C_2}{2(C_1+C_2)}(V_1+V_2)^2$

ELECTRIC FIELD



$E=\frac{\sigma}{\varepsilon_0}=\frac{Q}{A\varepsilon_0}=\frac{CV}{A\varepsilon_0}$

when plate seperation doubled

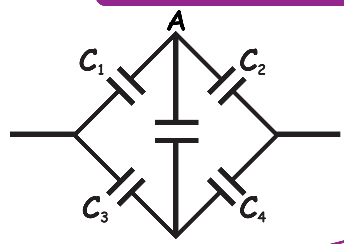


$C=\frac{\varepsilon_0 A}{d}$ $\quad C'=\frac{C}{2}$

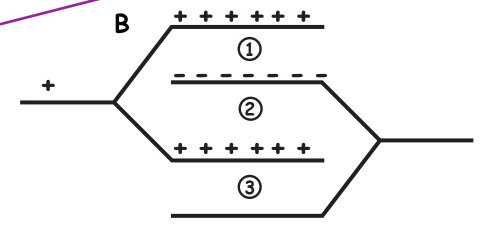
Dielectric inserted in capacitor

Battery removed	Battery remains connected
1. $C=KC'$	1. $C'=KC$
2. $Q'=Q$	2. $Q'=KQ$
3. $V'=\frac{V}{K}$	3. $V'=V$
4. $E'=\frac{E}{K}$	4. $E'=E$
5. $U'=\frac{U}{K}$	5. $U'=KU$

WHEATSTONE'S BRIDGE



$\frac{C_1}{C_2}=\frac{C_3}{C_4}$ $\quad V_A=V_B$

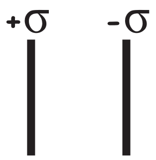


$C=\frac{3\varepsilon_0 A}{d}$

POTENTIAL

$V=Ed=\frac{Qd}{A\varepsilon_0}$

Force b/w plates of a parallel plate capacitor



$F=Q\times E_{\text{Due to one plate}}$

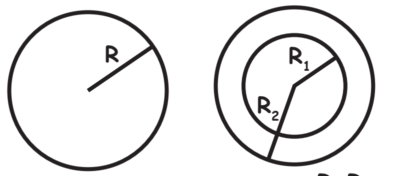
$=Q\times\frac{\sigma}{2\varepsilon_0}=Q\times\frac{Q}{2A\varepsilon_0}$

$=\frac{Q^2}{2A\varepsilon_0}=\frac{C^2V^2}{2A\varepsilon_0}=\frac{\varepsilon_0 A}{d}\times\frac{CV^2}{2A\varepsilon_0}$

$=\frac{CV^2}{2d}$

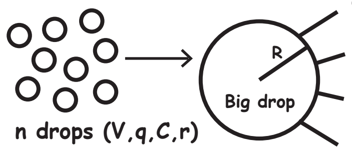
Battery connected	Battery Disconnected
$d\to 2d$	$d\to 2d$
1. V=Constant	1. Q=Constant
2. $C'=\frac{C}{2}$	2. $C'=\frac{C}{2}$
3. $Q=CV,\ Q'=\frac{Q}{2}$	3. $V=\frac{Q}{C},\ V'=2V$
4. $E=\frac{V}{d},\ E'=\frac{E}{2}$	4. $E=\frac{Q}{A\varepsilon_0}=$ Constant
5. $F=\frac{CV^2}{2d},\ F'=\frac{F}{4}$	5. $F=\frac{Q^2}{2A\varepsilon_0}=$ Constant
6. $U=\frac{CV^2}{2},\ U'=\frac{U}{2}$	6. $U=\frac{Q^2}{2C},\ U'=2U$

SPHERICAL CAPACITOR



$C=4\pi\varepsilon_0 R$ $\quad C=4\pi\varepsilon_0\left[\frac{R_1R_2}{R_2-R_1}\right]$

REDISTRIBUTION OF CHARGE



$Q'=nq$

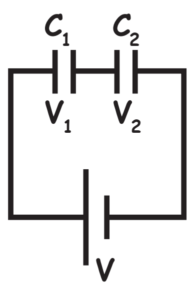
$C'=n^{1/3}C$

$V'=n^{2/3}V$

$U'=n^{5/3}U$

Grouping of capacitors

1. Series combination



$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2}$

$V=V_1+V_2$

$C_{eq}=\frac{(C_1C_2)}{(C_1+C_2)}$

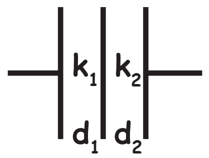
Voltage divider rule

$V\propto\frac{1}{C}$

$V_1=\left(\frac{C_2}{C_1+C_2}\right)V$ $\quad V_2=\left(\frac{C_1}{C_1+C_2}\right)V$

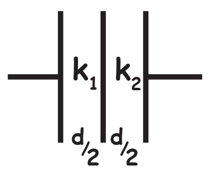
MULTIPLE DIELECTRICS

1. Series combination



$k_{eq}=\frac{\Sigma d}{\Sigma d/k}$

$k_{eq}=\frac{d_1+d_2}{\frac{d_1}{k_1}+\frac{d_2}{k_2}}$

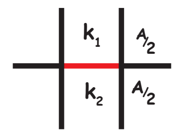


$k_{eq}=\frac{2k_1k_2}{k_1+k_2}$

2. Parallel combination

$k_{eq}=\frac{\Sigma kA}{\Sigma A}$

$k_{eq}=\frac{k_1A_1+k_2A_2+....}{A_1+A_2+....}$



$k_{eq}=\frac{k_1\frac{A}{2}+k_2\frac{A}{2}}{\frac{A}{2}+\frac{A}{2}}=\frac{k_1+k_2}{2}$