CHAPTER 2
ELECTROSTATIC POTENTIAL AND CAPACITANCE

PREVIOUS KNOWLEDGE

When an external force does work in taking a body from a point to another against a force like gravitational force, that work gets stored as potential energy of the body.

'Gravitational Potential energy difference' of a mass between two points is the work done by the external force (against gravitational force) to bring the mass from one point to another.

Gravitational potential difference between two points in a gravitational field is the work done by the external force (against gravitational force) to bring a unit mass from one point to another.

'ELECTROSTATIC PE DIFFERENCE' OF A CHARGE BETWEEN TWO POINTS

'Electrostatic PE difference' of a charge between two points is the work done by an external force (against electrostatic force) to bring the charge from one point to another with no acceleration.

$$W_{AB}=\int_A^B \overline{F_{ext}}.\overline{dr}=-\int_A^B F_e dr=-\int_A^B qE\,dr$$

This is the potential difference between the points

ELECTROSTATIC POTENTIAL DIFFERENCE BETWEEN TWO POINTS

Electrostatic potential difference between two points in an electric field is the work done by an external force (against electrostatic force) to bring **a unit charge** from one point to another with no acceleration.

Expression : $V_{AB}=\int_A^B \overline{F_{ext}}.\overline{dr}=-\int_A^B F_e\,dr$

=> $V_{AB}=-\int_A^B E\,dr$ (since q= 1 C)

=> $V_{AB}=-\int_A^B \frac{Q}{4\pi\varepsilon_0 r^2}dr=\frac{-Q}{4\pi\varepsilon_0}\int_A^B \frac{1}{r^2}dr$

=> $V_{AB}=\frac{-Q}{4\pi\varepsilon_0}\left[\frac{-1}{r}\right]_A^B$

=> $$\boxed{V_{AB}=\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_B}-\frac{1}{r_A}\right]}$$

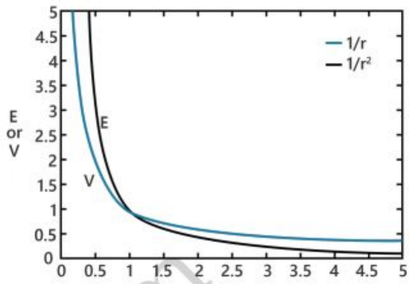
ELECTRIC POTENTIAL AT A POINT DUE TO A POINT CHARGE

Electrostatic potential at a point in an electric field is defined as the work done to bring a unit positive test charge from infinity to the point in the electric field.

ie, $V=\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r}-\frac{1}{\infty}\right]$

=> $$\boxed{V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}}$$

VARIATION OF ELECTRIC POTENTIAL AND ELECTRIC FIELD WITH DISTANCE 'r' FROM A CHARGE



RELATION BETWEEN ELECTRIC FIELD AND POTENTIAL

We know that the potential difference between A and B is the work done, to move +1C charge from A to B.

$$dV=dW=-Edr$$

Or $$\boxed{E=\frac{-dV}{dr}}$$

Example 2.1 NCERT

(a) Calculate the potential at a point P due to a charge of 4 × 10 $^{-7}$ C located 9 cm away.

(b) Hence obtain the work done in bringing a charge of 2 × 10 $^{-9}$ C from infinity to the point P. Does the answer depend on the path along which the charge is brought?

Solution

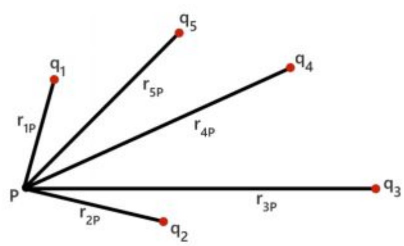
(a)

$$V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}=9x10^9 x\frac{4x10^{-7}}{0.09}=4x10^4 V$$

(b) $W=qV=2x10^{-9}x4x10^4=8x10^{-5}J$

(c) No, work done will be path independent.

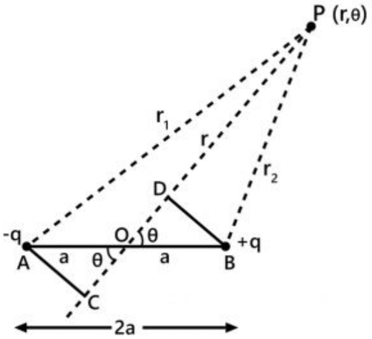
ELECTRIC POTENTIAL DUE TO A SYSTEM OF CHARGES



Potential at a point due to a system of charges is numerically equal to the sum of all potentials at that point due to the individual charges (Just add the potentials , doesn't mind the direction since potential is scalar)
ie,

$$V=\frac{q_1}{4\pi\varepsilon_0 r_{1P}}+\frac{q_2}{4\pi\varepsilon_0 r_{2P}}+\frac{q_3}{4\pi\varepsilon_0 r_{3P}}+\ldots\ldots\ldots$$

ELECTRIC POTENTIAL DUE TO AN ELECTRIC DIPOLE



- What is the potential at P due to the dipole?
- Dipole moment , $\vec{p}=q(2a)$ from -q to +q .
- P is a point at a distance r from the dipole.
- The angle between the dipole moment , $\vec{p}$ and $\vec{r}$, <POB = θ .
- AC and BD are perpendicular to $\vec{r}$.

V at P due to +q , $V_{+q}=\frac{1}{4\pi\varepsilon_0}\frac{q}{BP}$

V at P due to -q , $V_{-q}=\frac{-1}{4\pi\varepsilon_0}\frac{q}{AP}$

For an ideal dipole, let's assume r >> a
Then , BP ≈ DP = r – a cosθ and
AP ≈ CP = r + a cosθ

Total V at P = $V_{+q}+V_{-q}$

=> $$V=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(r-a\cos\theta)}-\frac{q}{(r+a\cos\theta)}\right]$$

=> $$V=\frac{q}{4\pi\varepsilon_0}\left[\frac{r+a\cos\theta-(r-a\cos\theta)}{r^2-a^2\cos^2\theta}\right]$$

=> $$V=\frac{q\,x\,2a\cos\theta}{4\pi\varepsilon_0(r^2-a^2\cos^2\theta)}$$

Since $a^2\cos^2\theta\ll r^2$, it can be neglected.

Therefore , $$V=\frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$

(Or) $$V=\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$$

Special Cases

(1) $V_{axial}=\frac{p}{4\pi\varepsilon_0 r^2}$ since, θ = 0

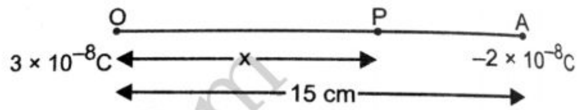
(2) $V_{equitorial}=0$ since, θ = 90^0

Note: The equatorial plane of the dipole is an equipotential surface having a potential zero.

Example 2.2 NCERT

Two charges 3 × 10 $^{-8}$ C and –2 × 10 $^{-8}$ C are located 15 cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero

Solution



Let V at P be zero

ie, $$V_P=\frac{3x10^{-8}}{4\pi\varepsilon_0 x}-\frac{2x10^{-8}}{4\pi\varepsilon_0(15-x)}=0$$

=> $$\frac{3x10^{-8}}{4\pi\varepsilon_0 x}=\frac{2x10^{-8}}{4\pi\varepsilon_0(15-x)}$$

=> $3(15-x)=2x$

=> $45-3x=2x$ => $45=5x$ => $x=9\,cm$

POTENTIAL DUE TO A UNIFORMLY CHARGED SPHERICAL SHELL

We know EF outside a spherical shell is as if the entire charge is concentrated at the centre.

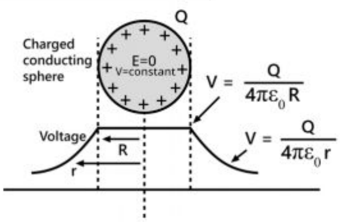
Let 'Q' be the total charge on the shell and 'R' be the radius of the shell.

Thus $$V_{outside}=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$ (if r > R)

$$V_{surface}=\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

We know the EF inside a shell is zero , implies that potential is constant inside the shell and which is same as that on the surface.

Ie, $$V_{inside}=\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

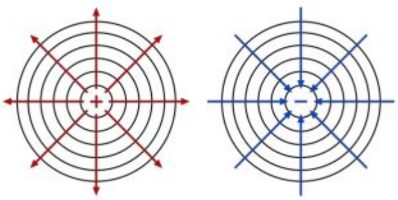


EQUIPOTENTIAL SURFACES

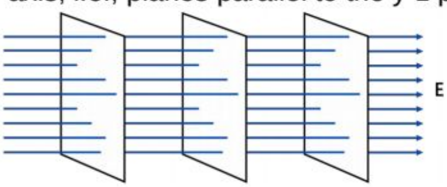
An equipotential surface is a surface with a constant value of potential at all points on the surface.

Work done in moving a charge between two points in an equipotential surface is zero, hence electric field is always perpendicular to an equipotential surface.

Equipotential surfaces of a single point charge are concentric spherical surfaces centred at the charge. ($V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$)



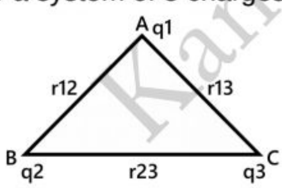
For a uniform electric field E, say, along the x -axis, the equipotential surfaces are planes normal to the x -axis, i.e., planes parallel to the y-z plane.



POTENTIAL ENERGY OF A SYSTEM OF CHARGES (In the absence of external electric field)

Here we are calculating the potential energy stored in a system of 3 charges (can be extended to n charges). It is equal to the total work done to build up this system of charges .

Consider a system of 3 charges q_1, q_2, q_3



Work done to bring the first charge q_1 at the point A, $W_1=q_1 V(A)$

But $V(A)=0$

Therefore, $W_1=0$ ....(1)

Similarly work done to bring the second charge q_2 at the point B, $W_2=q_2 V(B)$

But $V(B)=\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{12}}$

Therefore, $W_2=q_2\left(\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{12}}\right)$ ....(2)

Similarly $W_3=q_3 V(C)$

But $V(C)=\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{13}}+\frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{23}}$

Therefore $W_3=q_3\left(\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{13}}+\frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{23}}\right)$ .....(3)

Therefore the total work done in building up this 3 charge system, $W=W_1+W_2+W_3$

=> $W=\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}+\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_3}{r_{13}}+\frac{1}{4\pi\varepsilon_0}\frac{q_2 q_3}{r_{23}}$

=> $\boxed{W=\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}}+\frac{q_1 q_3}{r_{13}}+\frac{q_2 q_3}{r_{23}}\right)=U}$

NOTE

Potential energy of a system of two charges,

$$\boxed{U=\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}}\right)}$$

POTENTIAL ENERGY OF A SYSTEM OF CHARGES (In the presence of external electric field)

In what way this topic is different from the previous one?

Here we are concerned with PE of a charge in an external EF, which is not produced by the given charges whose PE we wish to calculate

1 . Potential Energy of a single charge in an external EF

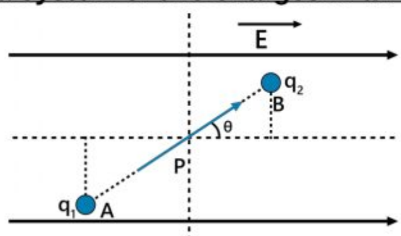
Let V(r) the potential at a point due to an external EF, E .

The potential energy of q at that point,PE = W = qV(r)

NOTE

Thus if an electron with charge q=e=1.6x10 $^{-19}$ C is accelerated by a pd of ΔV = 1 V , it would gain energy q ΔV =e ΔV= 1.6 x 10 $^{-19}$ J

2 .PE of a system of two charges in an external EF



PE of the system of charges is the total work done to assemble the charges from infinity.

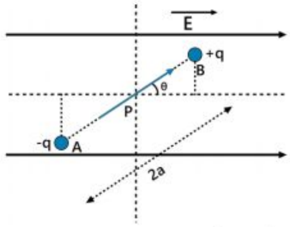
Work done to bring q $_1$ = q $_1$ V(A)

$$\text{Work done to bring } q_2=q_2 V(B)+\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{AB}}\right)$$

Therefore, the potential energy of the system of two charges is,

$$U = q_1 V(A) + q_2 V(B) + \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{AB}}\right)$$

3.PE of an electric dipole in an external EF



$$U = -qV(A) + qV(B) - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

=> $$U = q[V(B) - V(A)] - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

But we know $[V(B) - V(A)] = -\int_A^B E.dr$

=> $$U = -q\int_A^B E.dr - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

=> $$U = -q\int_A^B E\,dr\cos\theta - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

=> $$U = -qE\cos\theta\int_A^B dr - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

=> $$U = -qE\cos\theta(2a) - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

=> $$U = -pE\cos\theta - \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{2a}\right)$$

Note that the second term in the above equation is a constant for a given dipole. Since a constant is insignificant for potential energy we can drop the second term.

Therefore , $U = U(\theta) = -pE\cos\theta$

Example 2.5 NCERT

(a) Determine the electrostatic potential energy of a system consisting of two charges 7 μC and –2 μC (and with no external field) placed at (–9 cm, 0, 0) and (9 cm, 0, 0) respectively.

(b) How much work is required to separate the two charges infinitely away from each other?

Solution

(a) $$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

$$= 9x10^9 x \frac{(7)x(-2)x10^{-12}}{0.18} = -0.7\,J$$

(b) $W = 0 - U = +0.7\,J$

ELECTROSTATICS OF CONDUCTORS

1. Inside a conductor, electrostatic field is zero

Under static situation (No current flows through) the EF inside the conductor is zero. The conductor may be charged or neutral. There may also be an external electric field.

2. At the surface of a charged conductor, electrostatic field must be normal to the surface at every point.

If E were not normal to the surface, it would have some non-zero component along the surface. Free charges on the surface of the conductor would then experience force and move

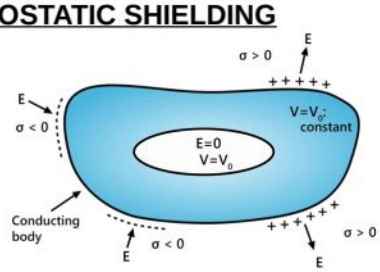
3.Under static situation excess charge inside a conductor is zero.

4. For a charged conductor the excess charge resides only at the outer surface of the conductor

5. Electric potential is constant inside and at the surface of each conductor(The surface of a conductor is an equipotential surfaces

6. Electric field at the surface of a charged conductor $E = \frac{\sigma}{\varepsilon_0}\hat{n}$

ELECTROSTATIC SHIELDING



The EF inside a cavity is zero, whatever be the size and shape of the cavity and whatever be the charge on the conductor and the external fields in which it might be placed. ie, whatever be the charge or field configuration outside, the cavity inside a conductor remains shielded from outside electric influence. The field inside the cavity is zero always. This is known as **electrostatic shielding.**

NOTE **:**Due to Electrostatic shielding, E=0 inside a car, it is safer to be inside a car during lightning

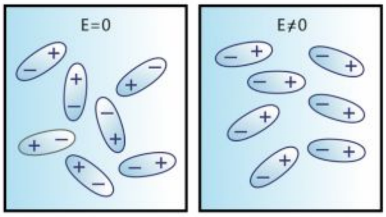
DIELECTRICS AND POLARISATION

Polar molecules

The molecules in which , the centre of gravity of positive charges and centre of gravity of negative charges do not coincide. These molecules are called polar molecules.

Eg: HCl, H_2O, NH_3 , etc.

Polar molecules in the absence of an electric field (E=0)	*Polar molecules in the presence of an electric field(E ≠0)*
Individual dipoles are there , but the net dipole moment of the sample is zero since each dipoles are randomly oriented.	Get permanent dipole moment for the sample in the presence of an external field.

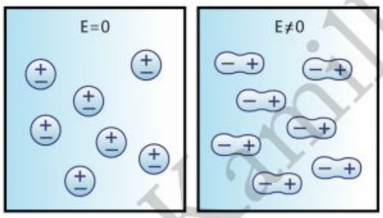


Non-polar molecules

The molecules in which the centre of gravity of positive charges and centre of gravity of negative charges coincide. These molecules are called non-polar molecules.

Eg: O_2 , N_2 , H_2 , CO_2 , etc.

Non polar molecules in the absence of an electric field (E=0)	*Non polar molecules in the presence ofan electric field (E=0)*
No individual dipoles and permanent dipole moment in the absence of external field	Get a permanent dipole moment for the sample in the presence of external field



DIELECTRICS

Dielectrics are the insulators. They do not conduct electricity, but they allow electric field to pass through.

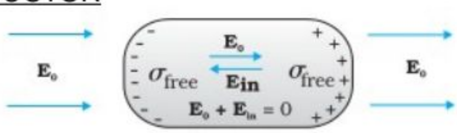
Dielectric is of two types.

1. Polar dielectric :A dielectric made up of polar molecules.

2. Non polar dielectric :A dielectric made up of non polar molecules

A CONDUCTOR AND A DIELECTRIC IN AN EXTERNAL ELECTRIC FIELD

CONDUCTOR



Conductor

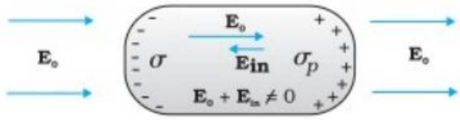
When a conductor is placed in an external electric field ($\vec{E}_0$) the electrons in the conductor are redistributed in such a way that an equal and opposite electric field (E_{in}) is set up inside the conductor.

So the net electrostatic field is zero inside the conductor.

$$E_0 + E_{in} = 0$$

DIELECTRIC

In a dielectric, the free movement of charges is not possible.



Dielectric

When a dielectric is placed in an external electric field (E_0), the molecular dipoles are arranged in such a way that an opposite electric field (E_{in}) is set up inside the dielectric. But this electric field is always less than the external electric field.

So the net electrostatic field is not zero inside the dielectric.

$$E = E_0 + E_{in} \neq 0$$

and the net electric field can be written in terms of E_0 as

$$E = \frac{E_0}{K}$$

where K is the dielectric constant (relative permittivity of the material)

POLARISATION $(\vec{P})$

The phenomenon of inducing dipole while subjected a dielectric to an external electric field.

The induced dipole moment per unit volume of the dielectric is called polarization .

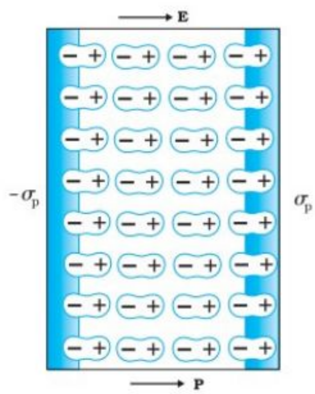
$$\vec{P} = \frac{\vec{p}}{V}$$

For linear isotropic dielectrics,

$$\vec{P} \alpha \vec{E} \quad \text{(Or)} \quad \vec{P} = \chi_e \vec{E}$$

Where χ_e is a constant called **susceptibility of the dielectric**.

A RECTANGULAR DIELECTRIC SLAB PLACED IN A UNIFORM EXTERNAL FIELD



A polarised dielectric is equivalent to two charged surfaces with induced surface charge density $-\sigma_b$ and $+\sigma_b$

CAPACITANCE

If a charge 'Q' is given to a conductor , its potential rises by 'V' . Then,

$$Q \alpha V \quad => \quad \boxed{Q = CV} \quad => \quad \boxed{C = \frac{Q}{V}}$$

Where C is the constant of proportionality called the **capacitance** of the conductor.

So the capacitance of a conductor may be defined as the ratio of charge given to the conductor to the rise in its potential.

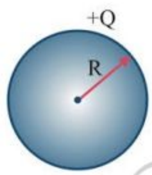
Unit : farad (F)

Capacitance of a capacitor is said to be one farad if one coulomb of charge raises its potential by one volt. Ie,

$$1F = \frac{1C}{1V}$$

1 . Capacitance Of an Isolated Spherical conductor

$$C = \frac{Q}{V} \quad => \quad C = \frac{Q}{\frac{Q}{4\pi\varepsilon_0 R}}$$



$$=> \quad \boxed{C = 4\pi\varepsilon_0 R}$$

2. Electrical Capacitance of the Earth

Electrical capacitance of the earth can be estimated by taking the earth to be a conducting sphere of radius 'R' .

$$C = 4\pi\varepsilon_0 R = \frac{1}{9x10^9} x\, 6.4 x 10^6 = 0.711 x 10^{-3} F$$

$= 711\ \mu F$

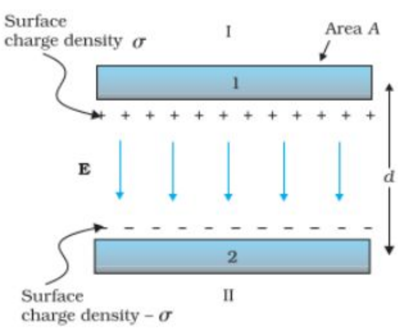
CAPACITORS

A capacitor is a system of two conductors separated by an insulator.

PARALLEL PLATE CAPACITOR

A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance.

1. Capacitance of a Parallel Plate Capacitor (No dielectric)



$$C_0 = \frac{Q_0}{V_0} = \frac{\sigma A}{E_0 d}$$

(since $Q_0 = \sigma A \quad V_0 = E_0 d$)

$$=> \quad C_0 = \frac{\sigma A}{E_0 d} = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0} d} \qquad \text{(since } E_0 = \frac{\sigma}{\varepsilon_0}\text{)}$$

$$=> \quad \boxed{C_0 = \frac{A\varepsilon_0}{d}}$$

2. Capacitance of a Parallel Plate Capacitor with a dielectric (Effect of dielectric on capacitance)

When a dielectric of dielectric constant 'K' is placed between the plates of an isolated charged capacitor (Battery is disconnected while dielectric is inserted) ,

$$Q = Q_0 \quad , \quad E = \frac{E_0}{K} \quad , \quad V = Ed = \frac{E_0}{K} d = \frac{V_0}{K}$$

Therefore the new capacitance ,

$$\boxed{C = \frac{Q}{V} = \frac{Q_0}{\frac{V_0}{K}} = \frac{K Q_0}{V_0} = K C_0}$$

That is the capacitance of a capacitor is increases from its vacuum value by a factor of 'K' when the space between the plate is filled with a dielectric of dielectric constant 'K' .

Do Example 2.8 NCERT

Problem

At what distance should the two plates each of area 0.2m X 0.1m of an air capacitor be placed in order to have the same capacitance as a spherical conductor of radius 0.5m?

Solution

$$4\pi\varepsilon_0 R = \frac{A\varepsilon_0}{d}$$

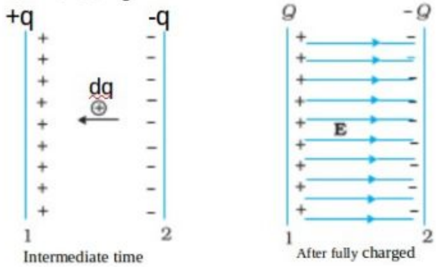
$$=> \quad d = \frac{A}{4\pi R} = \frac{0.2 x 0.1}{4 x 3.14 x 0.5} = 3.18 x 10^{-3} m$$

Problem (Do yourself)

A parallel plate capacitor with air between the plates has a capacitance of 8pF . What will be the capacitance if the distance between the plates is reduced by half, and the space between them is filled with a substance of dielectric constant 6? **(Ans : 12 x 8 = 96 pF)**

ENERGY STORED IN A CAPACITOR(U)

Consider a capacitor of a capacitance 'C'; it has given a voltage 'V'.The charge in the capacitor grows from 0 to Q.



Let at any instant the charge in the capacitor be 'q'. Now the work done to increase the charge by an amount 'dq' is given by

$$dW = V\,dq \quad => \quad dW = \frac{q}{C}dq$$

Therefore, the total work done to increase the charge from O to Q is given by

$$W = \int_0^Q \frac{q}{C}dq = \frac{1}{C}\int_o^Q q\,dq$$

=> $$W = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q \quad => \quad W = \frac{1}{2C}\left[Q^2 - 0\right]$$

=> $$\boxed{W = \frac{Q^2}{2C}}$$ But $Q = CV$

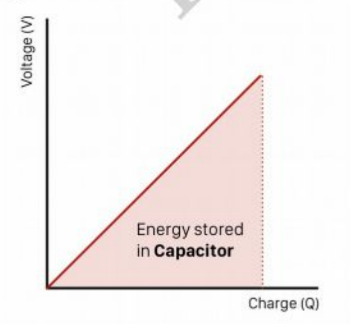
Therefore $$\boxed{W = \frac{1}{2}CV^2} \quad \text{(Or)} \quad \boxed{W = \frac{1}{2}QV}$$

This much work done is stored as the energy of the capacitor. Ie,

$$\boxed{U = \frac{Q^2}{2C}} \qquad \boxed{U = \frac{1}{2}CV^2} \qquad \boxed{U = \frac{1}{2}QV}$$

Alternate method

The Graph of Charge stored V/S voltage across a capacitor is given below



The area of the graph gives total energy stored (U) in the capacitor. Ie,

$$\boxed{U = \frac{1}{2}QV} \;=>\; \boxed{U = \frac{1}{2}CV^2} \;=>\; \boxed{U = \frac{Q^2}{2C}}$$

ENERGY DENSITY OF A PARALLEL PLATE CAPACITOR (u)

Energy density is the energy stored per unit volume.

Ie, $$u = \frac{U}{V} = \frac{U}{Ad} \quad ....(1)$$

we know $$U = \frac{Q^2}{2C} = \frac{\sigma^2 A^2}{\frac{2A\varepsilon_0}{d}}$$

=> $$U = \frac{\sigma^2 A d}{2\varepsilon_0} \quad ....(2)$$

But we know $E = \frac{\sigma}{\varepsilon_0}$ (or) $\sigma = \varepsilon_0 E$ ......(3)

sub (3) in (2)

=> $$U = \frac{\varepsilon_0^2 E^2 A d}{2\varepsilon_0} = \frac{\varepsilon_0 E^2 A d}{2} \quad ....(4)$$

Sub (4) in (1) we will get energy density.

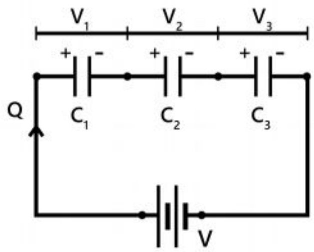
$$\boxed{u = \frac{\varepsilon_0 E^2}{2}}$$

DIFFERENT USES OF A CAPACITOR

(i) To store electric charge
(ii) To generate electromagnetic radiation
(iii)To reduce voltage fluctuation in power supply

COMBINATION OF CAPACITORS

(i) Capacitors in Series



In a series circuit the charge (Q) stored in each of the capacitors is the same but the voltages across them are different.

The applied voltage,

$$V = V_1 + V_2 + V_3 \quad ....(1)$$

But we know $V = \frac{Q}{C}$

So (1) => $$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \quad ....(2)$$

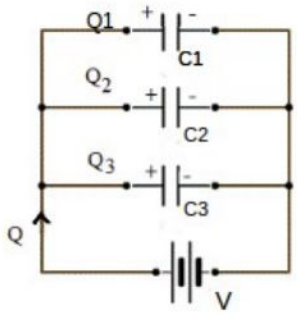
where C is the effective capacitance. And

(2) => $$\boxed{\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

If there are connected 'n' capacitors in series

$$\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}+\text{............}\frac{1}{C_n}$$

(ii) Capacitors in Parallel



In a parallel circuit, the voltage is the same but the charges stored in the capacitors are different.

The total charge,

$$Q=Q_1+Q_2+Q_3 \quad \text{..........(3)}$$

But we know $Q=CV$

So (3) => $CV=C_1V+C_2V+C_3V$ ....(4)

where C is the effective capacitance. And

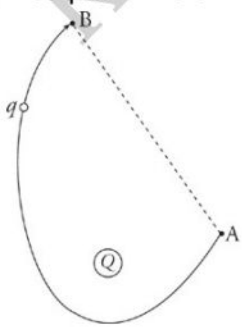
(4) => $$C=C_1+C_2+C_3$$

If there are connected 'n' capacitors in parallel

$$C=C_1+C_2+C_3+\text{........}C_n$$

ADDITIONAL PROBLEMS

1)Calculate the work done by electric field when a point charge q is moved from point B to A along the curved path. Given that electric field is created by the stationary charge Q and V_A=200V, V_B=100V, q=0.05C, length of line segment AB = 10 cm, length of curved path = 20 cm.



Soln)

$$WBA=q(VA-VB)=0.05(200-100)=5\,J$$

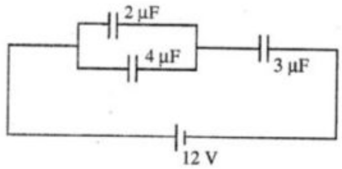
2. A capacitor is an electronic component having two conductors separated by an insulator.

a) An insulated capacitor with air between its plates has a potential difference of V_0 and a charge Q_0 . When the space between the plates is filled with oil, the potential difference becomes V and charge become Q. Which of the following relation is correct?

(i) $Q = Q_0$, $V > V_0$ (ii) $Q = Q_0$, $V < V_0$

(iii) $Q > Q_0$, $V = V_0$ (iv) $Q < Q_0$, $V = V_0$

b) Find out the effective capacitance of the following capacitor



PREVIOUS YEAR QUESTIONS

1.	How capacitance changes if the distance between the plates of a parallel plate capacitor is halved (a) Does not change (b) Becomes half (c) Doubled (d) Becomes one fourth	1
2.	Three capacitors of capacitances 2 pF, 3pF and 4 pF are connected in parallel.	
a)	Write the SI unit of capacitance.	1
b)	Calculate the effective capacitance of the combination.	1
c)	Determine the charge on each capacitor if the combination is connected to a 100 V supply	2
3.	In a capacitor the energy is stored in ------------- (i) the positive plate (ii) the negative plate (iii) in the electric field in between the plates (iv) none of these	1
4.a)	Obtain the expression for the capacitance of a parallel plate capacitor.	2
b)	A parallel plate capacitor with air between the plates has a capacitance of 8 pF. What will be the capacitance if the distance between the plates is reduced by half, and space between them is filled with a substance of dielectric constant 6.	2
5.	Calculate the electric potential at a point 9.0 cm away from a point charge of 4×10^{-7} C.	2

6.	Write any one difference between polar and non-polar molecule. Give one example each for polar and non-polar molecule.	1
7.a) b)	Draw a figure of a parallel combination of three capacitors of capacitances C_1 , C_2 and C_3 . Derive an expression for the effective capacitance of this combination.	1 3
8. a) b)	In a parallel plate capacitor with air between the plates, each plate has an area of 6 x 10 $^{-3}$ m ^{2} and the separation between the plates is 3 mm. Calculate the capacitance of the capacitor. If this capacitor is connected to 100 V supply, what would be the charge on each plate ?	 1.5 1.5
9. a) b)	Derive expression for the equivalent capacitance of three capacitors C_1 , C_2 and C_3 connected In series in parallel.	4
10.	Electrostatic field at the surface of a charged conductor, must be normal to the surface at every point. Is the statement true or false ?	1
11.	Write down any three properties of an equipotential surfaces	2
12.a) b)	SI unit of capacitance is ----------- Two capacitors C_1 and C_2 are connected in series. Derive an expression for the capacitance of the combination.	1 3
13.a) b)	Derive the expression for the capacitance of a parallel plate capacitor. What happens to the capacitance if a medium of dielectric constant K is introduced between the plates ?	2 1
14.a) b) c)	Give the relation between electric field and potential. Derive the expression for the potential due to an electric dipole. Calculate the potential at a point due to a charge of 4 x 10 $^{-7}$ C located 9 cm away.	1 2 2

15.	Work done to bring a charge from one place to another place in an equipotential surface is	1
16. a) b)	A capacitor is a system of two conductors separated by an insulator. Three capacitors of equal capacitance when connected in series have a net capacitance C_1 and when connected in parallel have a net capacitance C_2 . What will be the ratio C_1 / C_2 ? Write down the equations for equivalent capacitance when three capacitors of capacitance C_1 , C_2 and C_3 connected in (i) Series (ii) Parallel.	2 1
17. a) b) c)	A capacitor is a system of two conductors with charge + Q and – Q. What is the S.I. unit of capacitance ? When two capacitors are connected in series, the capacitance of the combination (i) Increases (ii) Decreases Write the expression for the energy stored in a capacitor.	 1 1 1
18.	What is an equipotential surface ? Give an example.	2
19.a) b) c)	What is the principle of a capacitor ? Derive the expression for capacitance of a parallel plate capacitor. A 12 pF capacitor is connected to 50 V battery. How much electrostatic energy is stored in the capacitor ?	1 2 2
20.	A positive charge +Q is placed at a point. A circle of radius r is drawn with the point as the centre. Another charge q is carried once in that circular path. What will be the work done?	1
21.a) b)	What is equipotential surface? Write any two properties of equipotential surface	1 2
22.a) b)	Two capacitors C_1 and C_2 are connected in parallel. Obtain an expression for the capacitance of the combination The given graph shows variation of charge 'q' versus potential difference	2 2

	‘V’ for two capacitors C_1 and C_2. Both the capacitors have same plate separation but plate area of C_2 is greater than that of C_1. Which line (A or B) corresponds to C1 and why?