FOCUS NCERT CBSE MODULE

CLASS XII

NCERT CHAPTER 2

ELECTROSTATICS PART-2

ELECTROSTATIC POTENTIAL & CAPACITANCE

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2. NCERT EXAMPLES AND BACK EXERCISES
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Chapter 2

ELECTROSTATIC POTENTIAL AND CAPACITANCE

TOPIC 1 electrostatic potential (V)

IN CHAPTER ONE ELECTRIC CHARGES AND FIELD WAS INTRODUCED WITH TOPICS LIKE COULOMB'S AND GAUSS'S LAW AND WE STUDIED THREE MAJOR PHYSICAL QUANTITIES LIKE CHARGE, FIELD AND ELECTRIC FLUX.

IN THIS CHAPTER WE'LL STUDY:

1. POTENTIAL (V)
2. CAPACITANCE (C)
3. CONDUCTORS & DIELECTRICS
4. VAN DE GRAAFF GENERATOR.

NOTE: Potential difference that we'll study in this chapter is very useful for studing current in next chapter.

Q.1 What are the various TOPICS which describes electrostatics potential ? write a brief note?

A. There are 6 major topics to understand electrostatic potential :

1. Potential at a point due to a single charge.

2. Potential difference between two points.

3. Potential due to electric dipole.

4. Potential due to system of charges.

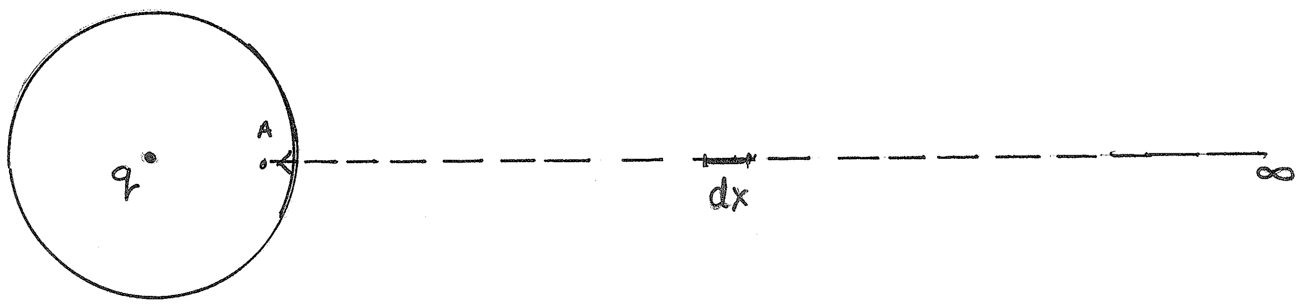
5. Equi-potential surfaces.

6. Potential energy of a system of charges.

Q.2 Explain potential at a point due to a single charge?

A. definition:

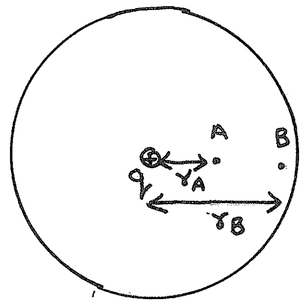
Expression for potential at a point inside electric field:



UNITS OF POTENTIAL:—

Q.3 What is potential difference between two points in electric field? Explain its various expressions?

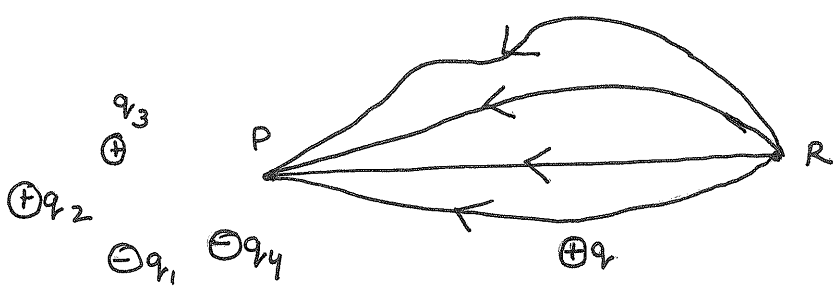
A.



Q.4 NCERT Example2.1 a) calculate the potential at a point P due to a charge of 4×10^{-7} C located 9cm away.

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

A.

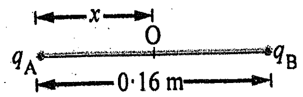


NCERT BACK EXERCISES

NCERT. 2.1. **Two charges 5×10^{-8} C and -3×10^{-8} C are located 16 cm apart. At what point(s) on the line joining the two charges is the electric potential zero ? Take the potential at infinity to be zero.**

Ans. Let the potential be zero at O, then

$V_A + V_B = 0,$



where V_A is electric potential due to charge q_A and V_B is the electric potential due to charge q_B.

i.e. $9 \times 10^9 \frac{q_A}{x} + 9 \times 10^9 \frac{q_B}{r - x} = 0$

i.e. $9 \times 10^9 \left[\frac{5 \times 10^{-8}}{x} + \frac{(-3 \times 10^{-8})}{(0{\cdot}16 - x)}\right] = 0$

i.e. $\frac{5 \times 10^{-8}}{x} = \frac{3 \times 10^{-8}}{(0{\cdot}16 - x)}$

i.e. $5(0{\cdot}16 - x) = 3x$

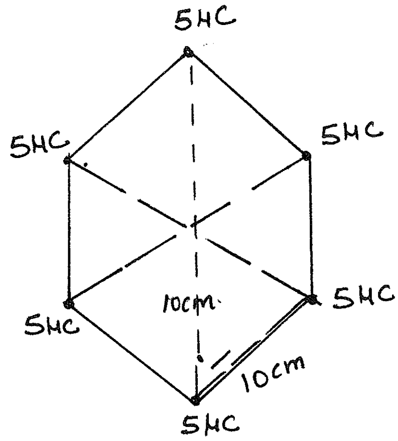
i.e. $0{\cdot}8 = 3x + 5x = 8x$

or $x = 0{\cdot}1 \text{ m} = 10 \text{ cm}.$

NCERT BACK EXERCISES

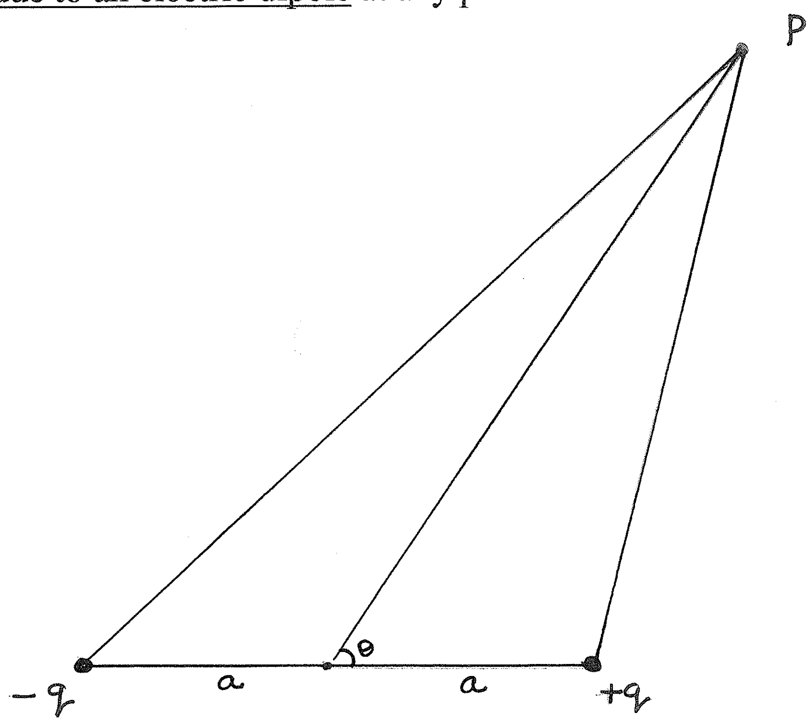
NCERT. 2.2. **A regular hexagon of side 10 cm has a charge 5 μC at each of its vertices. Calculate the potential at the centre of the hexagon.**

Ans.



Q.5 Obtain an expression for Potential due to an electric dipole at any point?

A.



SPECIAL CASES:-

Q.6 Find Potential due to a system of charges ?

A. Consider a system of charges $q_1, q_2, ---, q_n$ with position vectors $r_1, r_2 --- r_n$ relative to some origin. The potential V at point P can be obtain by adding the individual potentials of each charge as below:—

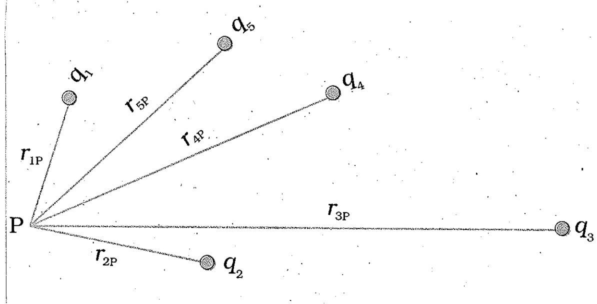
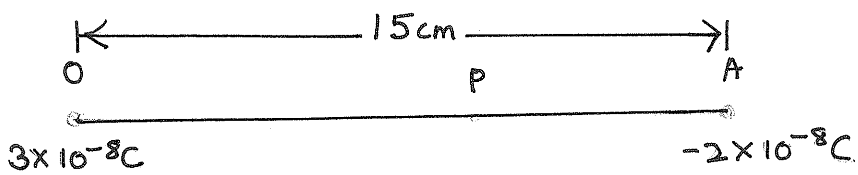


FIGURE 2.6 Potential at a point due to a system of charges is the sum of potentials due to individual charges.

Q.7 N.C.E.R.T example 2.2 Two charges 3×10^{-8} C and -2×10^{-8} C are located 15cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

A.



Q.8 NCERT **Example 2.3** Figures 2.8 (a) and (b) show the field lines of a positive and negative point charge respectively.

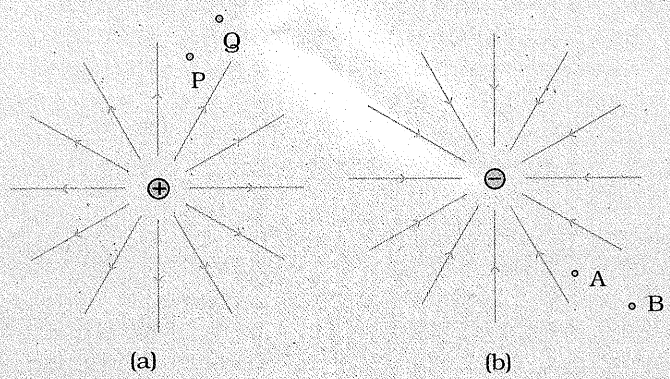


FIGURE 2.8

(a) Give the signs of the potential difference $V_P - V_Q$; $V_B - V_A$.

(b) Give the sign of the potential energy difference of a small negative charge between the points Q and P; A and B.

(c) Give the sign of the work done by the field in moving a small positive charge from Q to P.

(d) Give the sign of the work done by the external agency in moving a small negative charge from B to A.

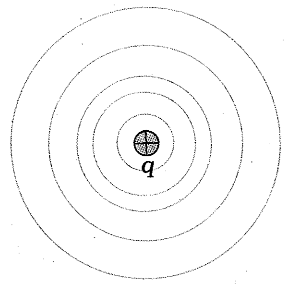
(e) Does the kinetic energy of a small negative charge increase or decrease in going from B to A?

Solution

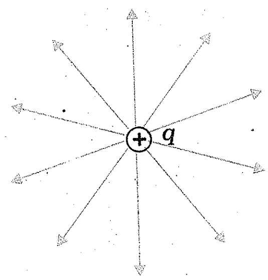
EQUIPOTENTIAL SURFACES

Q.9 What are equipotential surfaces ? write their important properties.

A. Definition:



(a)



(b)

Properties of equipotential surfaces:

1. the potential at every point on these surfaces is always constant

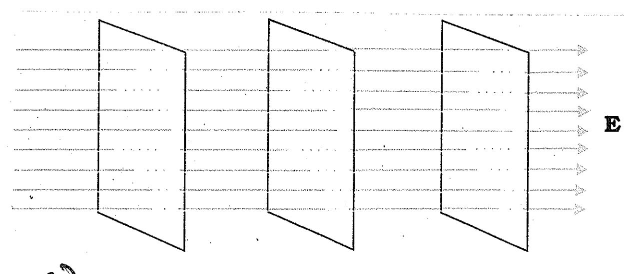
2.

3.

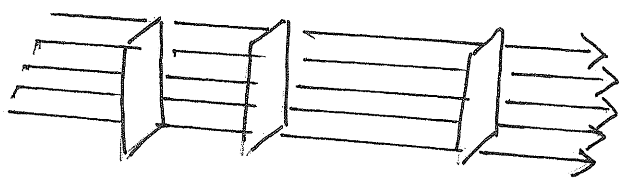
4.

5.

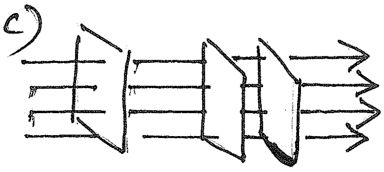
a)



b)



c)



NCERT ADDITIONAL EXERCISES

NCERT.

2.34. Describe schematically the equi-potential surfaces corresponding to

(*a*) a constant electric field in the z-direction,

(*b*) a field that uniformly increases in magnitude but remains in a constant (say, z) direction,

(*c*) a single positive charge at the origin, and

(*d*) a uniform grid consisting of long equally spaced parallel charged wires in a plane.

Ans. (*a*) A plane parallel to xy plane.

(*b*) Plane parallel to xy plane but the planes having different fixed potential will become closer with the increase in field intensity.

(*c*) Concentric spheres with origin as centre.

(*d*) A time dependent changing shape nearer to grid which slowly becomes planar and parallel to the grid at far off distances from the grid.

NCERT BACK EXERCISES

NCERT. **2.3. Two charges 2 μC and –2μC are placed at points A and B, 6 cm apart.**

(a) Identify an equipotential surface of the system.

(b) What is the direction of the electric field at every point on this surface ?

Ans. (a) The equipotential surface is the plane *perpendicular* to the line AB joining the two charges and passing through the *mid-point*. On this plane, potential is zero everywhere.

(b) The direction of electric field is from positive to negative charge *i.e.* A to B, which is infact perpendicular to the equipotential plane.

NCERT. **2.4. A spherical conductor of radius 12 cm has a charge of $1{\cdot}6 \times 10^{-7}$ C distributed uniformly on its surface. What is the electric field**

(a) inside the sphere

(b) just outside the sphere

(c) at a point 18 cm from the centre of the sphere?

Ans. (a) ***Inside a conductor,*** the electric field is zero because the charge resides on the surface of a conductor.

(b) ***Electric field just outside the sphere*** is given by

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{R^2}$$

$$= 9 \times 10^9 \times \frac{(1{\cdot}6\times10^{-7})}{(12\times10^{-2})^2}$$

$$= 10^5 \text{ N C}^{-1}$$

(c) ***Electric field at a distant point*** is given by

$$E' = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

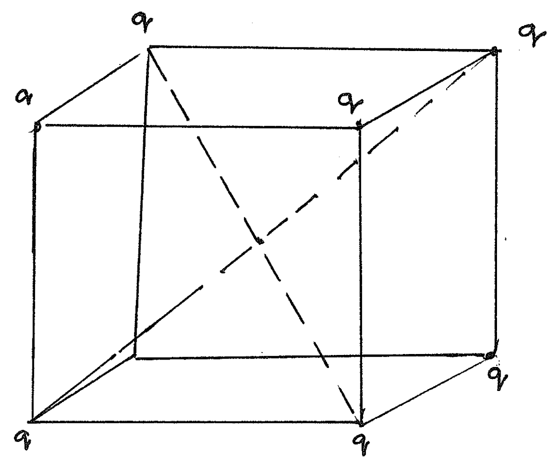
$$= (9\times10^9)\times\frac{(1{\cdot}6\times10^{-7})}{(18\times10^{-2})^2}$$

$$= 4{\cdot}44 \times 10^4 \text{ N C}^{-1}.$$

NCERT BACK EXERCISES

NCERT. 2.13. A cube of side b has a charge q at each of its vertices. Determine the potential and electric field due to this charge array at the centre of the cube.

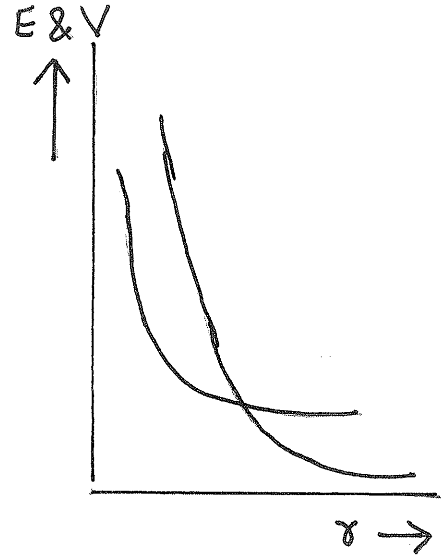
Ans.



Q.10 : What is the relation between electric field and potential?

Or

Explain potential gradient ?



Ans.

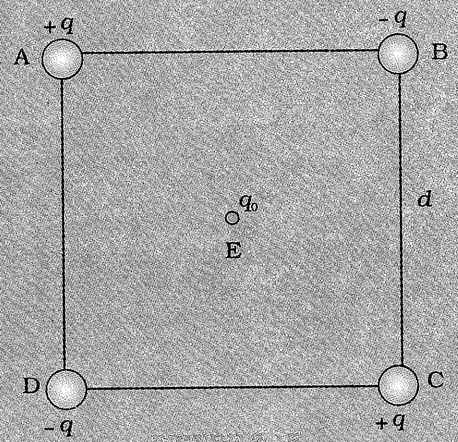
Q.11 Explain potential energy of a system of charges (for 2 charge system as well as for n-charges) ?

Ans.

NOTE :- The potential energy is characteristic of the present state of Configuration, and not the way the state is achieved.

Q.12 NCERT

Example 2.4 Four charges are arranged at the corners of a square ABCD of side d, as shown in Fig. 2.15.(a) Find the work required to put together this arrangement. (b) A charge q_0 is brought to the centre E of the square, the four charges being held fixed at its corners. How much extra work is needed to do this?



Solution

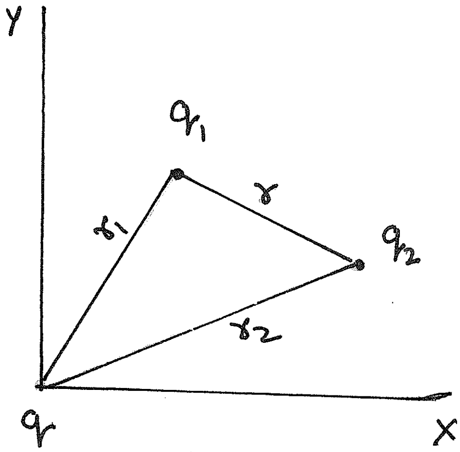
NCERT ADDITIONAL EXERCISES

NCERT **2.19.** If one of the two electrons of a H_2 molecule is removed, we get a hydrogen molecular ion H_2^+. In the ground state of an H_2^+, the two protons are separated by roughly 1·5 Å, and the electron is roughly 1 Å from each proton. Determine the potential energy of the system. Specify your choice of the zero of potential energy.

Ans:-

Q.13 Explain potential energy for a system of charges inside external field ?

A. Consider two charges q_1 & q_2 inside the external field of charge q. as below:—



Q.14 NCERT **Example 2.5**

(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?

(c) Suppose that the same system of charges is now placed in an external electric field $E = A\,(1/r^2)$; $A = 9 \times 10^5$ C m^{-2}. What would the electrostatic energy of the configuration be?

Solution

(a) $U = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r} = 9\times10^9 \times \dfrac{7\times(-2)\times10^{-12}}{0.18} = -0.7$ J.

(b) $W = U_2 - U_1 = 0 - U = 0 - (-0.7) = 0.7$ J.

(c) The mutual interaction energy of the two charges remains unchanged. In addition, there is the energy of interaction of the two charges with the external electric field. We find,

$$q_1V(\mathbf{r}_1) + q_2V(\mathbf{r}_2) = A\frac{7\mu\text{C}}{0.09\text{m}} + A\frac{-2\mu\text{C}}{0.09\text{m}}$$

and the net electrostatic energy is

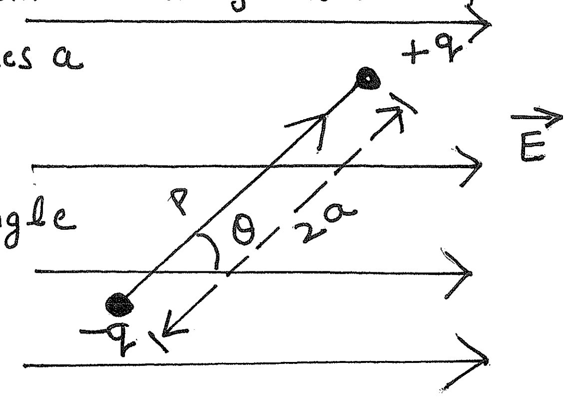
$$q_1V(\mathbf{r}_1) + q_2V(\mathbf{r}_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}} = A\frac{7\,\mu\text{C}}{0.09\,\text{m}} + A\frac{-2\,\mu\text{C}}{0.09\,\text{m}} - 0.7\,\text{J}$$

$$= 70 - 20 - 0.7 = 49.3\,\text{J}$$

Q.15. Obtain potential energy of dipole in an external field ? or find the work done by the torque experienced by an dipole due to external field?

Ans: As seen in the last chapter, in a uniform electric field the dipole experiences no net force; but experiences a torque τ given by $\tau = pE\sin\theta$

and the amount of work done by this external torque from θ_1 angle to θ_2 angle is given by:-



NCERT EXAMPLE

Q.16. NCERT. **Example 2.6** A molecule of a substance has a permanent electric dipole moment of magnitude 10^{-29} C m. A mole of this substance is polarised (at low temperature) by applying a strong electrostatic field of magnitude 10^6 V m^{-1}. The direction of the field is suddenly changed by an angle of 60º. Estimate the heat released by the substance in aligning its dipoles along the new direction of the field. For simplicity, assume 100% polarisation of the sample.

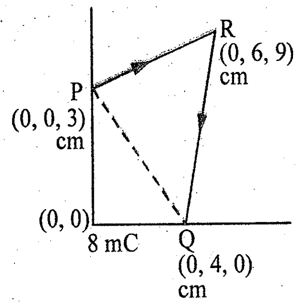
Solution Here, dipole moment of each molecules = 10^{-29} C m

NCERT BACK EXERCISES

NCERT. **2.12. A charge of 8 mC is located at the origin. Calculate the work done in taking a small charge of -2×10^{-9} C from a point P(0, 0, 3 cm) to a point Q (0, 4 cm, 0), via a point R(0, 6 cm, 9 cm.)**

Ans. The work done by electrostatic force on a charge is independent of the path followed by the charge. It depends only on the initial and final positions of the charge.

$$\text{Work done} = q_0(V_Q - V_P) = \frac{1}{4\pi\epsilon_0}\frac{qq_0}{r_B} - \frac{1}{4\pi\epsilon_0}\frac{qq_0}{r_A}$$



$$\textit{i.e.}\ \text{Work done} = \frac{1}{4\pi\epsilon_0}qq_0\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

$$\textit{i.e.}\ \text{Work done} = (9 \times 10^9)(8 \times 10^{-3})$$

$$(-2 \times 10^{-9})\left(\frac{1}{0{\cdot}04} - \frac{1}{0{\cdot}03}\right) = 1{\cdot}2\ \text{J}.$$

Since electrostatic work does not depend upon actual path, so point R is irrelevent here.

NCERT BACK EXERCISES

NCERT.

2.14. Two tiny spheres carrying charges 1·5 μC and 2·5 μC are located 30 cm apart. Find the potential and electric field :

(*a*) at the mid point of the line joining the two charges,

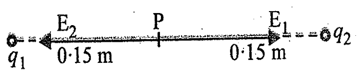
(*b*) at a point 10 cm from this mid-point in a plane normal to the line and passing through the mid-point.

Ans. (*a*) (*i*) Potential, $V = V_1 + V_2$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r}+\frac{q_2}{r}\right)$$

$$= 9\times10^9\left(\frac{1\cdot5\times10^{-6}}{0\cdot15}+\frac{2\cdot5\times10^{-6}}{0\cdot15}\right)$$

$$= 2\cdot4\times10^5\ \text{V}$$



(*ii*) Electric field, $E = E_2 - E_1$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q_2}{r^2}-\frac{q_1}{r^2}\right)$$

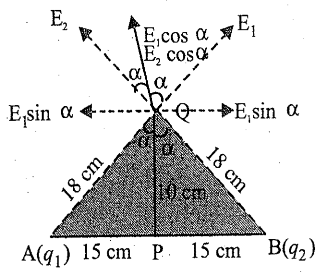
$$= 9\times10^9\left(\frac{2\cdot5\times10^{-6}}{0\cdot15^2}-\frac{1\cdot5\times10^{-6}}{0\cdot15^2}\right)$$

$$= 4\times10^5\ \text{NC}^{-1} \text{ towards } 1\cdot5\ \mu\text{C charge.}$$

(*b*) Let Q be the point in a plane perpendicular to the line passing through the mid point P, where PQ = 10 cm.

$$\text{Now AQ} = \text{BQ} = \sqrt{(15)^2+(10)^2} = \sqrt{325}$$

$$= 18\text{ cm} = 0\cdot18\text{ m}$$



(*i*) Now, potential at Q due to the system of charges

$$V_Q = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{AQ}+\frac{q_2}{BQ}\right]$$

$$= 9\times10^9\left[\frac{1\cdot5\times10^{-6}}{0\cdot18}+\frac{2\cdot5\times10^{-6}}{0\cdot18}\right] = 2\times10^5\text{V}$$

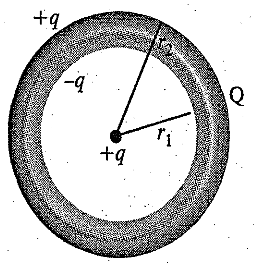
NCERT BACK EXERCISES

NCERT. **2.15. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q.**

(a) A charge q is placed at the centre of the shell. What is the surface charge density on the inner and outer surfaces of the shell ?

(b) Is the electric field inside a cavity (with no charge) zero, even if the shell is not spherical, but has any irregular shape ? Explain.

Ans. (a) Charge Q appears on the outer surface.



When charge q is placed at the centre, it induces $-q$ charge on the inner surface and $+q$ on the outer surface.

∴ charge density of the inner surface,

$$\sigma_1 = -\frac{q}{4\pi r_1^2}$$

and charge density of the outer surface, $\sigma_2 = \frac{Q+q}{4\pi r_2^2}$

(b) Consider a cavity of irregular shape with net charge to be zero inside it. Let a closed loop be partially inside and the rest outside the cavity. The field inside the conductor is zero, so some work is done by the field to carry a test charge in the closed loop, but this is against the provisions of an electrostatic field because as per Gauss' law, the net charge inside a Gaussian surface must be zero. Thus, there cannot be field lines inside the cavity irrespective of its shape.

NCERT BACK EXERCISES

NCERT.

2.16. ***(a)* Show that the normal component of electrostatic field has a discontinuity from one side of a charged surface to another given by**

$$(\vec{E}_2 - \vec{E}_1)\cdot\hat{n} = \frac{\sigma}{\varepsilon_0},$$

where $\hat{n}$ is a unit vector normal to the surface at a point and σ is the surface charge density at that point. (The direction of $\hat{n}$ is from side 1 to side 2.) Hence show that just outside a conductor, the electric field is $\sigma\hat{n}/\varepsilon_0$.

***(b)* Show that the tangential component of electrostatic field is continuous from one side of a charged surface to another.[Hint. For *(a)*, use Gauss's law. For , *(b)* use the fact that work done by electrostatic field on a closed loop is zero.]**

Ans. Consider a sheet of charge having charge density σ. E on either side of the sheet, perpendicular to the plane of sheet, has same magnitude at all points equidistant from the sheet.

Electric field intensity on the left side of the sheet,

$$\vec{E}_1 = -\frac{\sigma}{2\varepsilon_0}\hat{n}$$

Electric field intensity on the right side of the sheet,

$$\vec{E}_2 = \frac{\sigma}{2\varepsilon_0}\hat{n}$$

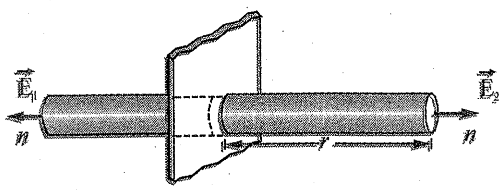
$\therefore$ Discontinuity in the normal component of the field from one side to other side is

$$\vec{E}_2 - \vec{E}_1 = \frac{\sigma}{2\varepsilon_0}\hat{n} + \frac{\sigma}{2\varepsilon_0}\hat{n} = \frac{\sigma}{\varepsilon_0}\hat{n}$$

or $$\left(\vec{E}_2 - \vec{E}_1\right)\cdot\hat{n} = \frac{\sigma}{\varepsilon_0}\hat{n}\cdot\hat{n}$$

Since inside the conductor, $\vec{E}_1 = 0$, therefore,

$$\vec{E}_1 = \vec{E}_2 = \frac{\sigma}{\varepsilon_0}\hat{n}.$$



The electric field tangential to the plate is continuous throughout.

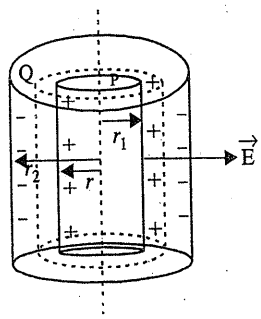
NCERT BACK EXERCISES

NCERT. **2.17. A long charged cylinder of linear charged density λ is surrounded by a hollow co-axial conducting cylinder. What is the electric field in the space between the two cylinders ?**

Ans. A cylinder P has linear charge density, λ, length l and radius r_1.

The charge on cylinder P, $q = \lambda l$.

A hollow co-axial conducting cylinder of length l and radius r_2 surrounds the cylinder P. Charge on cylinder Q = $-q$.



Consider a Gaussian surface in the form of a cylinder of radius r and length l. The electric flux through the curved surface of the Gaussian surface,

$$\phi = \int \vec{E}.\vec{dS} \int E\,dS\cos 0° = E\int dS = E \times 2\pi rl \ldots(i)$$

The electric flux through the circular caps of Gaussian surface = 0 as $\vec{E}$ is perpendicular to the surfaces of the circular caps.

According to Gauss's theorem, $\phi = \dfrac{q}{\varepsilon_0}$

or $E \times 2\pi rl = \dfrac{\lambda l}{\varepsilon_0}$ $\quad \therefore E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$.

NCERT ADDITIONAL EXERCISES

NCERT **2.18. In a hydrogen atom, the electron and proton are bound at a distance of about 0·53 Å :**

(*a*) Estimate the potential energy of the system in *e*V, taking the zero of the potential energy at infinite separation of the electron from proton.

(*b*) What is the minimum work required to free the electron, given that its kinetic energy in the orbit is half the magnitude of potential energy obtained in (*a*) ?

(*c*) What are the answers to (*a*) and (*b*) above if the zero of potential energy is taken at 1·06 Å separation?

Ans. (*a*) P.E., $U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$

$$= \frac{9\times10^9\times(-1{\cdot}6\times10^{-19})(1{\cdot}6\times10^{-19})}{0{\cdot}53\times10^{-10}}$$

$$= -43{\cdot}47 \times 10^{-19}\ \text{J}$$

$$= -\frac{43{\cdot}47\times10^{-19}}{1{\cdot}6\times10^{-19}} = -27{\cdot}17\ \text{eV}$$

Taking zero at infinity,

P.E. $= -27{\cdot}17 - 0 = -27{\cdot}17$ eV

(*b*) K.E. of electron is half of P.E.

$$\therefore \quad \text{K.E.} = \frac{27{\cdot}12}{2} = 13{\cdot}585$$

(K.E. is always positive)

Total energy of electron

$$= -27{\cdot}17 + 13{\cdot}585 = -13{\cdot}585\ \text{eV}$$

Work required to free the electron

$$= 0 - (-13{\cdot}585) = 13{\cdot}585\ \text{eV}.$$

(*c*) P.E. at $1{\cdot}06 \times 10^{-10}$ m separation,

$$U' = \frac{9\times10^9(-1{\cdot}6\times10^{-19})(1{\cdot}6\times10^{-19})}{1{\cdot}06\times10^{-10}}$$

$$= -21{\cdot}74 \times 10^{-19}\ \text{J}$$

$$= -\frac{21{\cdot}74\times10^{-19}}{1{\cdot}06\times10^{-19}} = -13{\cdot}585\ \text{eV}$$

Taking $-13{\cdot}585$ eV as zero of P.E., then

P.E. of the system

$= -27{\cdot}17 - (-13{\cdot}585) = -13{\cdot}585$ eV.

NCERT ADDITIONAL EXERCISES

NCERT. 2.20. **Two charged conducting spheres of radii a and b are connected to each other by a wire. What is the ratio of electric field at the surfaces of the two spheres ? Use the result obtained to explain why charge density on the sharp and pointed ends of a conductor is higher than on its flatter portions.**

Ans. Two charged conducting spheres of radii a and b connected by a wire will reach to same potential.

Using $E = \frac{dV}{dr}$, we get $V = Er$

Then $V = E_1 a$ and $V = E_2 b$

i.e. $E_1 a = E_2 b$ or $\frac{E_1}{E_2} = \frac{b}{a}$.

Clearly electric charge density for the pointed surface will be more because a flat surface can be equated to a spherical surface of large radius and a pointed portion to a spherical surface of small radius.

NCERT ADDITIONAL EXERCISES

NCERT. 2.21. Two charges $-q$ and $+q$ are located at points (0, 0, $-a$) and (0, 0, a), respectively.

(*a*) What is the electrostatic potential at the points (0, 0, z) and (x, y, 0) ?

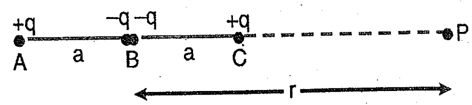
(*b*) Obtain the dependence of potential on the distance r of a point from the origin when $r/a >> 1$.

(*c*) How much work is done in moving a small test charge from the point (5, 0, 0) to (–7, 0, 0) along the x-axis ? Does the answer change if the path of the test charge between the same points is not along the x-axis ?

Ans.

NCERT ADDITIONAL EXERCISES

NCERT. **2.22. Figure shows a charge array known as an *electric quadrupole*. For a point on the axis of the quadrupole, obtain the dependence of potential on r for $r/a >> 1$, and contrast your results with that due to an electric dipole, and an electric monopole (*i.e.*, a single charge.)**



Ans. (*i*) For large distance, r, the potential V

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{(r+a)} - \frac{2q}{r} + \frac{q}{(r-a)}\right)$$

$$= \frac{q}{4\pi\varepsilon_0}\left(\frac{2a^2}{r(r^2-a^2)}\right) \simeq \frac{q(2a^2)}{4\pi\varepsilon_0 r^3}$$

i.e. of $\frac{1}{r^3}$ type.

(*ii*) Due to electric dipole, the potential is of $1/r^2$ type.

(*iii*) Due to an electric monopole, the potential is of $1/r$ type.

MCQ MULTIPLE CHOICE QUESTIONS

(Only One Option Correct)

1. Electric potential due to an electric dipole at a point of distance r from its centre and on the axial line varies as
   (a) r (b) r^{-1}
   (c) r^2 (d) r^{-2}.

Ans. (d).

2. Electric potential due to an electric dipole at a point of distance r on its equatorial line is
   (a) $\frac{1}{4\pi\epsilon_0}\frac{p}{r^2}$ (b) $\frac{1}{4\pi\epsilon_0}\frac{2p}{r^2}$
   (c) $\frac{1}{4\pi\epsilon_0}\frac{p}{r}$ (d) zero.

Ans. (d).

3. Work done to move a charge 1 C from one point to another point on the surface of a conductor is
   (a) 1 volt (b) 2 volt
   (c) 3 volt (d) zero.

Ans. (d). $W = q\,\Delta V = 0$ $(\because \Delta V = 0)$

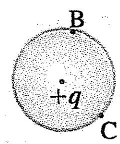
4. Work done in moving a positive charge on an equipotential surface is
   (a) negative (b) positive
   (c) zero (d) infinite.
   (H.P.S.E.B. 2009)

Ans. (c).

5. Electric field E and electric potential V are related as
   (a) $E = \frac{-dr}{dV}$ (b) $E = \frac{-dV}{dr}$
   (c) $E = \frac{dV}{dr}$ (d) $E = \frac{-dV}{dr}$
   (Jharkhand 2015)

Ans. (b)

6. A circle of radius r is drawn with charge $+q$ at the centre. A charge q_0 is brought from the point B to C on the circle. The work done is



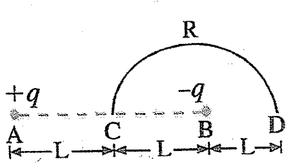
   (a) positive (b) negative
   (c) infinite (d) zero (H.P.S.E.B. 2018 C)

Ans. (d). Work done $= q_0\,\Delta V$. Since $\Delta V = 0$
$\therefore$ $W = 0$

7. At a point A, there is an electric field of 500 Vm^{-1} and potential of 3000 V due to a point charge. The distance between the point charge and point A is
   (a) 6 m (b) 12 m
   (c) 36 m (d) 144 m
   (H.P.S.E.B. 2018 C)

Ans. (a). $\left(r = \frac{V}{E}\right)$

8. Charges $+q$ and $-q$ are placed at points A and B respectively which are at distance 2 L apart. C is the mid point between A and B. The work done in moving a charge $+Q$ along the semicircle CRD is :
   (a) $\frac{Q}{6\pi\epsilon_0 L}$ (b) $\frac{-Q}{6\pi\epsilon_0 L}$
   (c) $\frac{qQ}{6\pi\epsilon_0 L}$ (d) $\frac{-qQ}{6\pi\epsilon_0 L}$.
   (C.B.S.E. PMT 2007)



Ans. (d)

Explanation.

$$W = Q\,[V_D - V_C]$$

$$= Q\left[\frac{1}{4\pi\epsilon_0}\frac{q}{3L} - \frac{1}{4\pi\epsilon_0}\frac{q}{L}\right] = -\frac{qQ}{6\pi\epsilon_0 L}$$

9. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 80 V. The potential at the centre of the sphere is :
   (a) 80 V (b) 800 V
   (c) 8 V (d) Zero.
   (A.F.M.C. 2007)

Ans. (a)

Explanation.

Potential at the centre of sphere= potential on its surface.

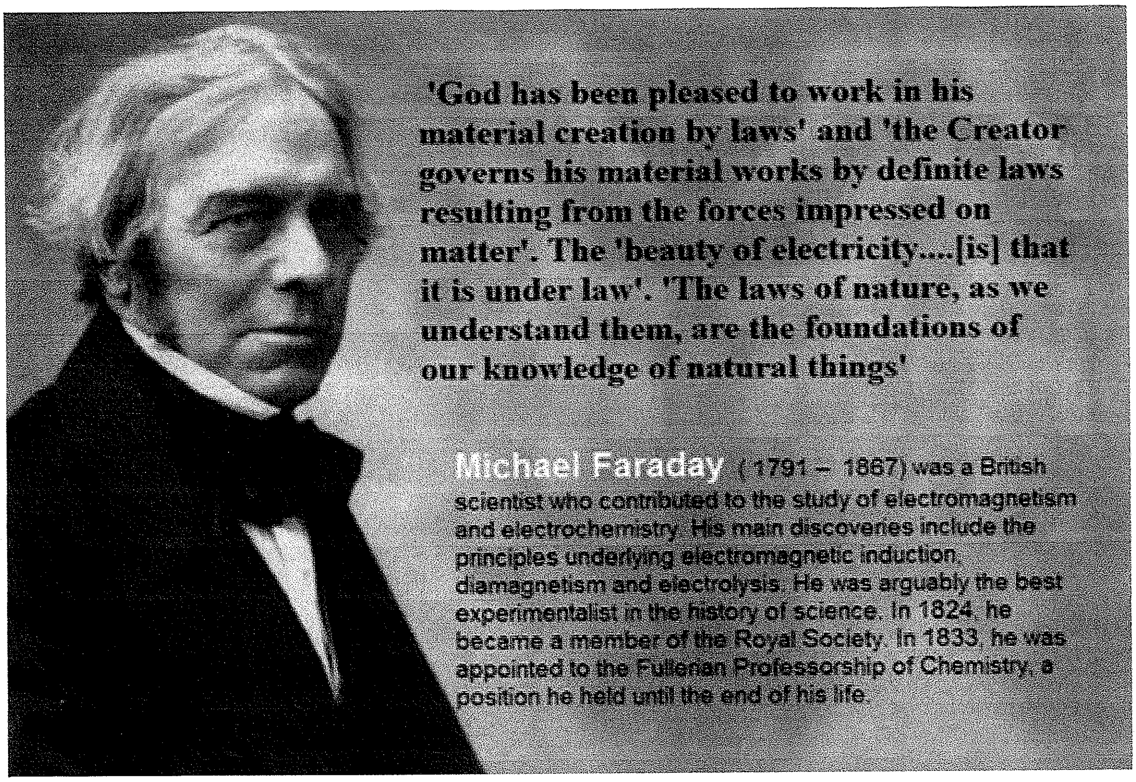
10. The electric potential at a point in free space due to a charge Q coulomb is $Q \times 10^{11}$ volts. The electric field at that point is :
   (a) $12\pi\epsilon_0 Q \times 10^{22}$ V/m
   (b) $4\pi\epsilon_0 Q \times 10^{22}$ V/m
   (c) $12\pi\epsilon_0 Q \times 10^{20}$ V/m
   (d) $4\pi\epsilon_0 Q \times 10^{20}$ V/m.
   (C.B.S.E. A.I.P.M.T. 2008)

Ans. (b)

Explanation.

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r} \quad \therefore r = \frac{1}{4\pi\epsilon_0}\frac{Q}{V}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{Q\times 10^{11}} = \frac{1}{4\pi\epsilon_0 \times 10^{11}}$$



Important Work:-

1. The concept of electric field was Introduced by Michael Faraday.
2. S.I unit of Capacitance is after his Name 'Farad'.
3. Principles of Electromagnetic Induction [E.M.I] [NCERT CH-6]
4. Laws of Electrolysis.

Topic 2: CONDUCTORS & INSULATORS

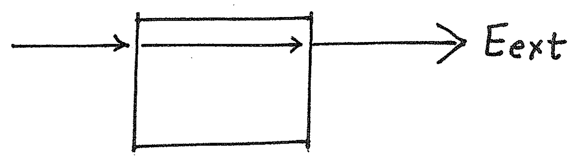
ELECTROSTATICS OF CONDUCTORS:

CONDUCTORS:

Q.1 What are important properties of conductors when kept inside external electric field?

A. Important properties of conductor:

1. inside a conductor, electrostatic field is zero:



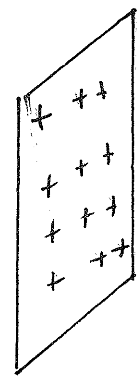
2. At the surface of a charged conductor, electric field must be normal to the surface at every point.

3. The interior of a conductor can have no excess charge in the static situation:

4. Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface.

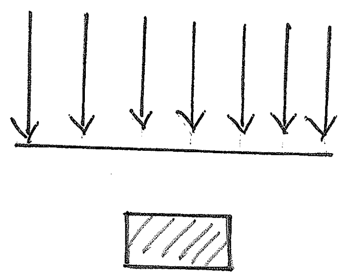
5. Electric field at the surface of a charged conductor:

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$$

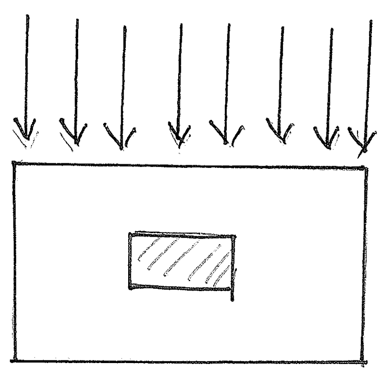


6. Electrostatic shielding:

WAY 1:



WAY 2:



Q.2 NCERT **Example 2.7**

(a) A comb run through one's dry hair attracts small bits of paper. Why?
What happens if the hair is wet or if it is a rainy day? (Remember, a paper does not conduct electricity.)

(b) Ordinary rubber is an insulator. But special rubber tyres of aircraft are made slightly conducting. Why is this necessary?

(c) Vehicles carrying inflammable materials usually have metallic ropes touching the ground during motion. Why?

(d) A bird perches on a bare high power line, and nothing happens to the bird. A man standing on the ground touches the same line and gets a fatal shock. Why?

Solution

(a) This is because the comb gets charged by friction. The molecules in the paper gets polarised by the charged comb, resulting in a net force of attraction. If the hair is wet, or if it is rainy day, friction between hair and the comb reduces. The comb does not get charged and thus it will not attract small bits of paper.

(b) To enable them to conduct charge (produced by friction) to the ground; as too much of static electricity accumulated may result in spark and result in fire.

(c) Reason similar to (b).

(d) Current passes only when there is difference in potential.

Dielectrics and Polarisation

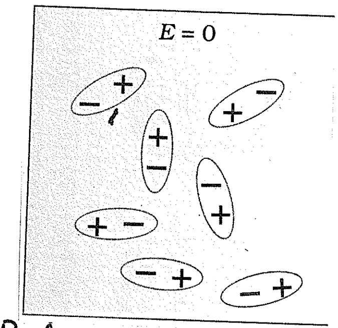
Q.3 What are dielectrics? Write their important types.

A. Dielectrics are non-conducting (insulating) substances. Which have no free electrons as charge carriers.

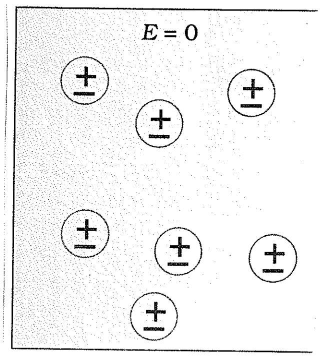
Dielectrics are of two types:

1. Polar dielectrics:

2. Non polar dielectrics:



a) Polar

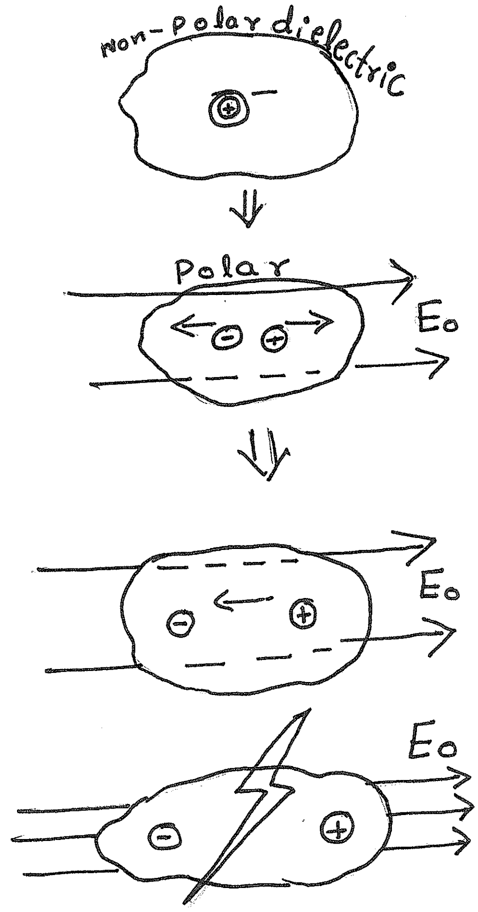


b) Non-polar

Q.4 What is dielectric constant or relative permittivity ? K or ϵ_r

Q.5 What are the properties of Dielectrics when kept inside external electric field? Also explain polaristion on the basis of these properties?

A.



POLARISATION:—

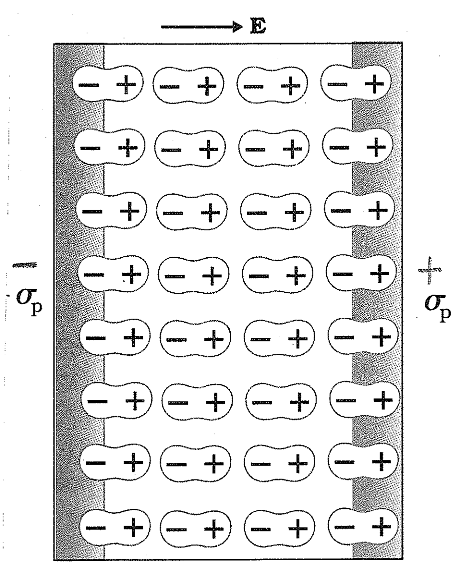


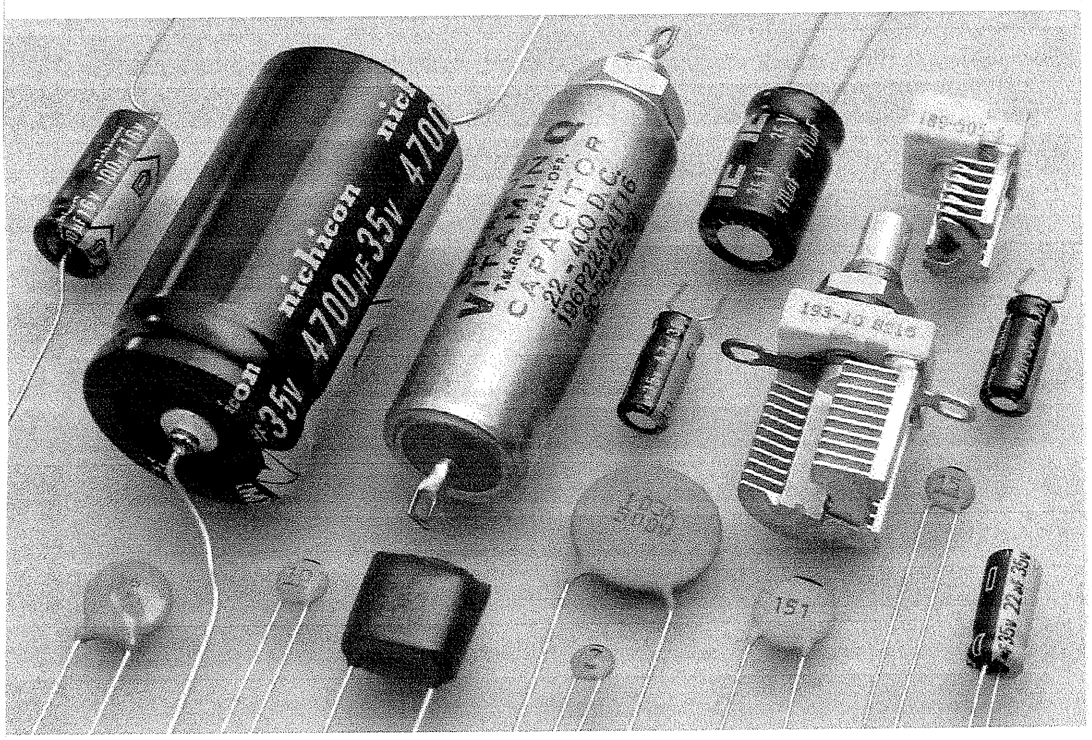
FIGURE 2.23 A uniformly polarised dielectric amounts to induced surface charge density, but no volume charge density.

$$\vec{P} = \chi_e \vec{E}$$

CAPACITANCE

Consumer Electronics and Computer Systems   Consumer Electronics and Tips   Electronics
Industrial electronics and automation

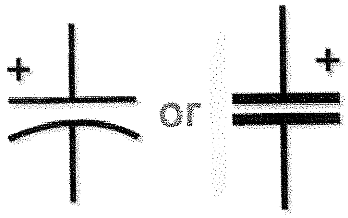
Capacitors



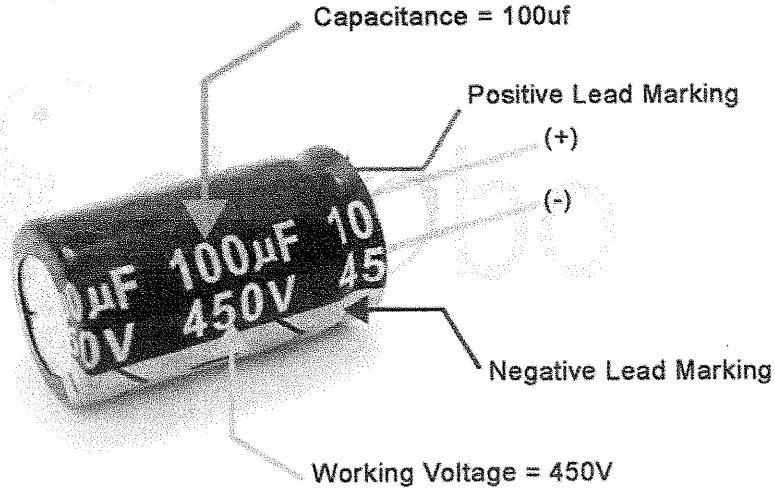
IMPORTANT DIAGRAMS TO UNDERSTAND CAPACITOR

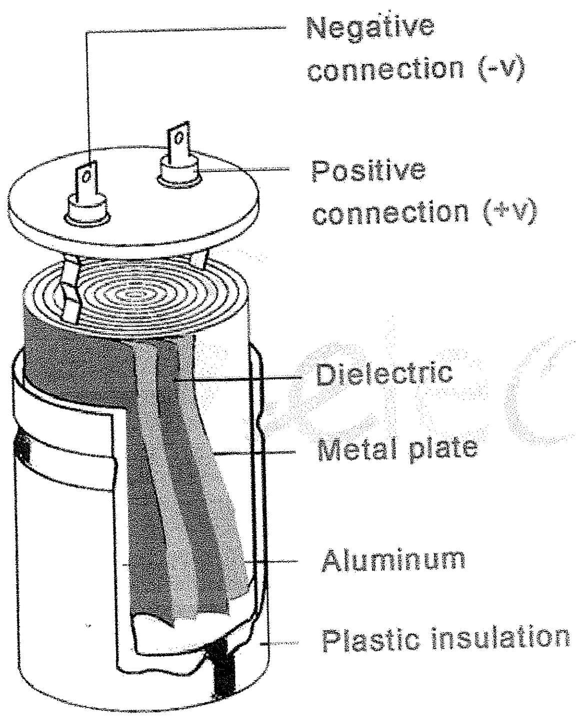
Electrolytic capacitor

Symbol



Shape





Inside the Capacitor

TOPIC-3 CAPACITORS AND CAPACITANCE

Capacitor:

Capacitance:

Q.1 What is capacitance ? write its units.

A.

Q.2 What are various types of capacitors?

A. Various types of capacitors are:

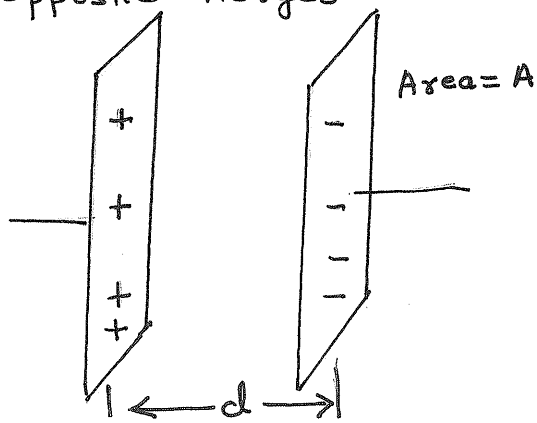
1. Parallel plate capacitor (4 FORMS)
2. Isolated sphere capacitor
3. Spherical capacitor
4. Cylindrical capacitor

THE PARALLEL PLATE CAPACITOR

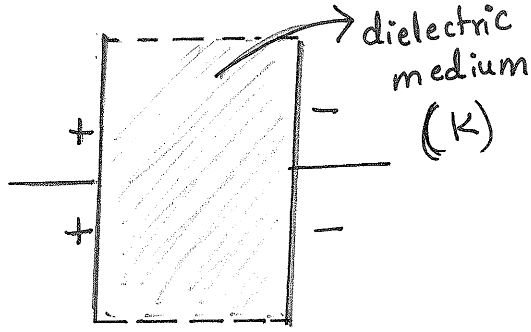
A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance. Its capacitance depends the intervening medium between the two plates.

Q.3 Study parallel plate capacitor for its capacitance when it is air filled?

A. Parallel plate capacitor consists of 2 parallel metallic plates of area A each and seperated by distance d in such a way that they are provided equal and opposite charges as below:-

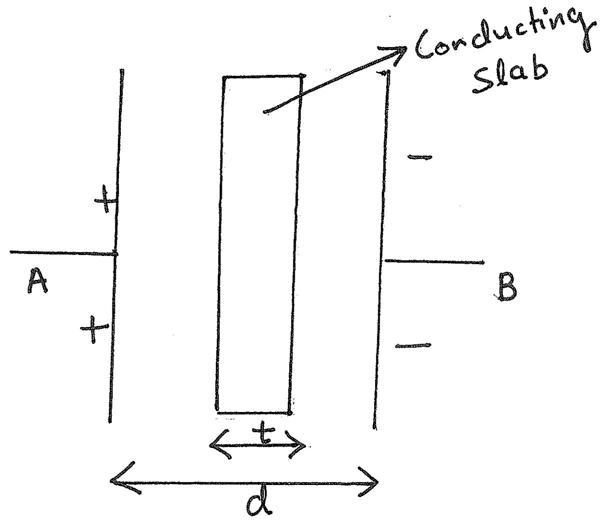


Q.4 Study parallel plate capacitor for its capacitance when it is medium (dielectric) filled?



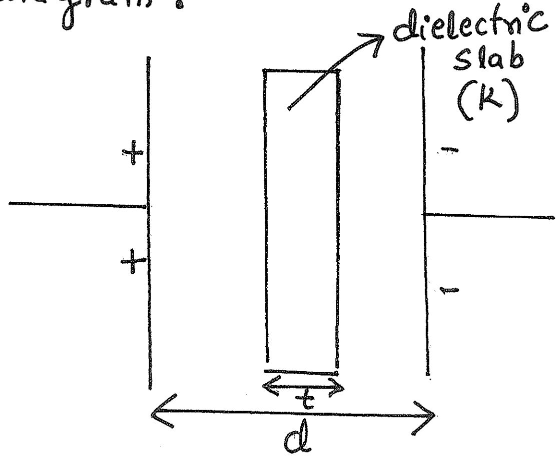
Q.5 Study parallel plate capacitor for its capacitance when an conducting slab of thickness t is inserted inside it?

Ans. Consider a parallel plate capacitor having plate area A and distance of seperation 'd'. Now an conducting slab of thickness 't' is inserted in between two plates: due to seperation of free electrons by the means of Induction an opposite field will induced inside the slab. which will cancels the external applied field as a result Net field Inside the slab will be zero. as shown in the diagram:—



Q.6 Study parallel plate capacitor for its capacitance when an dielectric slab of thickness t is inserted inside it?

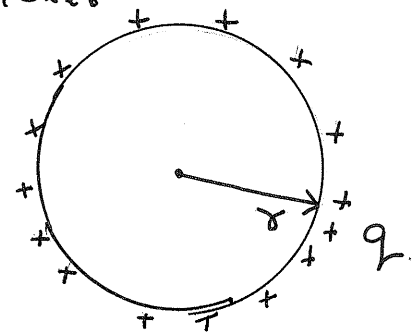
Ans. Consider a parallel plate capacitor having plate area A and distance of seperation 'd' Now a dielectric slab of thickness 't' is inserted in between two plates :- due to polarisation of dielectric atoms an opposite field will induced inside the slab which will decreases the field inside it by $\frac{1}{K}$ times of applied field E as shown in diagram :-



SPECIAL CAPACITOR:

Q.7 Find the capacitance of an isolated sphere?

A. Isolated sphere is a single charged shell:-

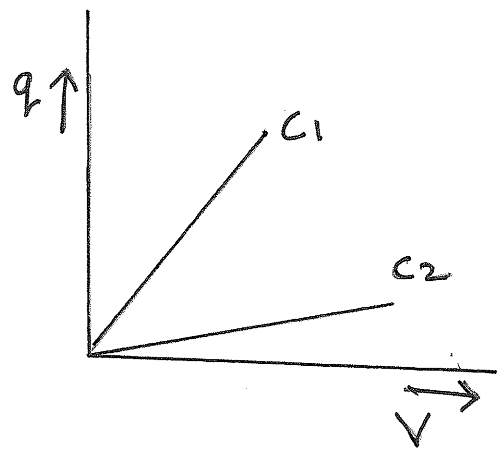


Q.8 Find the capacitance of earth? (given radius of earth R=6.4 × 10^6 km)

A.

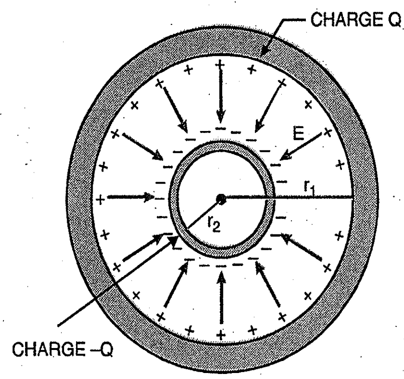
Q.9 Which capacitor is of higher capacitance?

A.



NCERT ADDITIONAL EXERCISES

Q. 10. → NCERT. **2.29. A spherical capacitor consists of two concentric spherical conductors held in position by suitable insulating supports (Figure.) Show that the capacitance of a spherical capacitor is given by**



$$C = \frac{4\pi\varepsilon_0 r_1 r_2}{r_1 - r_2}$$

where r_1 and r_2 are the radii of outer and inner spheres, respectively.

Ans:-

NCERT ADDITIONAL EXERCISES

NCERT EXAMPLE

NCERT. **Example 2.8** A slab of material of dielectric constant K has the same area as the plates of a parallel-plate capacitor but has a thickness $(3/4)d$, where d is the separation of the plates. How is the capacitance changed when the slab is inserted between the plates?

Ans.

TOPIC -4 COMBINATION OF CAPACITORS

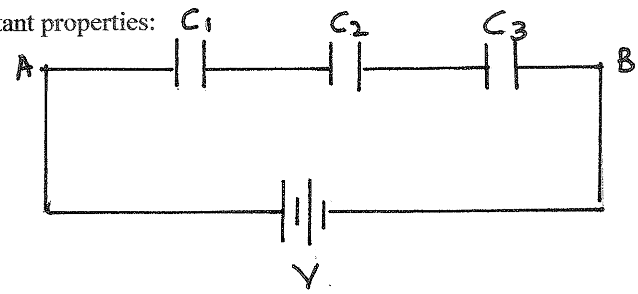
WE CAN COMBINE SEVERAL CAPACITORS OF CAPACITANCE C_1, C_2 ...... C_N TO OBTAIN A SYSTEM WITH SOME EFFECTIVE CAPACITANCE C

TWO BASIC COMBINATION OF CAPACITORS ARE:

1. SERIES COMBINATION

2. PARALLEL COMBINATION

Q.1 What is series combination of capacitors? Write its important properties:



A.

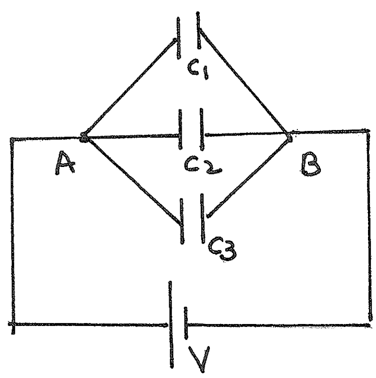
Properties:

1.

2.

3.

Q.2 What is parallel combination of capacitors? Write its important properties:



A.

Properties:

1.

2.

3.

NUMERICAL PROBLEMS BASED ON SERIES AND PARALLEL

TRICKS:

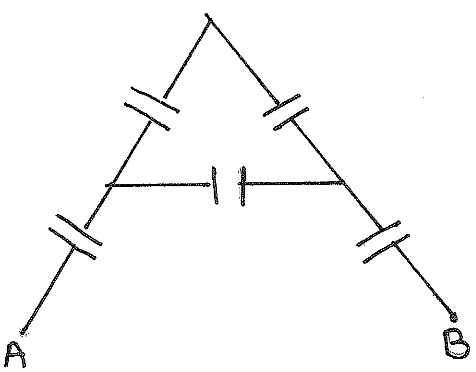
1.

2.

Q. 3 Find net capacitance and net charge of the circuit below:

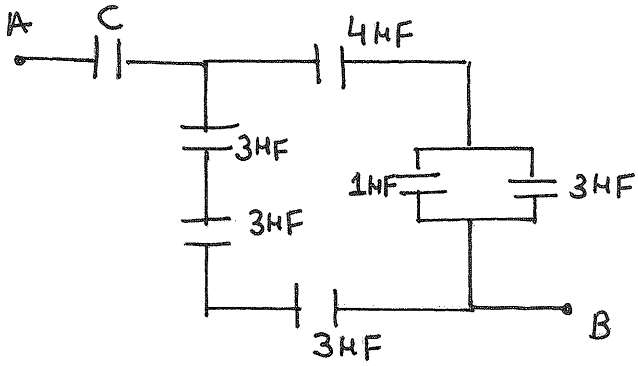
A.

Q.4 Find net capacitance across A and B ?



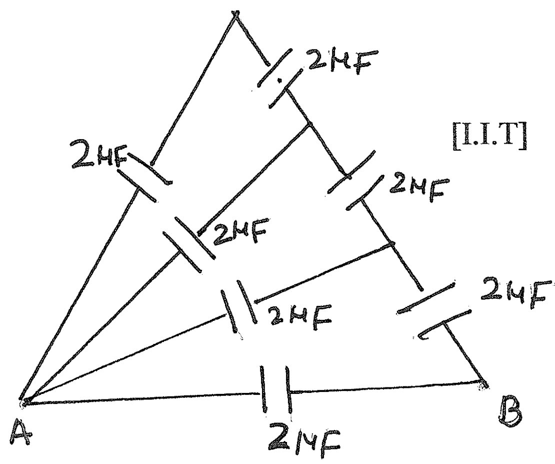
each Capacitor = 2μF

Q.5 Find the missing value of capacitance C if the effective capacitance across A & B is 10μF.



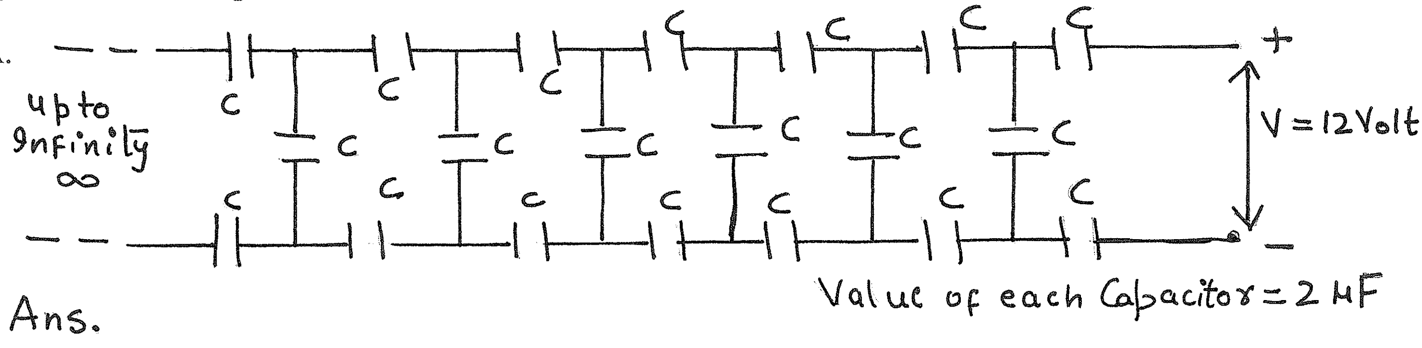
Q.6 find the net capacitance across A & B

[I.I.T]



Q.7 Find the net capacitance and charge in the infinite chain of 2μF each as shown below.

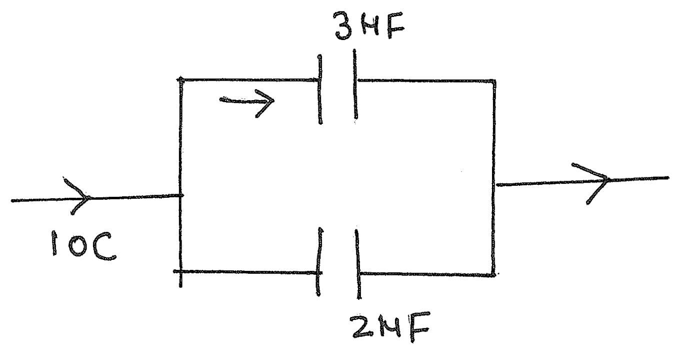
A.



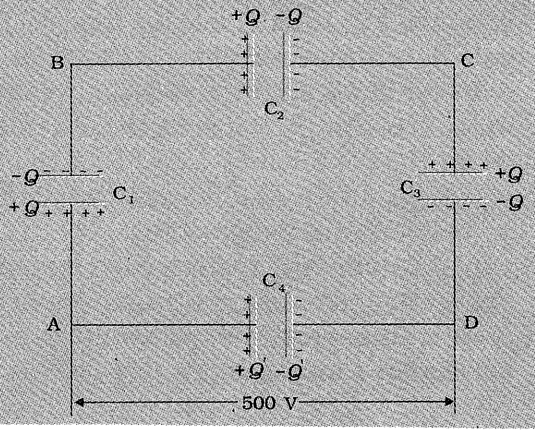
Ans.

Q.8 Find the charge stored in 3μF capacitor in the circuit diagram below? (Branching of charges)

A.



Q.9 NCERT **Example 2.9** A network of four 10 μF capacitors is connected to a 500 V supply, as shown in Fig. 2.29. Determine (a) the equivalent capacitance of the network and (b) the charge on each capacitor. (Note, the *charge on a capacitor* is the charge on the plate with higher potential, equal and opposite to the charge on the plate with lower potential.)



Solution:

NCERT BACK EXERCISES

NCERT. **2.5.** **A parallel plate capacitor with air between the plates has a capacitance of 8 *p*F (1 *p*F = 10^{-12} F.) 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.

NCERT BACK EXERCISES

NCERT. **2.6.** **Three capacitors each of capacitance 9 *p*F are connected in series.**

(*a*) What is the total capacitance of the combination?

(*b*) What is the potential difference across each capacitor if the combination is connected to a 120 V supply ?

Ans.

NCERT BACK EXERCISES

NCERT. **2.7. Three capacitors of capacitances 2 pF, 3 pF and 4pF are connected in parallel.**

(*a*) What is the total capacitance of the combination?

(*b*) Determine the charge on each capacitor if the combination is connected to a 100 V supply.

Ans. (*a*) Total capacitance

NCERT BACK EXERCISES

2.8. **In a parallel plate capacitor with air between the plates, each plate has an area of 6×10^{-3} m^2 and the distance between the plates is 3 mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 100 V supply, what is the charge on each plate of the capacitor ?**

Ans. Using $C = \frac{\epsilon_0 A}{d}$, we get

NCERT BACK EXERCISES

2.9. **Explain what would happen if in the capacitor given in Q. 2.8, a 3 mm thick mica sheet (of dielectric constant = 6) were inserted between the plates,**

(*a*) while the voltage supply remained connected.

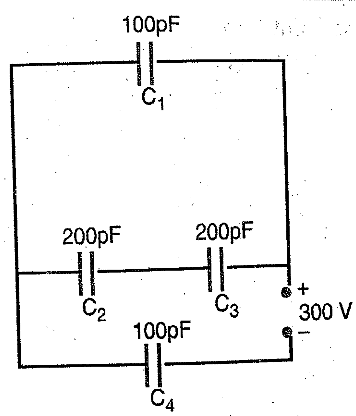
(*b*) after the supply was disconnected.

NCERT ADDITIONAL EXERCISES

2.23. An electrical technician requires a capacitance of 2 μF in a circuit across a potential difference of 1 kV. A large number of 1 μF capacitors are available to him each of which can withstand a potential difference of not more than 400 V. Suggest a possible arrangement that requires the minimum number of capacitors.

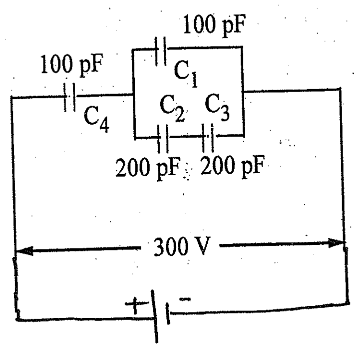
NCERT ADDITIONAL EXERCISES

NCERT. **2.25. Obtain the equivalent capacitance of the network in figure. For a 300 V supply, determine the charge and voltage across each capacitor.**

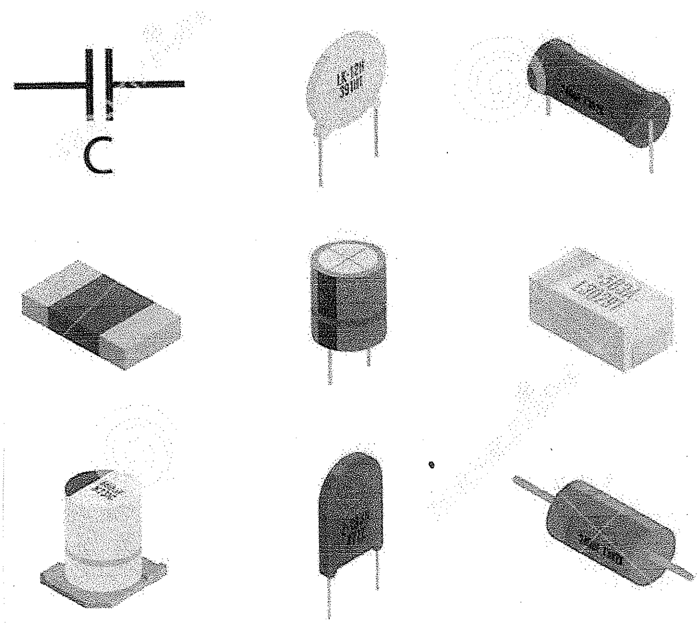


(C.B.S.E. 2008) 2015.

Ans. The equivalent circuit is as shown below :



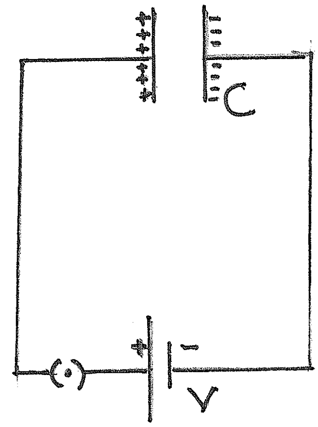
NCERT ADDITIONAL EXERCISES



ENERGY ASSOCIATED WITH CAPACITOR

Q.10 Explain electrostatic energy stored in a capacitor? Obtain an expression for it?

A.



Q.11 What is energy density in capacitor ?

A.

Q.12 NCERT **Example 2.10** (a) A 900 pF capacitor is charged by 100 V battery [Fig. 2.31(a)]. How much electrostatic energy is stored by the capacitor? (b) The capacitor is disconnected from the battery and connected to another 900 pF capacitor [Fig. 2.31(b)]. What is the electrostatic energy stored by the system?

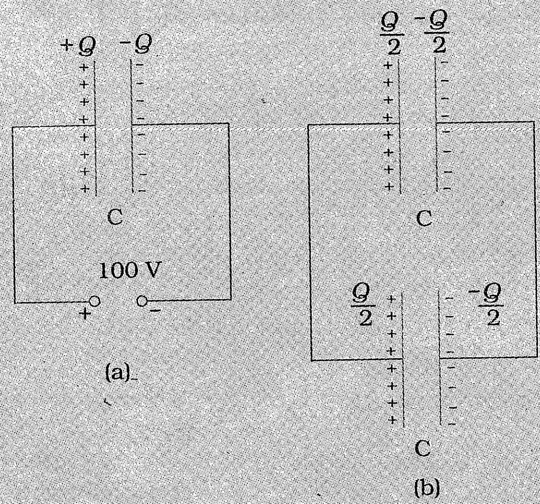


FIGURE 2.31

Solution :

NCERT BACK EXERCISES

NCERT. **2.10.** **A 12 *p*F capacitor is connected to a 50 V battery. How much electrostatic energy is stored in the capacitor ?**

Ans. $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 12 \times 10^{-12} \times 50 \times 50 = 1{\cdot}5 \times 10^{-8}$ J.

NCERT. **2.11.** **A 600 *p*F capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 600 *p*F capacitor. How much electrostatic energy is lost in the process ?**

NCERT ADDITIONAL EXERCISES

NCERT. **2.27.** A 4 μF capacitor is charged by a 200 V supply. It is then disconnected from the supply, and is connected to another uncharged 2 μF capacitor. How much electrostatic energy of the first capacitor is lost in the form of heat and electromagnetic radiation ?

Ans.

VAN DE GRAAFF GENERATOR

Q.1 Write the explanation, principle, construction, working and uses of Van de graaff generator? Also write the role of CH_4 and N_2 gas in it?

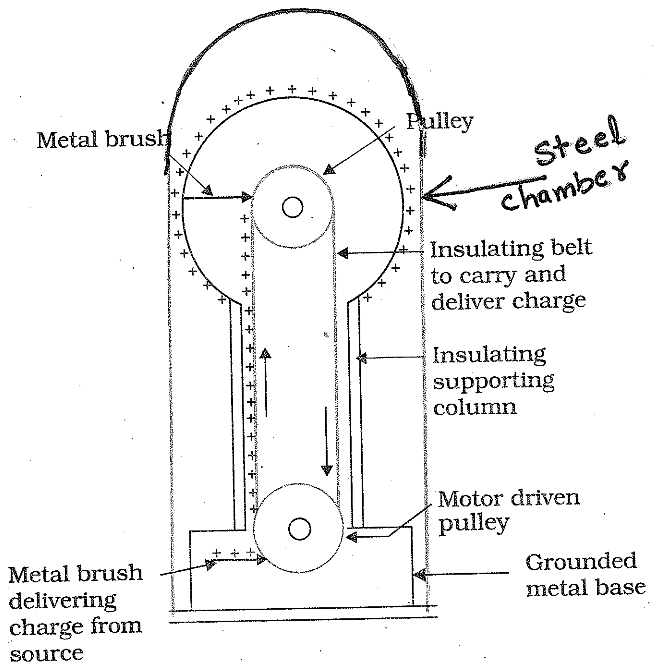
Ans. DEFINITION:

PRINCIPLE:

1. Corona discharge: (action of sharp points)

2. Potential difference of two concentric charged hollow sphere is independent on the charge of outer sphere.

CONSTRUCTION & WORKING:



USES OF VAN DE GRAAFF GENERATOR:

ROLE OF CH_4 AND N_2 GAS IN GENERATOR

NCERT ADDITIONAL EXERCISES

NCERT. **2.35.** **In a van de Graaff type generator a spherical metal shell is to be a 15×10^6 V electrode. The dielectric strength of the gas surrounding the electrode is 5×10^7 Vm^{-1}. What is the minimum radius of the spherical shell required ? (You will learn from this exercise why one cannot build an electrostatic generator using a very small shell which requires a small charge to acquire a high potential.)**

(*C.B.S.E. 2008*)

Ans.

NCERT ADDITIONAL EXERCISES

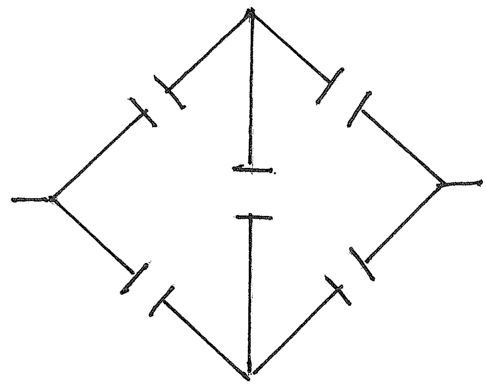
NCERT. **2.36.** A small sphere of radius r_1 and charge q_1 is enclosed by a spherical shell of radius r_2 and charge q_2. Show that if q_1 is positive, charge will necessarily flow from the sphere to the shell (when the two are connected by a wire) no matter what the charge q_2 on the shell is.

Ans.

ADDITIONAL questions :

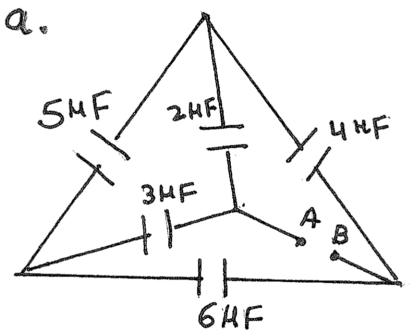
Q.1 How we can apply wheat stone bridge in capacitor circuit to find net capacitance, explain it by the help of an example?

A.

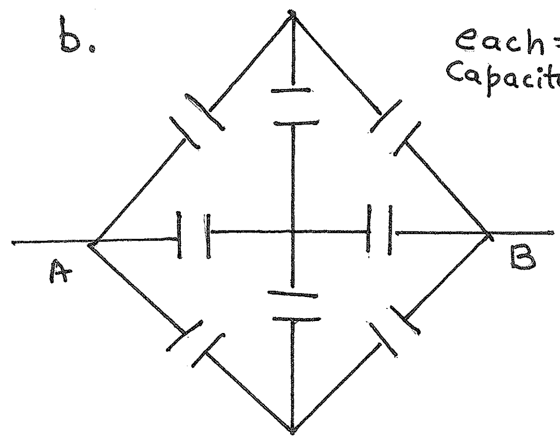


Q.2 find net capacitance across A & B in the given circuits?

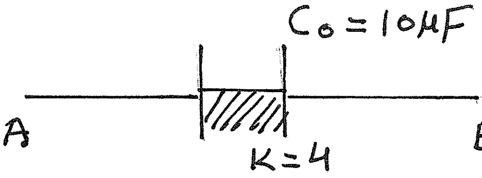
a.



b.

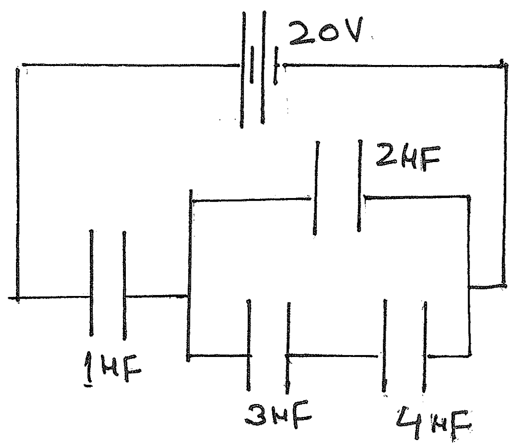


C.



Q.3 find net capacitance, NET CHARGE and ENERGY STORED in 2μf capacitor in the circuit diagram below?

A.



ADDITIONAL QUESTIONS ON CAPACITANCE FOR EXTRA MARKS

MASS PHYSICS

ADDITIONAL QUESTIONS FOR EXTRA MARKS

NCERT ADDITIONAL EXERCISES

NCERT. 2.24. **What is the area of the plates of a 2 F parallel plate capacitor, given that the separation between the plates is 0·5 cm ? (You will realise from your answer why ordinary capacitors are in the range of μF or less. However, electrolytic capacitors do have a much larger capacitance (0·1 F) because of very minute separation between the conductors.)**

Ans. Using $C = \frac{\epsilon_0 A}{d}$, we get

$$A = \frac{Cd}{\epsilon_0} = \frac{2 \times 0{\cdot}5 \times 10^{-2}}{8{\cdot}854 \times 10^{-12}}$$

$$= 1{\cdot}13 \times 10^{9}\ m^2.$$

NCERT ADDITIONAL EXERCISES

NCERT. **2.26. The plates of a parallel plate capacitor have an area of 90 cm^2 each and are separated by 2·5 mm. The capacitor is charged by connecting it to a 400 V supply.**

(a) How much electrostatic energy is stored by the capacitor ?

(b) View this energy as stored in the electrostatic field between the plates, and obtain the energy per unit volume *u*. Hence arrive at a relation between *u* and the magnitude of electric field E between the plates.

Ans. Using $C = \frac{\epsilon_0 A}{d}$,

we get $C = \frac{8{\cdot}854 \times 10^{-12} \times 90 \times 10^{-4}}{2{\cdot}5 \times 10^{-3}}$

$= 3{\cdot}187 \times 10^{-11}$ F

Work done,

$$W = \frac{1}{2} CV^2$$

$$= \frac{1}{2} \times 3{\cdot}187 \times 10^{-11} \times 400^2$$

$$= 2{\cdot}55 \times 10^{-6} \text{ J}.$$

Energy per unit volume,

$U = 0{\cdot}113$ J m^{-3}

Energy per unit volume,

$$U = \frac{1}{2}\frac{CV^2}{Ad}$$

But $E = \frac{V}{d}$ *i.e.* $V = Ed$

∴ Energy per unit volume,

$$U = \frac{1}{2}\frac{CE^2 d^2}{Ad} = \frac{1}{2}\frac{\varepsilon_0 A}{d}\frac{E^2 d^2}{Ad}$$

Relation between U and E is,

$$U = \frac{1}{2}\epsilon_0 E^2.$$

NCERT ADDITIONAL EXERCISES

NCERT. **2.28. Show that the force on each plate of a parallel plate capacitor has a magnitude equal to (½) QE, where Q is the charge on the capacitor and E is the magnitude of electric field between the plates. Explain the origin of the factor ½.**

Ans. Let F be the force on each plate of the capacitor. If the distance between the plates of the capacitor is increased by dx, then work done = F dx. This work done is stored as the potential energy of the capacitor. The increase in the volume of capacitor = A dx

The energy stored in capacitor = energy density × increase in volume $= \left(\frac{1}{2}\varepsilon_0 E^2\right) A\,dx$

$$\text{or } F\,dx = \frac{1}{2}\varepsilon_0 E^2 A\,dx$$

$$\text{or } F = \frac{1}{2}\varepsilon_0 E^2 A = \frac{1}{2}(\varepsilon_0 A\, E)E = \frac{1}{2}\left(\varepsilon_0 A\frac{V}{d}\right)E$$

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

$$\because F = \frac{1}{2}(C\,V)E \quad \text{or } F = \frac{1}{2}QE \qquad (\because Q = CV)$$

Since electric field inside a conductor is zero and outside the conductor, the electric field is E. Therefore, average of electric field $\left(\frac{0+E}{2} = \frac{E}{2}\right)$ contributes to the force.

NCERT ADDITIONAL EXERCISES

NCERT - **2.30. A spherical capacitor has an inner sphere of radius 12 cm and an outer sphere of radius 13 cm. The outer sphere is earthed and the inner sphere is given a charge of 2·5 μC. The space between the concentric spheres is filled with a liquid of dielectric constant 32.**

(a) Determine the capacitance of the capacitor.

(b) What is the potential of the inner sphere ?

(c) Compare the capacitance of this capacitor with that of an isolated sphere of radius 12 cm. Explain why the latter is much smaller.

Ans. (a) Using $C = 4\pi \epsilon_0 k \frac{ab}{b-a}$, we get

$$C = \frac{1}{9\times10^9} \frac{32\times12\times10^{-2}\times13\times10^{-2}}{(13\times10^{-2})-(12\times10^{-2})}$$

$$= 5\cdot547 \times 10^{-9} \text{ F}$$

(b) $$V = \frac{q}{C} = \frac{2\cdot5\times10^{-6}}{5\cdot547\times10^{-9}} = 450\cdot7 \text{ V}$$

(c) $$C' = 4\pi\epsilon_0 r$$

$$= \frac{1}{9\times10^9} \times 12 \times 10^{-12}$$

$$= 1\cdot33 \times 10^{-11} \text{ F}$$

$$\frac{C}{C'} = \frac{5\cdot547\times10^{-9}}{1\cdot333\times10^{-11}} = 416.$$

Clearly C′ is small because there is no nearby earthed conducting plate.

NCERT ADDITIONAL EXERCISES

Imp

2.31. Answer carefully :

(a) Two large conducting spheres carrying charges Q_1 and Q_2 are brought close to each other. Is the magnitude of electrostatic force between them exactly given by $Q_1Q_2/4\pi\varepsilon_0 r^2$, where r is the distance between their centres ?

(b) If Coulomb's law involved $1/r^3$ dependence (instead of $1/r^2$), would Gauss's law be still true ?

(c) A small test charge is released at rest at a point in an electrostatic field configuration. Will it travel along the field line passing through that point ?

(d) What is the work done by the field of a nucleus in a complete circular orbit of the electron ? What if the orbit is elliptical ?

(e) We know that electric field is discontinuous across the surface of a charged conductor. Is electric potential also discontinuous there ?

(f) What meaning would you give to the capacitance of a single conductor ?

(g) Guess a possible reason why water has a much greater dielectric constant (= 80) than say, mica (= 6).

NCERT ADDITIONAL EXERCISES

NCERT 2.32. **A cylindrical capacitor has two co-axial cylinders of length 15 cm and radii 1·5 cm and 1·4 cm. The outer cylinder is earthed and the inner cylinder is given a charge of 3·5 μC. Determine the capacitance of the system and the potential of the inner cylinder. Neglect end effects. (*i.e.*, bending of field lines at the ends.)**

Ans. ***Capacitance of a cylindrical capacitor*** is given by

$$C = \frac{2\pi \epsilon_0 l}{2{\cdot}303 \times \log_{10} \frac{b}{a}}$$

→ Capacitance of cylindrical Capacitance

$$\Rightarrow C = \frac{2\pi(8{\cdot}854 \times 10^{-12})(15 \times 10^{-2})}{2{\cdot}303 \log_{10}\left(\frac{1{\cdot}5 \times 10^{-2}}{1{\cdot}4 \times 10^{-2}}\right)}$$

$$= 1{\cdot}21 \times 10^{-10} \text{ F.}$$

Potential of inner cylinder

$$V = \frac{q}{C} = \frac{3{\cdot}5 \times 10^{-6}}{1{\cdot}21 \times 10^{-10}} = 2{\cdot}89 \times 10^4 \text{ V.}$$

NCERT ADDITIONAL EXERCISES

NCERT. **2.33. A parallel plate capacitor is to be designed with a voltage rating 1 kV, using a material of dielectric constant 3 and dielectric strength about 10^7 Vm^{-1}. (Dielectric strength is the maximum electric field a material can tolerate without breakdown, *i.e.*, without starting to conduct electricity through partial ionisation.) For safety, we should like the field never to exceed, say 10% of the dielectric strength. What minimum area of the plates is required to have a capacitance of 50 *p*F ?**

Ans. 10% of the given field *i.e.* 10^7 V m^{-1} gives E = 0·1 × 10^7 V m^{-1}

Using $E = \frac{dV}{dr}$

i.e. $E = \frac{V}{r}$, we get

$$r = \frac{V}{E} = \frac{1000}{0{\cdot}1 \times 10^7} = 10^{-3} \text{ m}$$

Using $C = \frac{\epsilon_0 \epsilon_r A}{d}$, we get

$$A = \frac{Cd}{\epsilon_0 \epsilon_r} = \frac{Cr}{\epsilon_0 \epsilon_r}$$

$$= \frac{(50 \times 10^{-12})(10^{-3})}{8{\cdot}854 \times 10^{-12} \times 3}$$

$= 19 \text{ cm}^2$.

NCERT ADDITIONAL EXERCISES

NCERT.

2.37. Answer the following :

(*a*) The top of the atmosphere is at about 400 kV with respect to the surface of the earth, corresponding to an electric field that decrases with altitude. Near the surface of the earth, the field is about 100 Vm^{-1}. Why then do we not get an electric shock as we step out of our house into the open ? (Assume the house to be a stell cage so there is no field inside !)

(*b*) A man fixes outside his house one evening a two metre high insulating slab carrying on its top a large aluminium sheet of area 1 m^2. Will he get an electric shock if he touches the metal sheet next morning ?

(*c*) The discharging current in the atmosphere due to the small conductivity of air is known to be 1800 A on an average over the globe. Why then does the atmosphere not discharge itself completely in due course and become electrically neutral ? In other words, what keeps the atmosphere charged ?

(*d*) What are the forms of energy into which the electrical energy of the atmosphere is dissipated during a lightning ?

[Hint. The earth has an electic field of about 100 Vm^{-1} at its surface in the downward direction, corresponding to a surface charge density = -10^{-9} C m^{-2}. Due to the slight conductivity of the atmosphere up to about 50 km (beyond which it is good conductor), about +1800 C is pumped every second into the earth as a whole. The earth, however, does not get discharged since thunderstorms and lightning occuring continually all over the globe pump an equal amount of negative charge on the earth.]

Ans. (*a*) Our body and the earth surface become equipotential *(at equal potential)*. It means there is no potential difference between the earth and our body. Hence no current flows through our body and therefore we do not experience an electric shock.

(*b*) Yes. The aluminium sheet and the earth form a capacitor with the insulating slab as dielectric. The down pour of the atmospheric charge will raise the potential of the sheet of aluminium. When we touch the aluminium sheet, charge will flow to the earth through our body. This flow of charge constitutes on electric current and we will experience a shock.

(*c*) No doubt the atmosphere conitnuously gets charged due to lightning, thunderstroms but simultaneously it gets discharged through normal weather zones. This keeps the system balanced.

(*d*) Electrical energy of the atmosphere appears as light, sound and heat energies during thunder storms and lightning.

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

IMPORTANT MCQS BASED ON CAPACITANCE

MCQ MULTIPLE CHOICE QUESTIONS

(Only One Option Correct)

1. Three capacitors of capacitances 2 μF, 4 μF, 6 μF are connected is series. The equivalent capacitance is

(a) 12 μF (b) $\frac{11}{16}$ μF

(c) $\frac{12}{11}$ μF (d) 12 × 11 μF.

Ans. (c). $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

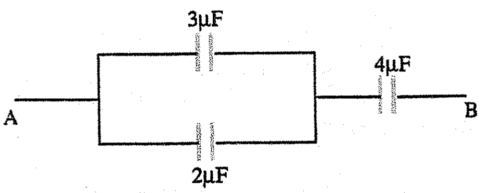
2. Three capacitors of capacitances 1μF, 2 μF and 3 μF are connected in parallel. The equivalent capacitance is

(a) 6 μF (b) $\frac{11}{16}$ μF

(c) $\frac{1}{6}$ μF (d) 0·55 μF.

Ans. (a). $C = C_1 + C_2 + C_3$.

3. The equivalent capacity between A and B is :



(a) $\frac{20}{9}$ μF (b) 9 μF

(c) 1 μF (d) $\frac{1}{9}$ μF.

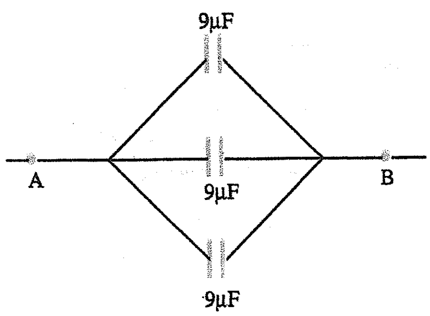
(Bihar Board 2013)

Ans. (a).

Explanation.

$$C = \frac{(C_1 + C_2)C_3}{C_1 + C_2 + C_3} = \frac{5 \times 4}{9} = \frac{20}{9} \mu F.$$

4. What will be the resultant capacitance of the capacitors connected as shown in Fig. ?



(a) 1/3 μF (b) 27 μF

(c) 9/3 μF (d) 27/3 μF.

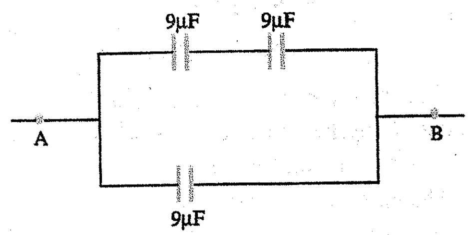
(H.P.S.E.B. 2013)

Ans. (b).

Explanation.

$C = C_1 + C_2 + C_3 = 27$ μF.

5. What will be the resultant capacitance of the capacitors connected as shown in Fig. between the points A and B ?



(a) 11·5 μF (b) 12·5 μF

(c) 13·5 μF (d) 14·5 μF.

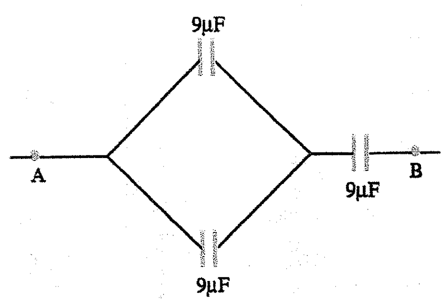
(H.P.S.E.B. 2013)

Ans. (c).

Explanation.

$$C = \frac{C_1C_2}{C_1+C_2} + C_3 = \frac{9\times9}{9+9} + 9 = \frac{27}{2} = 13\cdot5 \text{ μF}.$$

6. What will be the resultant capacitance of the capacitors connected as shown in Fig. between the points A and B ?



(a) 6 μF (b) 2 μF

(c) 27 μF (d) 4 μF. *(H.P.S.E.B. 2013)*

Ans. (a).

Explanation.

$C' = C_1 + C_2 = 18$ μF

$$\therefore \ C = \frac{C'C_3}{C'+C_3} = \frac{18\times9}{27} = 6 \text{ μF}.$$

7. For capacitance in series, total capacitance C is given by,

(a) $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\ldots$

(b) $C = C_1 + C_2 + \ldots$

(c) $C = C_1C_2 + C_2C_3 + \ldots$

(d) $C = \frac{1}{C_1+C_2+\ldots}$ *(Haryana 2015)*

ANS. (a). $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\ldots\ldots\ldots\ldots\ldots$

8. For capacitance in parallel, total capacitance C is given by,

(a) $C = C_1 + C_2 + \ldots$

(b) $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\ldots$

(c) $C = C_1C_2 + C_2C_3 + \ldots$

(d) $C=\frac{1}{C_1+C_2+C_3+\ldots}$ *(Haryana 2015)*

ANS. (a). $C_1 + C_2 + C_3 \ldots\ldots$

9. Energy stored in a capacitor of 10 pF connected to a 100 V battery is

(a) 10×10^{-8} J (b) 5×10^{-10} J

(c) 5×10^{-8} J (d) 10^{-10} J.

ANS. (c). $U = \frac{1}{2}CV^2 = \frac{1}{2} \times 10 \times 10^{-12} \times 10^4$

$= 5 \times 10^{-8}$ J

10. Energy per unit volume for a capacitor having area A and separation d kept at potential difference V is given by :

(a) $\frac{1}{2}\frac{\epsilon_0 V^2}{d^2}$ (b) $\frac{1}{2\epsilon_0}\frac{V^2}{d^2}$

(c) $\frac{1}{2}CV^2$ (d) $\frac{Q^2}{2C}$.

(Meghalaya, C.B.S.E. 2001)

ANS. (a).

Energy per unit volume of capacitor

$$= \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\frac{\epsilon_0 V^2}{d^2} \left(\because E = \frac{V}{d}\right)$$

11. A parallel plate air capacitor has a capacitance 18 μF. If the distance between plates is trebled and a dielectric is introduced, the capacitance becomes 72 μF. The dielectric constant of the medium is :

(a) 4 (b) 9

(c) 12 (d) 2

(e) 0. *(Kerala Med. 2001)*

ANS. (c).

$$C_0 = \frac{\epsilon_0 A}{d} \text{ and } C = \frac{K\epsilon_0 A}{3d}$$

$$\therefore \quad C = \frac{KC_0}{3} \text{ or } K = \frac{3C}{C_0} = \frac{3 \times 72}{18} = 12.$$

12. The potentials of the two plates of capacitors are +10V and −10V. The charge on one of the plates is 40C. The capacitance of capacitor is

(a) 2 F (b) 4 F

(c) 0·5 F (d) 0·25 F. *(A.F.M.C. 2005)*

ANS. (a).

$$C = \frac{Q}{V} = \frac{40}{10-(-10)} = \frac{40}{20} = 2 \text{ F}.$$

13. A 4 μF capacitor is charged to 400 V and then the plates are joined through a resistor. Heat produced in resistor is :

(a) 0·64 J (b) 0·32 J

(c) 0·16 J (d) 1·28 J.

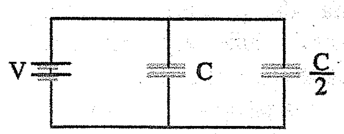
(Manipal PMT 2005)

ANS. (b).

Heat produced in resistor = Energy stored in capacitor $= \frac{1}{2}CV^2$

$$= \frac{1}{2} \times 4 \times 10^{-6} \times 400 \times 400 = 0{\cdot}32 \text{ J}.$$

14. Two condensers, one of capacity C and the other of capacity $\frac{C}{2}$ are connected to a V-volt battery as shown. The work done in charging fully both the condensers is



(a) $\frac{1}{2}CV^2$ (b) $\frac{1}{4}CV^2$

(c) $\frac{3}{4}CV^2$ (d) $2\,CV^2$.

(C.B.S.E. PMT 2007)

ANS. (c).

Equivalent capacitance,

$$C' = C + \frac{C}{2} = \frac{3C}{2}.$$

$\therefore$ Work done = energy stored

$$= \frac{1}{2}C'V^2 = \frac{1}{2} \times \frac{3C}{2} V^2 = \frac{3C}{4} V^2.$$

ELCTROSTATIC POTENTIAL & CAPACITANCE

IMPORTANT TOPICS WITH FORMULAS FOR NUMERICALS

TOPIC 1 POTENTIAL [V]

1. $V = \frac{W}{q_0} = \frac{q}{4\pi\epsilon_0 r}$ [at a point]
2. $V = \frac{q}{4\pi\epsilon_0 r_A} - \frac{q}{4\pi\epsilon_0 r_B}$ [for 2 points]
3. $V = \oint \vec{E}\cdot\vec{dl} = E\,l\cos\theta$ [Potential difference]
4. V = work done per unit test charge

Units of V

Volt or J/C

Potential is a scalar quantity

So Relax about its direction

TOPIC-2 RELATION BETWEEN E & V

1. $E = \frac{F}{q_0} = \frac{q}{4\pi\epsilon_0 r^2}$
2. $V = \frac{W}{q_0} = \frac{q}{4\pi\epsilon_0 r}$

Relation $E = \left|-\frac{dV}{dr}\right|$ Potential gradient

TOPIC-3 ENERGY ASSOCIATED:

{ SYSTEM OF CHARGES & CAPACITOR}

1. $U = \frac{kq_1q_2}{r}$
2. $U = \frac{kq_1q_2}{r_1} + \frac{kq_2q_3}{r_2} + \frac{kq_3q_1}{r_3}$
3. $U = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}CV^2$
4. energy density $\sigma = \frac{1}{2}\epsilon_0 E^2$

TOPIC 4 CAPACITANCE [C]

Main formula $q = CV$

1. $C = \frac{q}{V}$ [S.I unit Farad [F]]
2. $C = \frac{\epsilon_0 A}{d}$ [Parallel plate [air filled]]
3. $C = \frac{\epsilon_0 A}{d-t}$ [Conducting slab]
4. $C = \frac{K\epsilon_0 A}{d}$ [medium filled]
5. $C = \frac{\epsilon_0 A}{d - t + \frac{t}{K}}$ [dielectric slab]
6. $C = 4\pi\epsilon_0 r$ [Isolated Sphere]
7. $C = \frac{4\pi\epsilon_0 r_A r_B}{(r_A - r_B)}$ [Spherical Capacitor]
8. $C = \frac{2\pi\epsilon_0 l}{\log_e\left(\frac{r_1}{r_2}\right)}$ [Cylindrical Capacitor]
9. $C = C_1 + C_2 + C_3$ [Parallel Combination]
10. $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ [Series Combination]

Note:-

1. If dielectric divides distance between the plates then the parts are in series.
2. If the dielectric divides Area of the plates then the parts are in Parallel.

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

SELF ASSESSMENT TEST FOR BOARD EXAM

SELF ASSESSMENT TEST

Total Marks : 55

1. State SI unit of potential difference. 1
2. What is an equipotential surface ? 1
3. What is joule ? Define it. 1
4. What is the work done in moving a 2 μC point charge from corner A to corner B of a square ABCD (figure A) when a 10 μC charge exists at the centre of the square ? 1

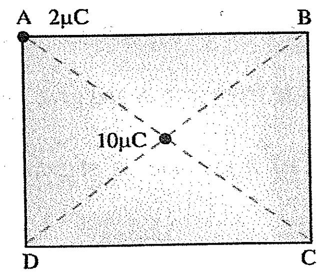


Figure A

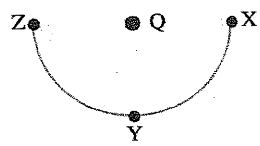


Figure B

5. In figure B, what is the work done in moving a point charge from X to the points Y and Z respectively ? 1
6. Name the physical quantity having SI unit as farad per metre. 1
7. What is the electric field inside a conductor ? 1
8. Two spheres of metal, having same radii but one hollow and other solid, are charged to same potential. Which of the two spheres *i.e.*, hollow or solid will have more charge ? 1
9. What is the approximate value of capacitance of earth ? 1
10. What is the value of dielectric constant of metal ? 1
11. Electric field is always normal to the equipotential surface. Explain why ? 2
12. What is the difference between electric potential and potential difference ? 2
13. n small drops of same size are charged to V volt each. They coalesce to form a bigger drop. Calculate potential of bigger drop. 2
14. Arrange three charges $+q$, $+q$ and $-q$ using distances r, $2r$ and $2r$ to get a system with zero potential energy. 2
15. What do you mean by line integral of electric field ? 2
16. Explain as to why potential inside the conductor is constant. 2
17. Is it possible to build a spherical conductor of capacity 1 F ? Explain. 2
18. Derive an expression for equivalent capacitance of parallel combination of 3 capacitors. 2
19. Derive an expression for energy stored in a capacitor. 2
20. Explain principle of a capacitor. 2
21. Three point charges, q each, are placed on the circumference of a circle of radius r to form a triangle having all the sides forming angles of 60° with each other. Find potential at the centre of the circle. Take Coulomb's constant k as 1. 3
22. Two charged metal spheres of radii R_1 and R_2 (where $R_1 > R_2$) are far apart. The separation between them is much larger than radius R_1. The spheres are connected by a conducting wire (figure C). The charges at steady state on the spheres become q_1 and q_2 respectively. What is the potential at the surface of each sphere and also find q_1/q_2 ? 3

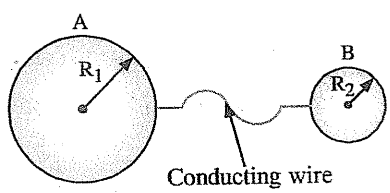


Figure C

SELF ASSESSMENT TEST FOR BOARD EXAM

23. Figure D shows the electric lines of force of a positive and negative charge respectively.

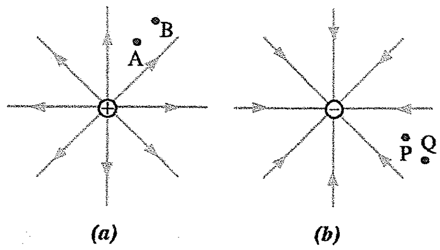


Figure D

(a) What are the signs of potential differences $(V_A - V_B)$ and $(V_Q - V_P)$?

(b) What are the signs of the potential energy difference of a small negative charge between B and A ; P and Q ?

(c) Give the sign of the work done in moving a positive charge from B to A and give sign of work done by external agency in moving a small negative charge from Q to P. 3

24. Three point charges are arranged at the three vertices of a triangle as shown in figure E. Calculate the electrostatic potential energy of the system if

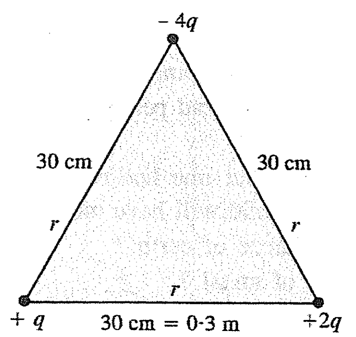


Figure E

$q = 3 \times 10^{-7}$ C. 3

25. An electron and a proton in an atom are bound at a distance of 53×10^{-12} m. Find the potential energy of the system. 3

26. *(a)* 75% of the distance *d* between the parallel plates of a capacitor is filled with a material of dielectric constant *k*. Find the charge in capacitance if original capacitance was C_0.

(b) Four capacitors of 1 pF, 2 pF, 3 pF and 4 pF are connected in parallel. Find charge on each capacitor if supply voltage is 200 V. 5

27. *(a)* Calculate equivalent capacitance Figure F :

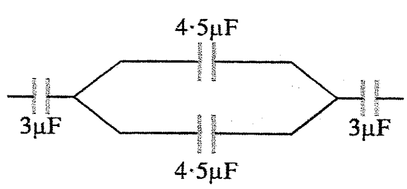


Figure F

(b) How much work must be done to charge a 24 μF capaxcitor, when potential difference between the plates is 500 V ? 5

Objective question bank

Focus NCERT CBSE MODULE FOR CLASS XII EXAMS

Focus NCERT CBSE MODULE FOR CLASS XII EXAMS

MCQ'S (SINGLE & MULTIPLE RESPONSE TYPE), FILL IN THE BLANKS, TRUE/FALSE, MATCHING TYPE QUESTIONS, ASSERTION-REASON TYPE QUESTIONS & CASE- BASED INTEGRATED QUESTIONS

POTENTIAL & CAPACITANCE
CHAPTER 2
FOCUS NCERT

ELECTROSTATIC POTENTIAL AND CAPACITANCE 2

OBJECTIVE QUESTION BANK

TYPE–A MULTIPLE CHOICE QUESTIONS
(Only one option correct)

Based on Electric Potential due to a point charge and due to electric dipole

1. The electric potential at the surface of an atomic nucleus (Z=50) of radius $9{\cdot}0 \times 10^{-15}$ m is :

   (a) 9 V (b) 9×10^5 V (c) 8×10^6 V (d) 80 V.

2. Equal charges are given to two spheres of different radii. The potential will :

   (a) be more on smaller sphere

   (b) be more on bigger sphere

   (c) be equal on both the spheres

   (d) depend on the nature of the materials of the spheres.

3. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 80 V. The potential at the centre of the sphere is :

   (a) 80 V (b) 800 V (c) 8 V (d) Zero.

4. The electric potential at a point in free space due to a charge Q coulomb is $Q \times 10^{11}$ volts. The electric field at that point is :

   (a) $12\pi\epsilon_0 Q \times 10^{22}$ V/m (b) $4\pi \epsilon_0 Q \times 10^{22}$ V/m

   (c) $12\pi\epsilon_0 Q \times 10^{20}$ V/m (d) $4\pi \epsilon_0 Q \times 10^{20}$ V/m.

5. Earth's surface is considered to be at :

   (a) zero potential (b) negative potential (c) positive potential (d) infinite potential

6. Using usual notations, electric potential at a point due to an electric dipole is given by :

   (a) $V = \frac{p \cos\theta}{4\pi \epsilon_0 r}$ (b) $V = \frac{p}{4\pi \epsilon_0 r^2}$ (c) $V = \frac{p \cos\theta}{4\pi \epsilon_0 r^2}$ (d) $V = \frac{p \sin\theta}{4\pi \epsilon_0 r}$.

7. A charge of 100 μC has a potential at a distance of 9 m as :

(a) 10^6 V (b) 10^{-6} V (c) 10^5 V (d) 10^{-5} V.

8. A soap bubble is charged to a potential of 16 V. Its radius is then doubled. The potential of the bubble now will be :

(a) 16 V (b) 8 V (c) 4 V (d) 2 V.

Based on Equipotential Surfaces

9. Equipotential surfaces associated with an electric field which is increasing in magnitude along x direction are :

(a) planes parallel to yz plane
(b) planes parallel to xy plane
(c) planes parallel to xz plane
(d) coaxial cylinders of increasing radii around x-axis.

10. Which of the following is not the property of equipotential surfaces ?

(a) They do not cross each other.
(b) They are concentric spheres for non-uniform electric field.
(c) Rate of change of potential with the distance on them is zero.
(d) They can be imaginary spheres.

11. Work done in moving a positive charge on an equipotential surface is :

(a) negative (b) zero (c) positive (d) positive infinite.

12. On rotating a point charge, having charge 'q' around a charge 'Q' in a circle of radius r, the work done will be :

(a) $q \times 2\pi r$ (b) $\frac{q \times 2\pi Q}{r}$ (c) zero (d) $\frac{Q}{2 \epsilon_0 r}$.

Based on $E = \frac{-dV}{dr}$

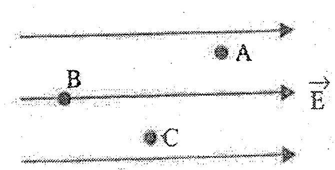
13. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field $\vec{E}$ at that point is :

(a) $\vec{E} = 2xy\,\hat{i} + (x^2 + y^2)\,\hat{j} + (3uz = -y^2)\,\hat{k}$ (b) $\vec{E} = z^3\,\hat{i} + xyz\,\hat{j} + z^2\,\hat{k}$

(c) $\vec{E} = (2xy - z^3)\,\hat{i} + xy^2\,\hat{j} + 3z^2x\,\hat{k}$ (d) $\vec{E} = (2xy + z^3)\,\hat{i} + x^2\,\hat{j} + 3xz^2\,\hat{k}$.

14. A, B and C are three points in a uniform electric field. The electric potential is :

(a) same all the three points A, B and C
(b) maximum at A
(c) maximum at B
(d) maximum at C.

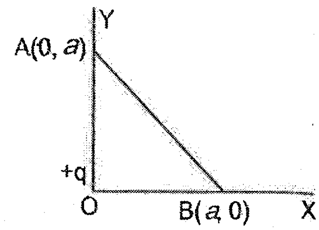


15. A uniform electric field pointing in positive x direction exists in a region. Let A be the origin, B be the point on the x-axis at $x = 1$ cm and C be the point on the y axis at $y = 1$ cm. Then the potential at the points A, B and C satisfy,

(a) $V_A < V_B$ (b) $V_A > V_B$ (c) $V_A < V_C$ (d) $V_A > V_C$.

16. If an electron is brought towards another electron, the electric potential energy of the system :
(a) increases (b) decreases (c) becomes zero (d) remains the same.

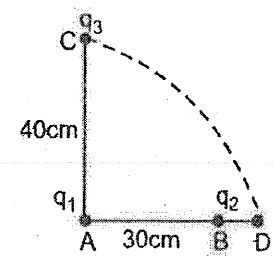
17. A point charge $+q$ is placed at the origin O as shown in figure. Work done in taking another charge $-Q$ from point $A(O, a)$ to another point $B(a, O)$ along the straight path AB is :



(a) $\left(\frac{1}{4\pi \epsilon_0} \frac{qQ}{a^2}\right)$ (b) $\left(-\frac{1}{4\pi \epsilon_0} \frac{qa}{a^2}\right)\sqrt{2}a$

(c) $\left(\frac{1}{4\pi \epsilon_0} \frac{qa}{a^2}\right)\frac{a}{\sqrt{2}}$ (d) Zero.

18. Two charges q_1 and q_2 are placed 30 cm apart as shown in figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D. The change in the potential energy of the system is $\frac{q_3 k}{4\pi \epsilon_0}$, where k is :



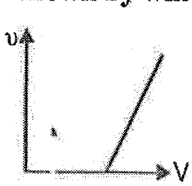
(a) $8q_1$ (b) $6q_1$
(c) $8q_2$ (d) $6q_2$.

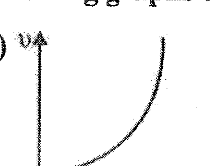
19. How much work is required to carry a 6 μC charge from the negative to the positive terminal of a qV battery ?
(a) 54×10^{-3} J (b) 54×10^{-9} J (c) 54×10^{-6} J (d) 54×10^{-12} J.

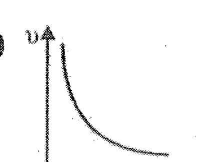
20. An electron initially at rest is accelerated through a potential difference of 200 volt so that it acquires a velocity $8{\cdot}4 \times 10^6$ m s^{-1}. The value of e/m of electron will be :
(a) $1{\cdot}76 \times 10^{11}$ C/kg (b) $2{\cdot}76 \times 10^{12}$ C/kg (c) $0{\cdot}76 \times 10^{12}$ C/kg (d) None of these.

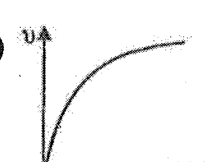
21. There is 10 units of charge at the centre of a circle of radius 10 m. The work done in moving 1 unit of charge once around the circle is :
(a) Zero (b) 100 units (c) 10 units (d) 150 unit.

22. The velocity v acquired by an electron starting from rest and moving through a potential difference V is shown by which of the following graphs ?

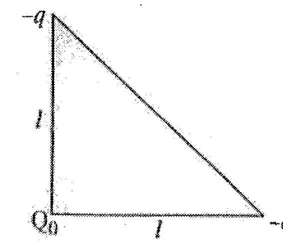
(a) 

(b) 

(c) 

(d) 

23. Three charges Q_0, $-q$ and $-q$ are placed at the vertices of an isosceles triangle as shown in figure. The net electrostatic potential energy is zero if Q_0 is equal to :



(a) $\frac{q}{4}$ (b) $\frac{2q}{\sqrt{32}}$

(c) $\sqrt{2}q$ (d) $+q$.

24. Capacity of an isolated conducting sphere of radius R is proportional to :

(a) R^2 (b) $\frac{1}{R^2}$ (c) $\frac{1}{R}$ (d) R.

25. A parallel plate air capacitor has a capacitance 18 μF. If the distance between plates is trebled and a dielectric is introduced, the capacitance becomes 72 μF. The dielectric constant of the medium is :

(a) 4 (b) 9 (c) 12 (d) 2.

26. Putting a dielectric substance between two plates of condenser, the capacity, potential and potential energy respectively :

(a) increases, decreases, decreases (b) decreases, increases, increases

(c) increases, increases, increases (d) decreases, decreases, decreases.

27. Three capacitors each of 4 μF are to be connected in such a way that the effective capacitance is 6 μF. This can be done by connecting.

(a) them in parallel (b) them in series

(c) two in series and one in parallel (d) two in parallel and one in series.

28. If potential difference across a capacitor is changed from 5V to 30V, work done is W. What will be the work done when potential difference is changed from 30V to 60V ?

(a) 2 W (b) 3 W (c) 4 W (d) 6 W.

29. Capacity of parallel plate capacitor in air and on immersing it into oil is 50 μF and 110 μF respectively. The dielectric constant of oil is :

(a) 0·45 (b) 0·55 (c) 1·10 (d) 2·20.

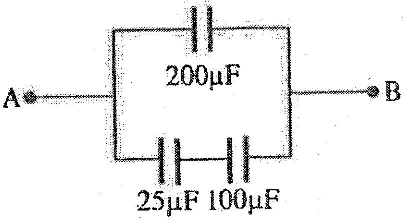
30. Find the equivalent of capacitance of the given circuit.

(a) 220 μF

(b) 260 μF

(c) 340 μF

(d) 420 μF.



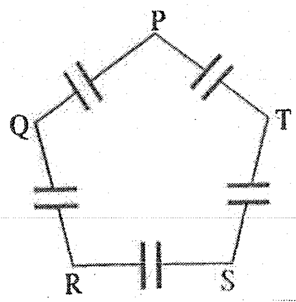
31. A 4 μF capacitor is charged to 400 V and then the plates are joined through a resistor. Heat produced in resistor is :

(a) 0·64 J (b) 0·32 J (c) 0·16 J (d) 1·28 J.

32. Five capacitors, each of capacitance C are connected as shown. The ratio of capacitance between P and R and the capacitance between P and Q is :

(a) 3 : 1 (b) 5 : 2

(c) 2 : 3 (d) 1 : 1.



33. If the distance between the plate of a capacitor is increased, then capacitance :

(a) increases (b) decreases

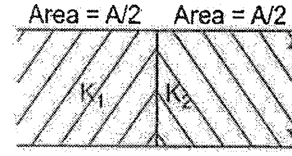
(c) remains the same (d) first increases then decreases.

34. The dimensions of $\frac{1}{2} \epsilon_0 E^2$, where ϵ_0 is permittivity of free space and E is electric field, are :

(a) $[M L T^{-1}]$ (b) $[M L^{-1} T^{-2}]$ (c) $[M L^2 T^{-2}]$ (d) $[M L^2 T^{-1}]$.

35. Two materials of dielectric constants K_1 and K_2 are filled between two parallel plates of a capacitor as shown in figure.

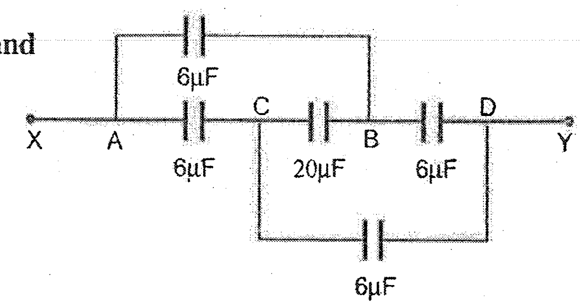
The capacitance of the capacitor is :



(a) $\frac{A\epsilon_0(K_1+K_2)}{2d}$ (b) $\frac{A\epsilon_0}{2d}\left(\frac{K_1+K_2}{K_1K_2}\right)$

(c) $\frac{A\epsilon_0}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)$ (d) $\frac{2A\epsilon_0}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)$.

36. What is the effective capacitance between points X and Y ?



(a) 24 μF

(b) 18 μF

(c) 12 μF

(d) 6 μF.

37. The equivalent capacity of two capacitors in series is 3μF and in parallel is 16 μF. Their individual capacities (in μF) are :

(a) 12, 4 (b) 8, 8 (c) 10, 16 (d) 12, 2.

38. If earth is supposed to be a metallic sphere, its capacity will be nearly :

(a) 700 pF (b) 711 μF (c) 700 F (d) $6{\cdot}4 \times 10^6$ F.

39. While a capacitor remains connected to a battery, a dielectric slab is slipped between the plates of the capacitor.

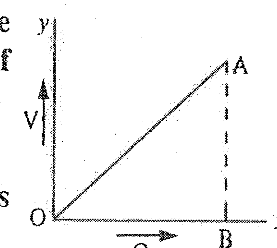
(a) The energy stored in the capacitor increases

(b) The electric field between the plates increases

(c) The potential difference between the plates is changed

(d) Charge on the capacitor remains the same.

40. Charge Q on a capacitor varies with voltage V as shown in the figure where Q is taken along the X-axis and V-along the Y-axis. The area of triangle OAB represents :



(a) capacitance (b) capacitive reactance

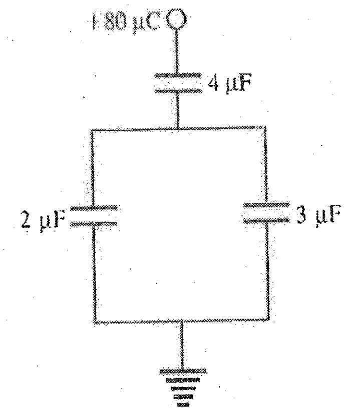
(c) magnetic field between the plates (d) electric flux between the plates

(e) energy stored in capacitor.

41. If n drops, each of capacitance C, coalesce to form a single big drop, then the ratio of the energy stored in the big drop to that in each small drop will be :

(a) $n : 1$ (b) $n^2 : 1$ (c) $n^{1/3} : 1$ (d) $n^{5/3} : 1$.

42. In a given circuit, a charge of +80 μC is given to the upper plate of 4 μF capacitor. Then in the steady state, the charge on the upper plate of the 3 μF capacitor is



(a) + 32 μC

(b) +40 μC

(c) +48 μC

(d) + 80 μC.

ANSWERS

1. (c)	2. (a)	3. (a)	4. (b)	5. (a)	6. (c)	7. (c)	8. (b)	9. (a)
10. (c)	11. (b)	12. (c)	13. (d)	14. (c)	15. (b)	16. (a)	17. (d)	18. (c)
19. (c)	20. (a)	21. (a)	22. (b)	23. (b)	24. (d)	25. (c)	26. (a)	27. (c)
28. (b)	29. (d)	30. (a)	31. (b)	32. (c)	33. (b)	34. (b)	35. (a)	36. (d)
37. (a)	38. (b)	39. (a)	40. (d)	41. (c)	42. (b)			

HINTS AND EXPLANATIONS

1. $V = 9 \times 10^9 \frac{Ze}{r}$.

2. $V \propto \frac{1}{r}$.

3. Potential at the centre of sphere= potential on its surface.

4. $V = \frac{1}{4\pi \epsilon_0} \frac{Q}{r} \quad \therefore r = \frac{1}{4\pi \epsilon_0} \frac{Q}{V} = \frac{1}{4\pi \epsilon_0} \frac{Q}{Q \times 10^{11}} = \frac{1}{4\pi \epsilon_0 \times 10^{11}}$

$$\text{Now, } E = \frac{V}{r} = \frac{Q \times 10^{11}}{\frac{1}{4\pi \epsilon_0 \times 10^{11}}} = 4\pi \epsilon_0 Q \times 10^{22} \text{ V/m.}$$

7. Using, $V = \frac{q}{4\pi\varepsilon_0 r}$, we get $V = \frac{9 \times 10^9 \times 100 \times 10^{-6}}{9} = 10^5$ V.

8. (b) Using, $V \propto \frac{1}{r}$, we get $\frac{V_2}{V_1} = \frac{r_1}{r_2}$

$i.e., \frac{V_2}{16} = \frac{r_1}{2r_1}$ $i.e.,$ $V_2 = 8$ V.

9. Electric field is perpendicular to the equipotential surface.

11. $W = \frac{\Delta V}{q} = 0.$

12. A circle of radius r around the charge Q is equipotential.

13. $\vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$

$$E_x = -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial x}(-x^2y - xz^3 + 4) = (2xy + z^3)$$

$$E_y = -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial y}(-x^2y - xz^3 + 4) = x^2$$

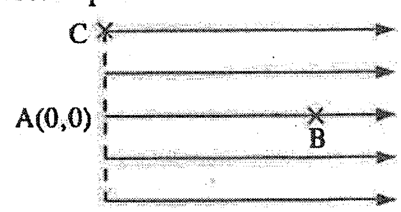
$$E_z = -\frac{\partial V}{\partial z} = -\frac{\partial V}{\partial z}(-x^2y - xz^3 + 4) = 3xz^2$$

$$\therefore \vec{E} = (2xy + z^3)\hat{i} + x^2\hat{j} + 3xz^2\hat{k}.$$

14. $E = -\frac{dV}{dr}$

$-$ve sign shows that electric field is in the direction of decreasing electric potential.

15. Field lines start from higher to lower charge.



$\therefore$ potential decreases in the direction of electric field.

$\therefore$ $V_A = V_C$ and $V_A > V_B$

($\because$ V_A and V_C lie on equipotential surface)

16. Work is done against the repulsive force, so potential energy of the system increases.

17. Points A and B are equidistant from charge $+q$. Therefore, potential at A = potential at B.

$\therefore$ $W = -Q(V_B - V_A) = 0.$

18. Initial P.E., $U_i = \frac{1}{4\pi \epsilon_0}\left[\frac{q_1q_3}{0{\cdot}4} + \frac{q_2q_3}{0{\cdot}5} + \frac{q_1q_2}{0{\cdot}3}\right]$ ($\because$ BC = 50 cm)

Final P.E, $U_f = \frac{1}{4\pi \epsilon_0}\left[\frac{q_1q_3}{0{\cdot}4} + \frac{q_2q_3}{0{\cdot}1} + \frac{q_1q_2}{0{\cdot}3}\right]$.

Change in P.E. $= U_f - U_i = \frac{1}{4\pi \epsilon_0}\left[\frac{q_2q_3}{0{\cdot}1} + \frac{q_2q_3}{0{\cdot}5}\right] = \frac{1}{4\pi \epsilon_0}(8q_2q_3) = \frac{q_3k}{4\pi \epsilon_0}$

$\therefore k = 8q_2.$

19. $W = qV = 6 \times 10^{-6} \times 9 = 54 \times 10^{-6}$ J.

20. $\frac{1}{2}mv^2 = eV$

$$\therefore \frac{e}{m} = \frac{v^2}{2V} = \frac{(8{\cdot}4 \times 10^6)^2}{2 \times 200} = 1{\cdot}76 \times 10^{11} \text{ C/kg}.$$

21. $W = q\Delta V$

Since every point on the circle is equidistant from its centre, so potential on every point on the circle is same. That is potential diff., $\Delta V = 0$. Therefore, $W = 0$.

22. $\frac{1}{2}mv^2 = eV$ $\quad\therefore v^2 \propto V$.

Therefore, graph between v and V is parabola.

23. $$U = \frac{1}{4\pi \epsilon_0}\left[-\frac{Q_0 q}{l} - \frac{Q_0 q}{l} + \frac{q^2}{\sqrt{2}\,l}\right] = 0$$

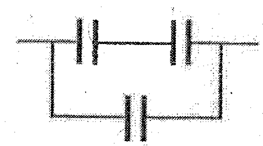
$$\therefore Q_0 = \frac{q}{\sqrt{8}} = \frac{2q}{\sqrt{32}}.$$

24. $C = (4\pi \epsilon_0)R$.

25. $C_0 = \frac{\epsilon_0 A}{d}$ and $C = \frac{K \epsilon_0 A}{3d}$

$$\therefore C = \frac{KC_0}{3} \text{ or } K = \frac{3C}{C_0} = \frac{3 \times 72}{18} = 12.$$

27. If two capacitors are in series, then



$$C' = \frac{C_1C_2}{C_1 + C_2} = \frac{4 \times 4}{4 + 4} = 2\ \mu F$$

Now connecting the third capacitor in parallel will give

$C_{eq} = C' + C = 2 + 4 = 6\ \mu F$.

28. $$W = \frac{1}{2}C\left(V_2^2 - V_1^2\right) = \frac{1}{2}C\,[900 - 25] = \frac{875C}{2}.$$

Now $$W_1 = \frac{1}{2}C[3600 - 900] = \frac{2700}{2}C = 1350C$$

$$\therefore \frac{W_1}{W} = \frac{1350 \times 2}{875} \simeq 3.$$

29. $C' = K\,C$ *i.e.* $K = \frac{C'}{C} = \frac{110}{50} = 2{\cdot}2$.

30. Equivalent capacitance of capacitors connected in series

$$C_{eq} = \frac{25 \times 100}{25 + 100} = \frac{2500}{125} = 20\ \mu F$$

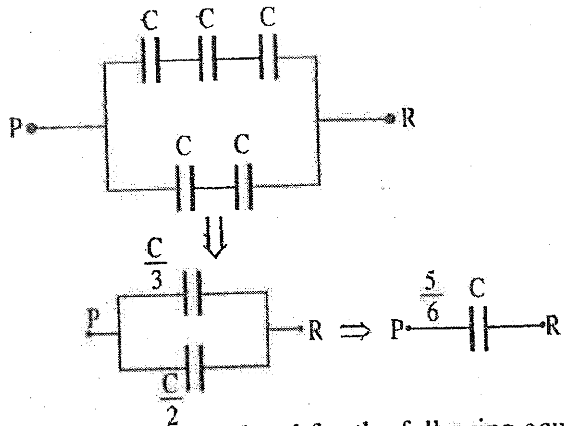
Equivalent capacitance of 20 μF and 200 μF connected in parallel = 20 + 200 = 220 μF.

31. Heat produced = Energy stored = $\frac{1}{2}CV^2$

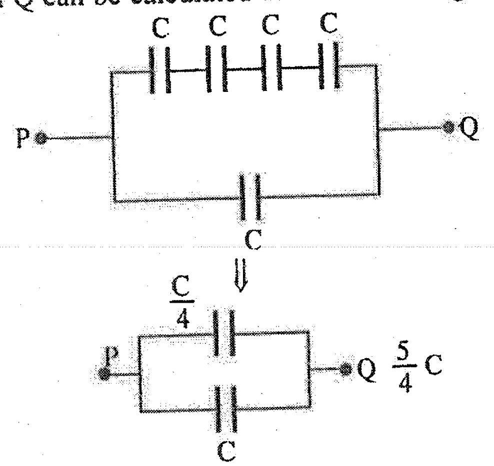
$$= \frac{1}{2} \times 4 \times 10^{-6} \times 400 \times 400 = 0{\cdot}32\ J.$$

This energy produces heat in resistor.

32. Capacitance between P and R can be calculated from the following equivalent circuits :



Capacitance between P and Q can be calculated for the following equivalent circuit :



$\therefore \quad \dfrac{C_{PR}}{C_{PQ}} = \dfrac{5C/6}{5C/4} = \dfrac{2}{3}$

33. $C = \dfrac{\epsilon_0 A}{d}$. Since d increases so C decreases.

34. $\dfrac{1}{2}\epsilon_0 E^2$ = Energy/Volume $= \dfrac{[ML^2T^{-2}]}{[L^3]} = [M L^{-1}T^{-2}]$

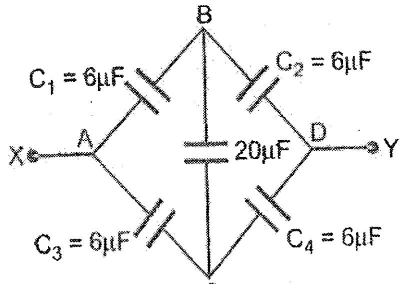
35. $C_1 = \dfrac{A/2\, \epsilon_0 k_1}{d} = \dfrac{A\epsilon_0 k_1}{2d}$

$C_2 = \dfrac{A\epsilon_0 k_2}{2d}$

Both capacitors are in parallel

$\therefore C = C_1 + C_2 = \dfrac{A\epsilon_0}{2d}(k_1 + k_2)$

36.



Network is a balanced wheatstone bridge as $\frac{C_1}{C_2} = \frac{C_3}{C_4}$

Therefore capacitor between B and C is neglected.

$$C_{ABD} = \frac{C_1C_2}{C_1+C_2} = \frac{36}{12} = 3\ \mu F$$

$$C_{ACD} = \frac{C_3C_4}{C_3+C_4} = \frac{36}{12} = 3\ \mu F$$

Now C_{ABD} and C_{ACD} are in parallel, therefore,

$$C_{XY} = 6\ \mu F.$$

37. $C_S = \frac{C_1C_2}{C_1+C_2} = 3\ \mu F$

$C_p = 16\ \mu F \Rightarrow C_1 + C_2 = 16\ \mu F$ ...(*i*)

$\therefore\ C_1C_2 = 3(C_1+C_2) = 48\ \mu F$

$(C_1 - C_2)^2 = (C_1+C_2)^2 - 4C_1C_2$

$= 256 - 4 \times 48 = 256 - 192 = 64$

$C_1 - C_2 = 8\ \mu F$ ...(*ii*)

Solving eqns. (*i*) and (*ii*), we get,

$C_1 = 12\ \mu F$ and $C_2 = 4\ \mu F$.

38. $C = (4\pi \epsilon_0)R = \frac{1}{9\times10^9} \times 6{\cdot}4 \times 10^6 = 711\ \mu F.$

39. $U = K\ U_0$

40. Area of $\Delta OAB = \frac{1}{2} OB \times AB = \frac{1}{2} QV$

$= \frac{1}{2} CV^2$ $(\because Q = CV)$

= energy stored in capacitor.

41. Capacitance $\propto$ radius *i.e.* $C \propto r$

Volume of big drop = n × volume of small drop

$\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$; $R = n^{1/3} r$

Capacitance of big drop, $C_1 \propto R$ or $C_1 \propto n^{1/3} r$

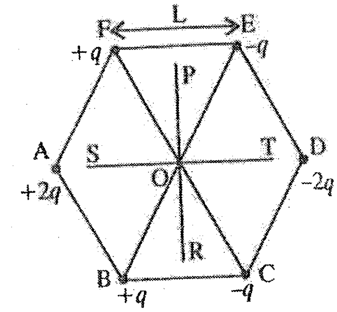
$\therefore\ \frac{C_1}{C} = n^{\frac{1}{3}}.$

42. Let q = charge on the upper plate of 3 μF capacitor, then charge on 2 μC capacitor = $(80 - q)$. Since both capacitors are connected in parallel, so potential difference a cross 2 μF capacitor = potential difference across 3 μF.

i.e., $\frac{80-q}{2} = \frac{q}{3}$ or $q = +40\ \mu C$.

TYPE-B MULTIPLE RESPONSE QUESTIONS
(More than one correct option)

43. Six point charges are kept at the vertices of a regular hexagon of side L and centre O, as shown in the figure. Given that $K = \frac{1}{4\pi\varepsilon_0}\frac{q}{L^2}$. Which of the following statements (s) is (are) correct ?



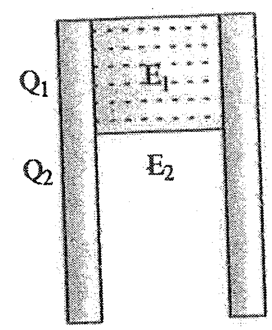
(a) The electric field at O is 6 K along OD.

(b) The potential at O is zero.

(c) The potential at all points on the line PR is same.

(d) The potential at all points on the line ST is same.

44. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers 1/3 of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1. When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2. The electric field in the dielectric is E_1 and that the other portion is E_2. Chosse the correct option/options, ignoring edge effects.



(a) $\frac{E_1}{E_2} = 1$

(b) $\frac{E_1}{E_2} = \frac{1}{K}$

(c) $\frac{Q_1}{Q_2} = \frac{3}{K}$

(d) $\frac{C}{C_1} = \frac{2+K}{K}$.

45. A spherical metal shell A of radius R_A and a solid metal sphere B of radius R_B ($< R_A$) are kept far apart and each is given charge +Q. Now they are connected by a thin metal wire. Then

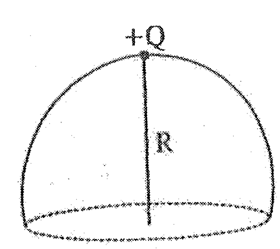
(a) $E_{A\ inside} = 0$

(b) $Q_A > Q_B$

(c) $\frac{\sigma_A}{\sigma_B} = \frac{R_B}{R_A}$

(d) $E_{A\ on\ surface} < E_{B\ on\ surface}$.

46. A point charge +Q is placed just outside an imaginary hemispherical surface of radius R a shown in the figure. Which of the following statements is/are correct ?



(a) The circumference of the flat surface is an equipotential.

(b) The component of the electric field normal to the flat surface is constant over the surface

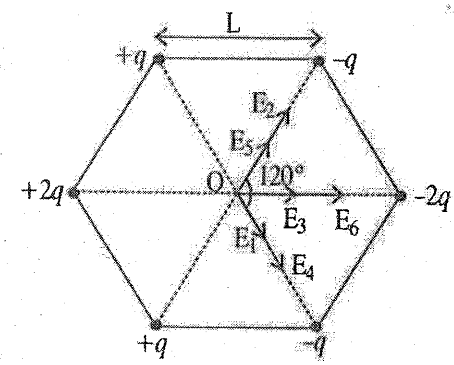
(c) Total flux through the curved and the flat surface is Q/ε_0.

(d) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$.

ANSWERS

43. (a, d, c) 44. (a, d) 45. (a, b, c, d) 46. (a, d)

HINTS AND EXPLANATIONS



43. $E' = E_2 + E_5 = 2\times \frac{1}{4\pi\epsilon_0}\frac{q}{L^2} = 2K$

$E'' = E_1 + E_4 = 2\times \frac{1}{4\pi\epsilon_0}\frac{q}{L^2} = 2K$

$E''' = E_3 + E_6 = 2\times \frac{1}{4\pi\epsilon_0}\frac{2q}{L^2} = 4K$

E′ and E″ are inclined at an angle of 120°

$E_R = \sqrt{(E')^2 + (E'')^2 + 2E'E''\cos 120^\circ}$

$= E_1 = 2K$ along OD

$\therefore$ Net electric field at O $= E_1 + E'' = 6$ K along OD

$$V \text{ at } O = \frac{1}{4\pi\epsilon_0}\left[\frac{q}{L}-\frac{q}{L}-\frac{2q}{L}-\frac{q}{L}+\frac{q}{L}+\frac{2q}{L}\right] = O$$

The system consists of three dipoles and line PR is equatorial line for three dipoles. Therefore, potential at any point on the line PR is zero.

44. When capacitor is charged, both parts of the capacitor have common potential V.

Therefore, $E_1 = \frac{V}{d}$ and $E_2 = \frac{V}{d}$.

Hence, $\frac{E_1}{E_2} = 1$

$$C_1 = \frac{K\varepsilon_0(A/3)}{d} = \frac{K\varepsilon_0 A}{3d}$$

$$C_2 = \frac{\epsilon_0(2A/3)}{d} = \frac{2\epsilon_0 A}{3d}$$

Both capacitors are in parallel, therefore

$$C = C_1 + C_2 = \frac{\epsilon_0 A}{3d}(K+2)$$

$$\therefore \frac{C}{C_1} = \frac{K+2}{K}.$$

45. (*a*) Electric field inside a shell is zero.

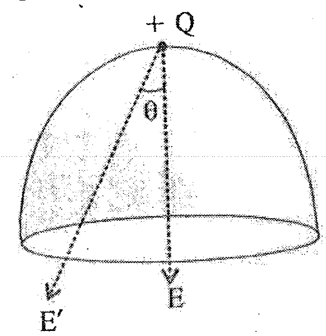
When connected with wire, both have same potential V.

(*b*) $\frac{Q_A}{Q_B} = \frac{VC_A}{VC_B} = \frac{4\pi\varepsilon_0 R_A}{4\pi\varepsilon_0 R_B} = \frac{R_A}{R_B} > 1$

(*c*) $\sigma = \frac{Q}{R^2}$. Therefore, $\frac{\sigma_A}{\sigma_B} = \left(\frac{Q_A}{Q_B}\right)\left(\frac{R_B}{R_A}\right)^2 = \left(\frac{R_A}{R_B}\right)\left(\frac{R_B}{R_A}\right)^2 = \frac{R_B}{R_A}$

(*d*) $E \propto \frac{Q}{R^2}$. Therefore, $\frac{E_A}{E_B} = \left(\frac{Q_A}{Q_B}\right)\left(\frac{R_B}{R_A}\right)^2 = \frac{R_B}{R_A} < 1$.

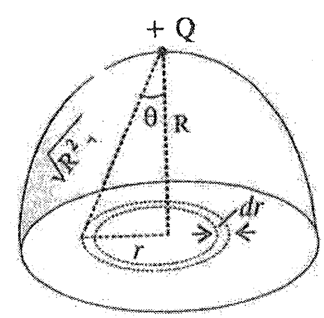
46. (*a*) The circumference of the flat surface is equidistant from point charge + Q, so potential at every point on this surface is equal.



(*b*) The component of electric field normal to the flat surface = E′ cos θ Since angle θ varies, so the component of electric field normal to the surface is not constant.

(*c*) Since curved and flat surfaces encloses no change so, electric flux through them is zero.

(*d*) Consider a ring of radius *r* and thickness *dr* on the flat surface. The electric flux through the ring,



$$d\phi = (E\cos\theta)\,dS = E \times \frac{R}{\sqrt{R^2+r^2}} \times 2\pi r dr$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q}{(R^2+r^2)} \times \frac{R}{\sqrt{R^2+r^2}} \times 2\pi r\, dr$$

$$= \frac{Q}{2\epsilon_0}\frac{Rr\,dr}{(R^2+r^2)^{3/2}}$$

Hence, electric flux through the flat surface,

$$\phi = \int_0^R d\phi = \int_0^R \frac{Q}{2\epsilon_0}\frac{Rr\,dr}{(R^2+r^2)^{3/2}} = \frac{Q}{2\epsilon_0}\left(1-\frac{1}{\sqrt{2}}\right).$$

Now, electric flux through the curved surface

$$= -\text{ electric flux through the flat surface} = -\frac{Q}{2\epsilon_0}\left(1-\frac{1}{\sqrt{2}}\right).$$

TYPE–C FILL IN THE BLANKS WITH APPROPRIATE ANSWERS

47. Electrostatic force is a .... force.
48. If potential at infinity is chosen to be zero, then the potential at a point, whose distance from change Q is r is ....
49. A surface over which potential has a constant value is called .... surface.
50. The potential energy of an electric dipole of dipole moment $\vec{p}$ in a uniform electric field $\vec{E}$ is ....
51. The electrostatic field $\vec{E}$ in the interior of a conductor is ....
52. SI unit of capacitance is ....
53. Electric potential due to a point charge q at its own location is ....
54. The phenomenon of shielding a cavity inside a conductor from external electric field is called ....

ANSWERS

47. Conservative
48. $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$
49. equipotential
50. $-\vec{p}\cdot\vec{E}$
51. zero
52. farad (or CV^{-1})
53. not defined
54. electrostatic shielding

TYPE–D STATE, WHETHER THE STATEMENT IS TRUE OR FALSE

55. Work done to move a charge from on point to another point on an equipotential surface is zero.
56. Electrostatic potential at a distance r from q varies inversely as the square of the distance (r).
57. Electric field is in the direction in which the electric potential increases steepest.
58. Electron volt is the unit of electric potential.
59. The capacitance of a capacitor depends only the nature of the dielectric saparating the plates of the capacitor.
60. The capacitance of a capacitor decreases if a dielectric of dielectric constant k is introduced between the plates of the capacitor.
61. Energy is stored in a capacitor in the form of magnetic field energy.

ANSWERS

55. True.(W = $q\Delta V$. Since $\Delta V = 0$ on the equipotential surface, so W = 0)

56. False. $\left(V=\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\right)$

57. False. $\left(E=-\frac{dV}{dr}\right)$

58. False.(It is the unit of energy)

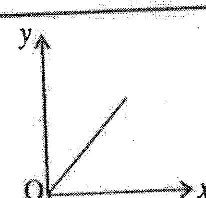
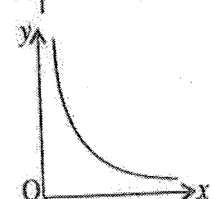
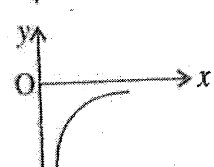
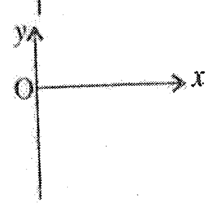
59. False. $\left(C=-\frac{\varepsilon A}{d}\right)$

60. False. ($C = KC_0$)

61. False.(Electric field exist between the plates of the capacitor)

TYPE–E MATCHING TYPE QUESTIONS

62. **Match the physical quantity drawn along y-axis given in column I with the variation of the quantity with distance r drawn along x-axis shown in column II**

Column I	Column II
(A) Electric potential of a charge $-q$	(p) 
(B) Electric potential of a charge $+q$	(q) 
(C) Capacitance of a Spherical conductor of radius r	(r) 
(D) Electric potential due to on electric dipole on its equatorial line	(s) 

(a) A → r, B → q ; C → p ; D → s
(b) A → s ; B → q ; C → p ; D → r
(c) A → q ; B → r ; C → s ; D → p
(d) A → p ; B → q ; C → r ; D → s.

63. Match the physical quantities given in column I with the units given in column II

Column I	Column II
(A) Electric potential	(p) V m^{-1}
(B) Energy	(q) CV^{-1}
(C) Capacitance	(r) JC^{-1}
(D) Dielectric strength	(s) eV

(a) A $\rightarrow p$, B $\rightarrow q$; C $\rightarrow r$; D $\rightarrow s$
(b) A $\rightarrow r$; B $\rightarrow s$; C $\rightarrow q$; D $\rightarrow p$
(c) A $\rightarrow q$; B $\rightarrow p$; C $\rightarrow s$; D $\rightarrow r$
(d) A $\rightarrow s$; B $\rightarrow r$; C $\rightarrow p$; D $\rightarrow q$.

ANSWERS

62. (a) 63. (b)

TYPE-F ASSERTION-REASON TYPE QUESTIONS

Each question has two statements I (Assertion) and II (reason). Of the following statements, choose the correct code if.

(a) Both statements are true and statement II is the correct explanation of statement I.
(b) Both statements are true but statement II is not the correct explanation of statement I.
(c) Statement I is true but statement II is false.
(d) Statement I is false but statement II is true.

64. **Statement 1 :** Electrons move away from a low potential to high potential region.
Statement 2 : Electron has negative charge.

65. **Statement 1 :** Surface of a symmetrical conductor can be treated as equipotential surface.
Statement 2 : Charges can easily flow in a conductor.

66. **Statement 1 :** Dielectric has no significance in a parallel plate capacitor.
Statement 2 : Dielectric is an insulator which can be easily polarised on the application of electric field.

67. **Statement 1 :** The capacity of a given conductor remains same even if charge is varied on it.
Statement 2 : Capacitance depends upon nearly medium as well as size and shape of conductor.

68. **Statement 1 :** Two capacitors of same capacity are firstly connected in parallel and then in series. The ratio of equivalent capacitances in two cases is 2 : 1.
Statement 2 : In series capacitance decreases.

69. **Statement 1 :** A dipole is in stable equilibrium when angle between dipole moment and electric field is zero.
Statement 2 : The electric potential energy has minimum value when angle between dipole moment and electric field is zero.

70. **Statement 1** : A charged capacitor is disconnected from a battery. Now if its plate are separated farther, the potential energy will fall.

Statement 2 : Energy stored in a capacitor is equal to the work done in charging it.

71. **Statement 1** : For a charged particle moving from point P to Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

Statement 2 : The net work done by a conservative force on an object moving along a closed loop is zero.

ANSWERS

64. (*a*) **65.** (*b*) **66.** (*d*) **67.** (*a*) **68.** (*d*) **69.** (*a*) **70.** (*b*) **71.** (*d*)

HINTS AND EXPLANATIONS

64. Low potential as compared to high potential means negative potential *i.e.* low potential region has more electrons so the electrons will move away from this region.

65. Potential is constant on the surface of a conductor, so it behaves as an equipotential surface.

66. Dielectric is very important in a capacitor because capacitance,

$C = \frac{\epsilon_0 KA}{d}$, where K is dielectric constant.

67. Capacitance is basically a geometrical quantity.

68. In series, $C_{eq} = \frac{CC}{C+C} = \frac{C}{2}$

In parallel, $C'_{eq} = C + C = 2C$ $\quad \therefore \frac{C'_{eq}}{C_{eq}} = \frac{2C}{C/2} = 4.$

69. $U = -pE\cos\theta$. For $\theta = 0°$, $U = -pE$ (*i.e.*, minimum)

70. Energy $= 1/2CV^2 = \frac{1}{2}\frac{\varepsilon_0 A}{d}V^2$ *i.e.*, Energy $\propto \frac{1}{d}$.

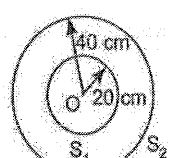
71. Electrostatic field is conservative in nature.

Case-based/Passage-based Integrated Questions

2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

CASE-BASED/PASSAGE-BASED INTEGRATED QUESTIONS

Q. 1. Consider a conducting sphere S_1 of radius 20 cm. A positive charge is given to it so that maximum electric field on it is 2.0×10^4 N/C. The same amount of negative charge is given to another isolated conducting hollow sphere of radius 40 cm. If one shell is now placed inside another so that they are both concentric as shown below. Now answer the following questions:



(i) The electric field intensity just inside the outersphere is ________.

(ii) The electrostatic potential at any point inside sphere S_1 is ________.

(iii) If sphere S_1 and S_2 are joined by a wire, then what will happen?

Ans. (i) Given electric field on sphere S_1

$$E_1 = 2 \times 10^4 \text{ N/C}$$

$$\therefore \quad E_1 = 2 \times 10^4 \text{ N/C} = \frac{kQ}{r_1^2}$$

Now just inside outer sphere Electric field

$$E_2 = \frac{kQ}{r_2^2},$$

$$\frac{E_2}{E_1} = \frac{r_1^2}{r_2^2}$$

Here $r_1 = 0.20$ m, $r_2 = 0.40$ m

$$E_2 = 2 \times 10^4 \times \left(\frac{0.2}{0.4}\right)^2 = 0.5 \times 10^4 \text{ N/c.}$$

(ii) Electrostatic potential inside S_1

$$V_1 = \frac{kQ}{r_1} = r_1 E_1 \qquad \left[\because \frac{E_1}{V_1} = \frac{1}{r_1}\right]$$

$$= 0.2 \times 2 \times 10^4$$

$$= 0.4 \times 10^4 = 4 \times 10^3 \text{ V}$$

(iii) If S_1 and S_2 are joined by a wire entire amount of energy stored in the system will get converted into heat.

Reason: Both the charges on spheres S_1 and S_2 will get neutralized and energy of the system will be dissipated as heat.

Or

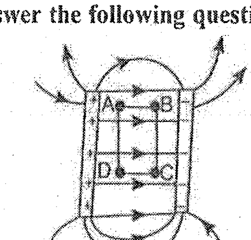
After connecting, the charge will transfer from higher potential sphere to lower potential sphere and finally potential of both sphere will be equal.

Q 2. Electric field between oppositely charged parallel conducting plates:

When two plane parallel conducting plates, having the size and spacing shown in figure given below are given equal and opposite charges, the field between and around them is approximately as shown, while most of the charge accumulates at the opposing faces of the plates and the field is essentially uniform in the space between them, there is a small quantity of charge on the outer surfaces of the plates and a certain spreadwing or "fringing of the field at the edges of the plates.

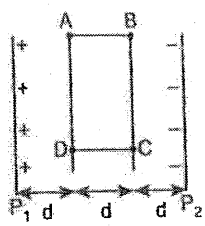
As the plates are made larger and the distance between them diminished, the fringing becomes relatively less. This kind of arrangement is called capacitors.

Now if two plates are separated by a distance '3*d*', and are maintained at a potential difference '*V*' then answer the following questions.



(i) What is the use of capacitors?

(ii) If two protons are placed at points A and B respectively, then which one will experience more force?



(*iii*) **When both the protons are released then which one will gain more K.E. just before striking the –ve plate?**

(*iv*) **If one proton is moved along**

(*a*) **A to B**

(*b*) **B to C**

(*c*) **C to D**

(*d*) **Along ABCD, then how much work is done by external agent?**

(*v*) **Which property of electric field is shown by answer to (*iv*) (*d*) part?**

Ans. (*i*) Capacitors are used to store electric charges and electric energy.

(*ii*) Both the protons will experience same force.

Reason: $F = qE$; E = constant; $q = +e$ (same)

(*iii*) $\because V_D = V_A > V_B = V_C$

[In the direction of electric field potential decreaes]

$V_A > V_B$ or $(P.D)_{AP_2} > (P.D)_{BP_2}$

$\therefore$ Gain in K.E. $= q \times$ P.D.

$\therefore$ Gain in K.E. of proton released from point A will be more.

(*iv*) (*a*) $W_{A \to B} = e(V_B - V_A)$ $\quad \left[\because W = q \times \text{P.D.},\ E = \frac{V}{d}\right]$

$= e[E.2d - E.d]$

$= eE.d$

(*b*) $\because \quad V_B = V_C$

$\therefore \quad W_{BC} = 0$

(*c*) $W_{CD} = e[V_D - V_C]$

$= e[E.(d) - E(2d)]$

$= -eEd$

(*d*) $W_{ABCD} = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$= eEd + 0 - eEd + 0$

$= 0$

(*v*) Electric field is conservative as work done along a closed path is zero.

Self Evaluation Test - 2

Electrostatics

Maximum Marks : 30 *Duration : 75 minutes*

1 Mark Questions

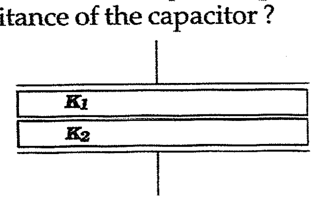
1. Force of attraction between two point electric charges placed at a distance d in a medium is F. What distance apart should these be kept in the same medium so that the force between them becomes F/4 ?
2. Define the unit of electric charge.
3. Give the SI unit of electric field intensity.
4. What is the relation between electric intensity and flux ?
5. How much work is done in moving a 0.5 C charge between two points on an equipotential surface ?
6. In what form is the energy stored in a charged capacitor ?
7. On inserting a dielectric between the plates of a capacitor, its capacitance is observed to increase 5 times. What is the relative permittivity of the dielectric ?
8. What is the SI unit of capacitance ?

2 Marks Questions

9. State the important properties of an electric charge.
10. Determine the magnitude and direction of an electric field that will balance the weight of an electron.
11. What is the principle of electrostatic shielding ?
12. Two point charges of +0.2 μC and –0.2 μC are separated by a distance of 10^{-8} m. Determine the electric field at an axial point at a distance of 0.1 m from their mid-point.

3 Marks Questions

13. Two point charges A and B of values + 15 μC and + 9 μC are kept 18 cm apart in air. Calculate the work done when charge B is moved 3 cm towards A.
14. Two material slabs of dielectric constants K_1 and K_2 are filled in between the two plates as shown. What will be the capacitance of the capacitor ?



15. Using Gauss's Theorem, derive the expression for electric field intensity due to an infinite charged conducting plate.

5 Marks Questions

16. Sketch a labelled diagram of a Van de Graff generator. State its principle.

SELF EVALUATION TEST OF ELECTROSTATICS

SOLUTIONS

Hints / Answers

1. $F = K\dfrac{q_1q_2}{r_1^2}$ $\dfrac{F}{4} = K\dfrac{q_1q_2}{r_2^2}$

   $\therefore\ 4 = \dfrac{r_2^2}{r_1^2} = \dfrac{r_2^2}{d^2}$ $\therefore\ r_2 = 2d$

2. 1 coulomb of charge is the amount of charge accompanying the flow of current of 1 ampere for 1 second.
3. N/C.
4. Electric flux, $\phi_E = \oint_s \vec{E}.\vec{dS}$
5. Zero
6. Electric potential energy
7. Relative permittivity = 5
8. farad

12. As $a << r$, $\therefore\ E = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{2p}{r^3}$

   $\Rightarrow E = 9\times10^9\times\dfrac{2\times(0.2\times10^{-6})\times(10^{-8})}{(0.1)^3} = 3.6\times10^{-2}$ N/C

13. $W = U_1 - U_2 = \dfrac{kQ_1Q_2}{r_2} - \dfrac{kQ_1Q_2}{r_1}$

   $= (9\times10^9)\times(15\times10^{-6})(9\times10^{-6})\left[\dfrac{1}{15\times10^{-2}} - \dfrac{1}{18\times10^{-2}}\right]$

   $= 1215\times10^{-3}\left[\dfrac{3}{15\times18\times10^{-2}}\right] = 1.35$ J

14. $\dfrac{\varepsilon_0 A}{d}\left[\dfrac{2k_1k_2}{k_1+k_2}\right]$