MASS PHYSICS

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.

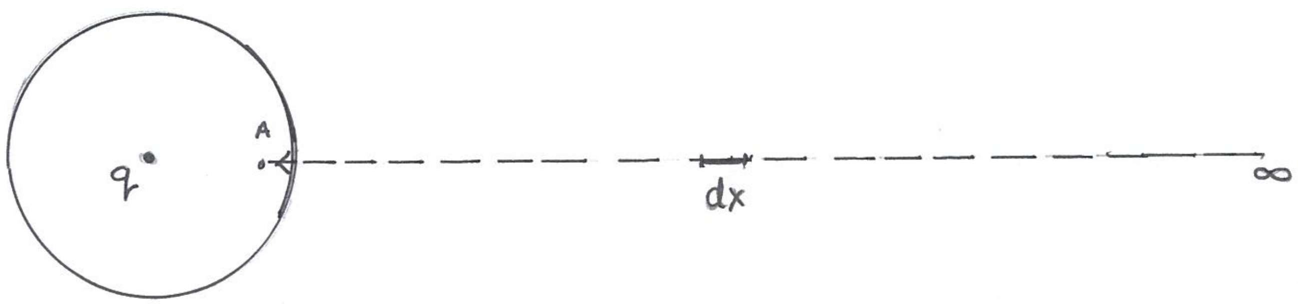
5. Equi-potential surfaces.

6. Potential energy of a system of charges.

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

A. definition:

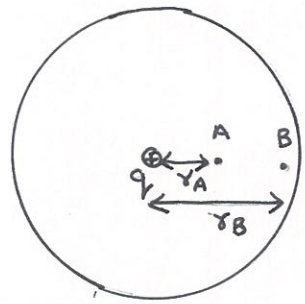
Expression for potential at a point inside electric field:



UNITS OF POTENTIAL:—

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

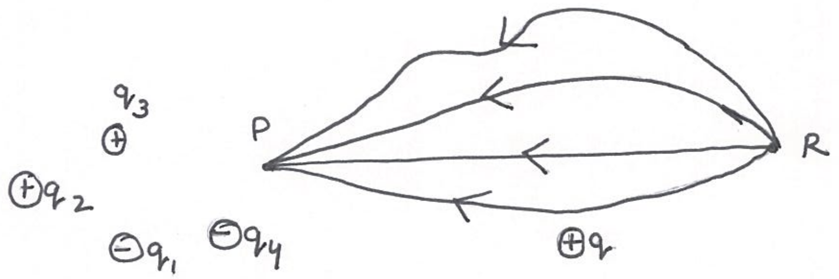
A.



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.

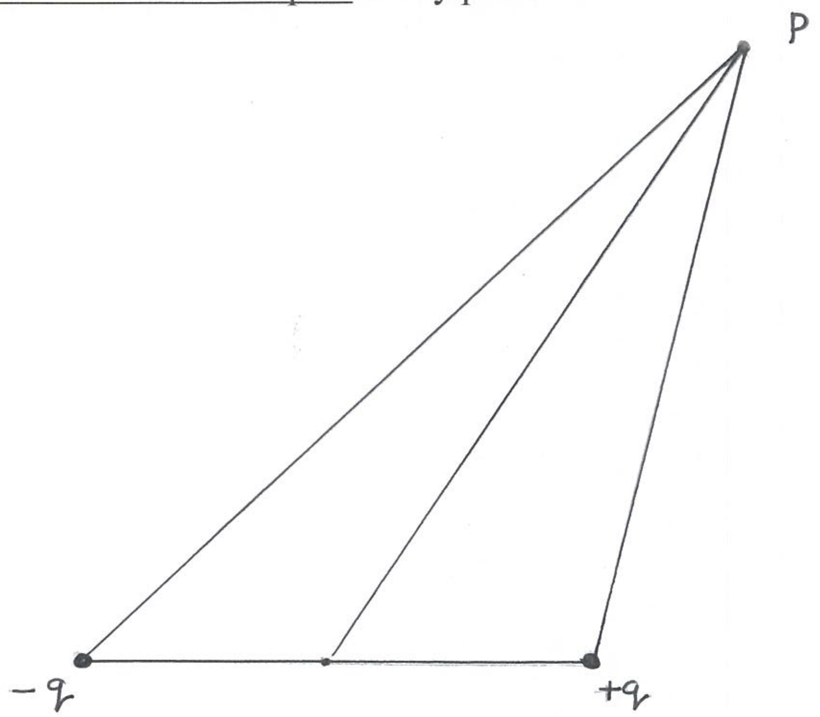
b) Hence obtain the work done in bringing a charge of 2×10^{-9} C from infinity to a point P. Does the answer depend on the path along which the charge is brought ?

A.



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:—

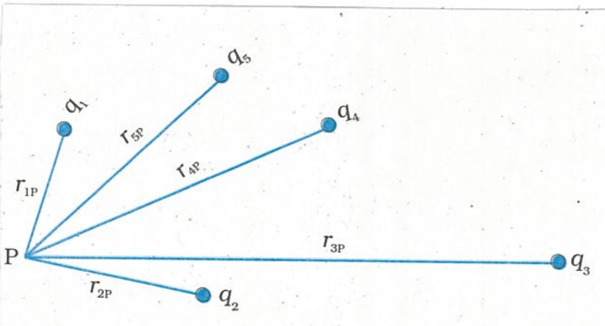
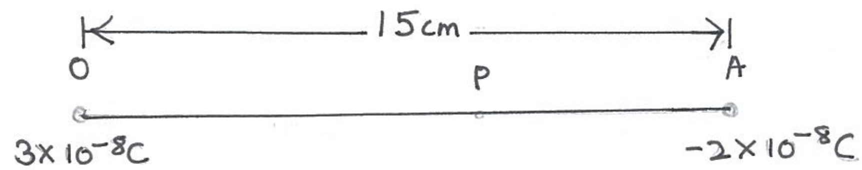


FIGURE 2.6 Potential at a point due to a system of charges is the sum of potentials due to individual charges.

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.

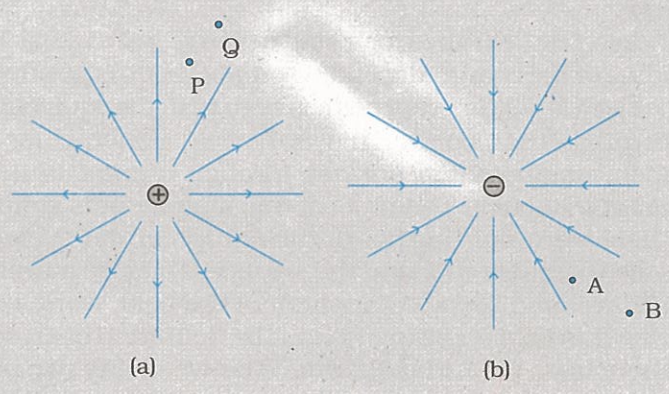


FIGURE 2.8

(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.

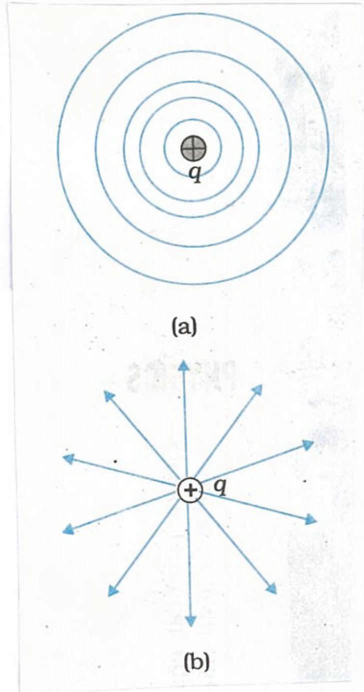
(e) Does the kinetic energy of a small negative charge increase or decrease in going from B to A?

Solution

EQUIPOTENTIAL SURFACES

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

A. Definition:



Properties of equipotential surfaces:

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

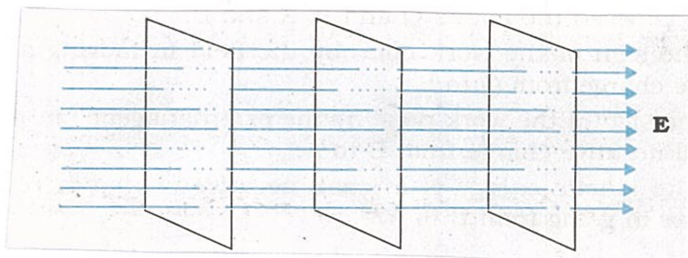
2.

3.

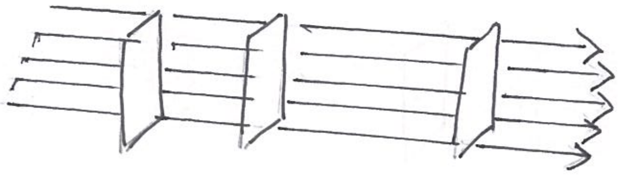
4.

5.

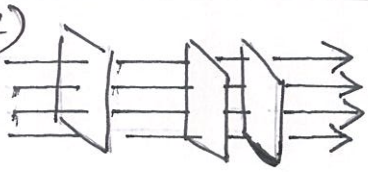
a)



b)



c)

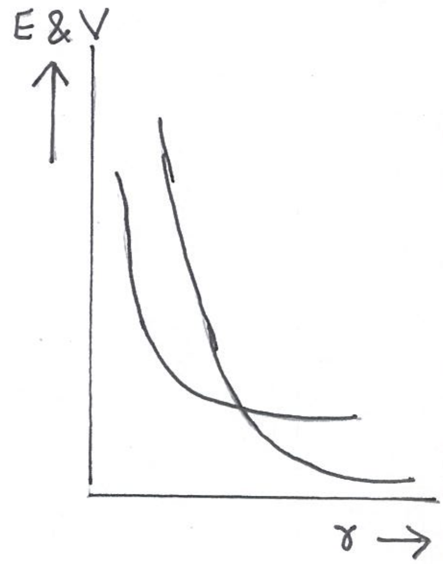


Q.10 : What is the relation between electric field and potential?

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?

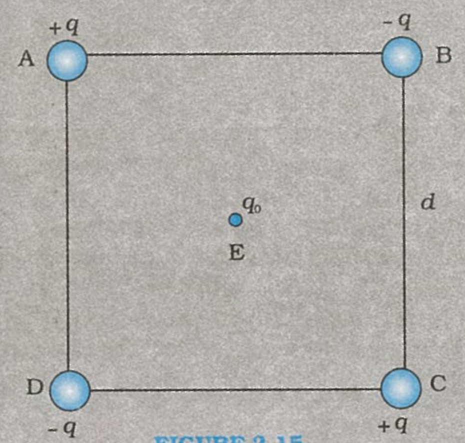
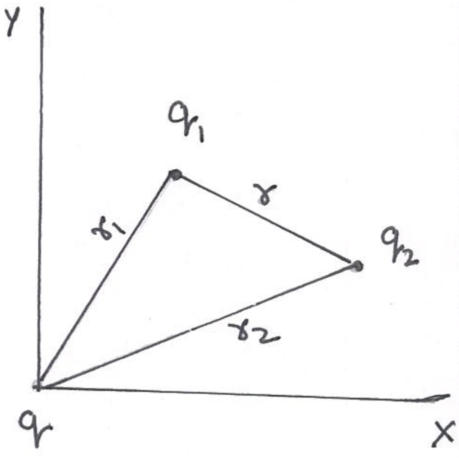


FIGURE 2.15

Solution

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 $E = A\,(1/r^2)$; $A = 9 \times 10^5\ \mathrm{C\ m^{-2}}$. 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,

$$q_1 V(\mathbf{r}_1) + q_2 V(\mathbf{r}_2) = A\frac{7\mu C}{0.09 m} + A\frac{-2\mu C}{0.09 m}$$

and the net electrostatic energy is

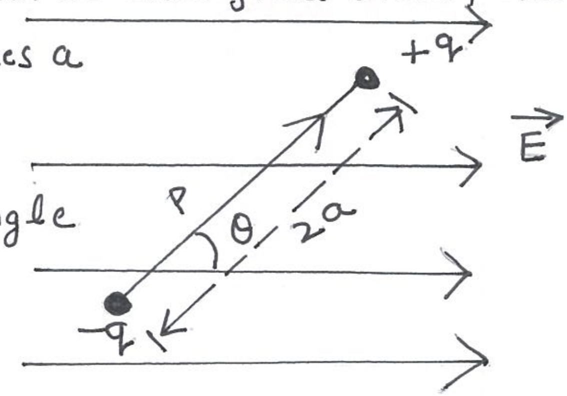
$$q_1 V(\mathbf{r}_1) + q_2 V(\mathbf{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}} = A\frac{7\,\mu C}{0.09\,m} + A\frac{-2\,\mu C}{0.09\,m} - 0.7\ J$$

$$= 70 - 20 - 0.7 = 49.3\ J$$

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:-



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:-

Topic 2: CONDUCTORS & INSULATORS

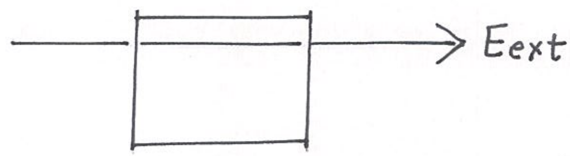
ELECTROSTATICS OF CONDUCTORS:

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:



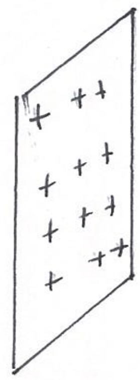
2. At the surface of a charged conductor, electric field must be normal to the surface at every point.

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.

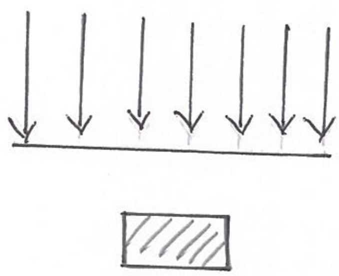
5. Electric field at the surface of a charged conductor:

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

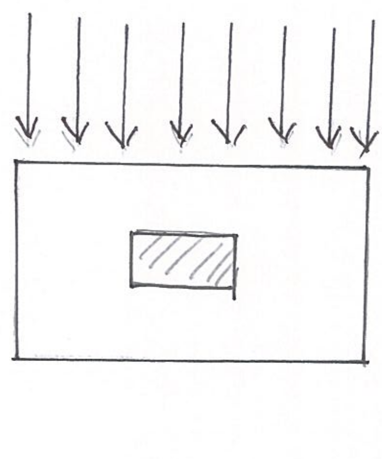


6. Electrostatic shielding:

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.

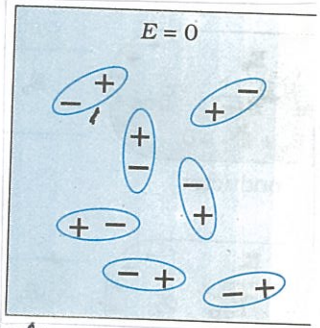
Dielectrics and Polarisation

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

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

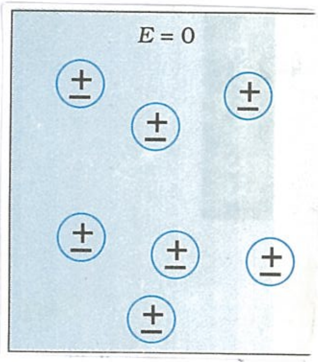
Dielectrics are of two types:

1. Polar dielectrics:



a) Polar

2. Non polar dielectrics:

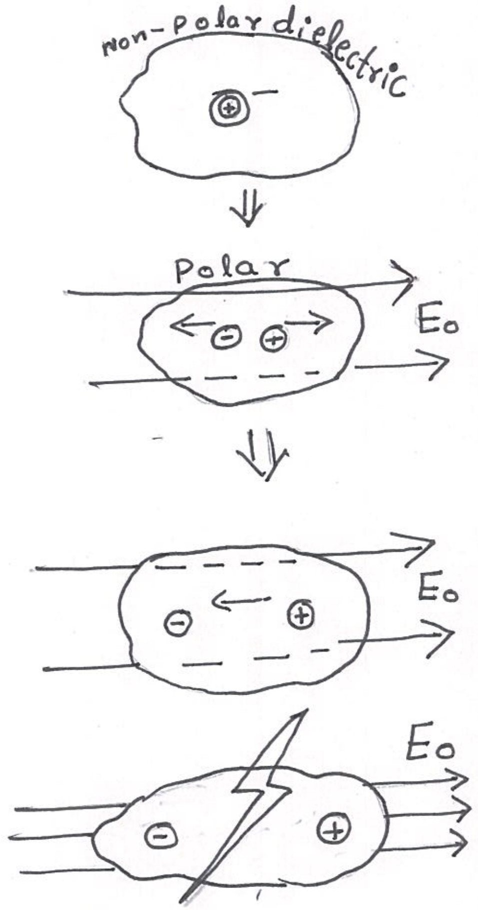


b) Non-polar

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.



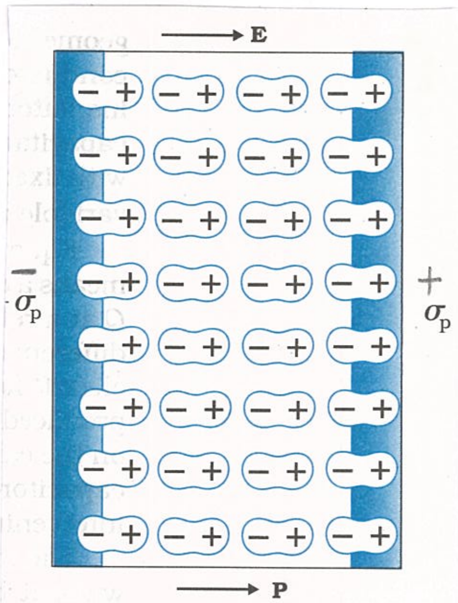


FIGURE 2.23 A uniformly polarised dielectric amounts to induced surface charge density, but no volume charge density.

POLARISATION:—

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

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:

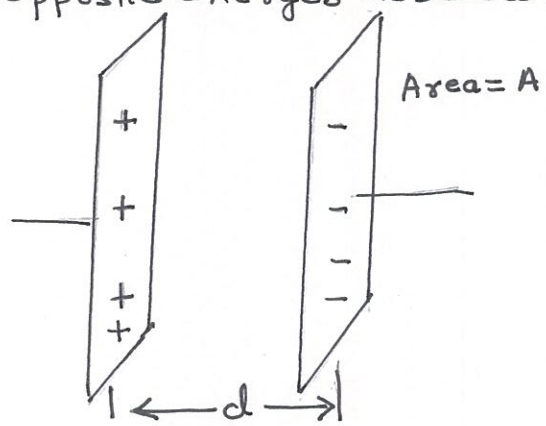
1. Parallel plate capacitor (4 FORMS)
2. Isolated sphere capacitor
3. Spherical capacitor
4. Cylindrical capacitor

THE PARALLEL PLATE CAPACITOR

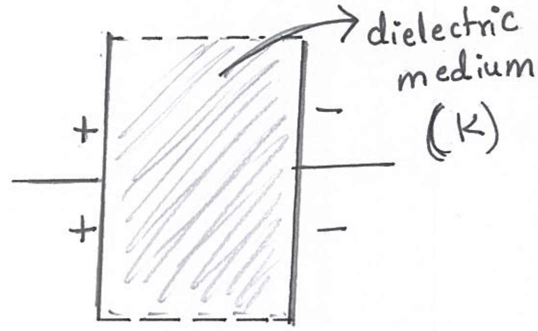
A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance. Its capacitance depends the intervening medium between the two plates.

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 asbelow:-

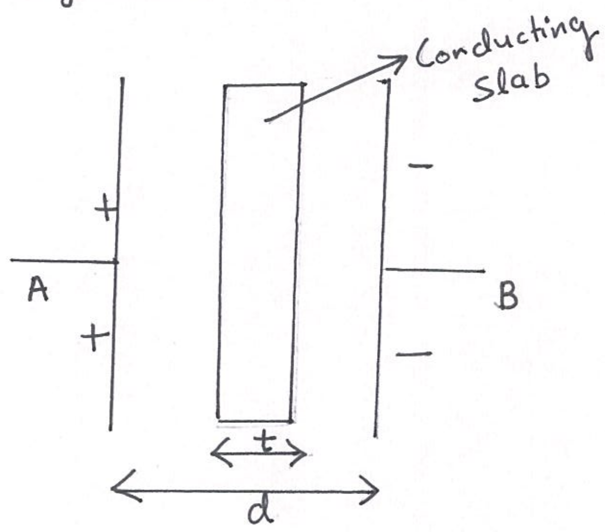


Q.4 Study parallel plate capacitor for its capacitance when it is medium (dielectric) filled?



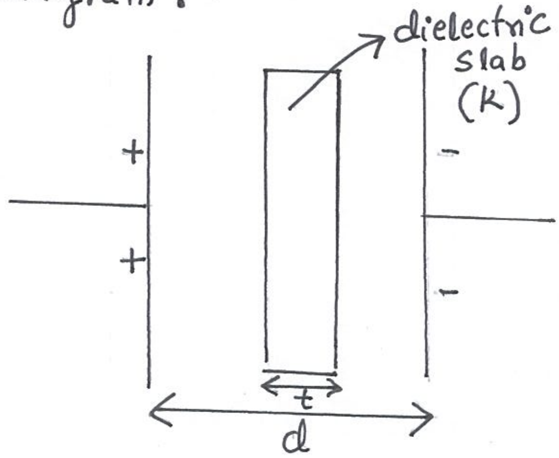
Q.5 Study parallel plate capacitor for its capacitance when an conducting slab of thickness t is inserted inside it?

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?

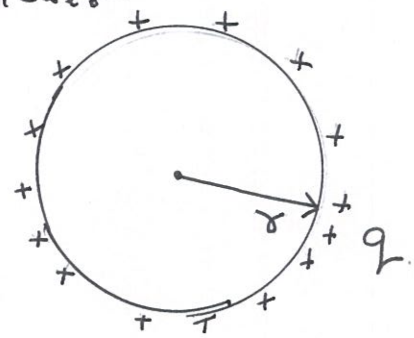
Ans. Consider a parallel plate capacitor having plate area A and distance of seperation 'd'. Now a dielectric slab of thickness 't' is inserted in between two plates :- due to polarisation of dielectric atoms an opposite Field will Induced inside the slab which will decreases the field inside it by $\frac{1}{K}$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



SPECIAL CAPACITOR:

Q.7 Find the capacitance of an isolated sphere?

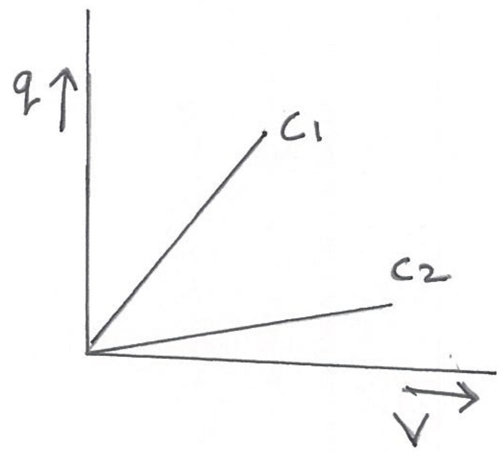
A. Isolated sphere is a single charged shell:-



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

A.

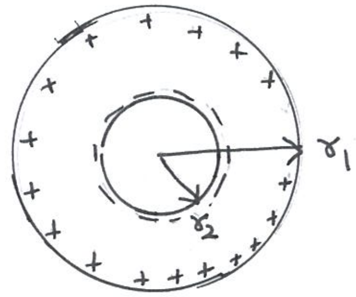
Q.9 Which capacitor is of higher capacitance?



A.

Q.10 . Obtain the expression for spherical capacitor?

Ans. Spherical Capacitor Consist of 2 Concentric metallic Shells. having opposite charges as shown in the diagram :-



Q.11 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 ¾ d, where d is the separation of the plates , how is the capacitance changed when the slab is inserted between the plates?

A. Use:- Formula for dielectric slab in parallel plate Capacitor

$$C = \frac{\epsilon_0 A}{d - t + \frac{t}{K}}$$

TOPIC -4 COMBINATION OF CAPACITORS

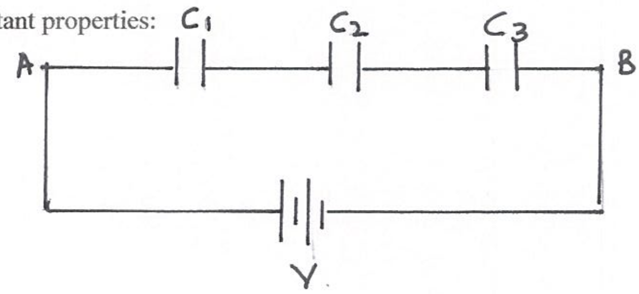
WE CAN COMBINE SEVERAL CAPACITORS OF CAPACITANCE C_1, C_2 ___ C_N TO OBTAIN A SYSTEM WITH SOME EFFECTIVE CAPACITANCE C

TWO BASIC COMBINATION OF CAPACITORS ARE:

1. SERIES COMBINATION

2. PARALLEL COMBINATION

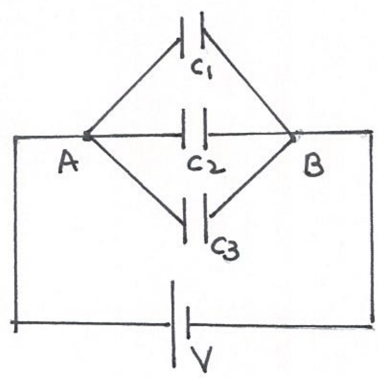
Q.1 What is series combination of capacitors? Write its important properties:



A.

Properties:

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



A.

Properties:

NUMERICAL PROBLEMS BASED ON SERIES AND PARALLEL

TRICKS:

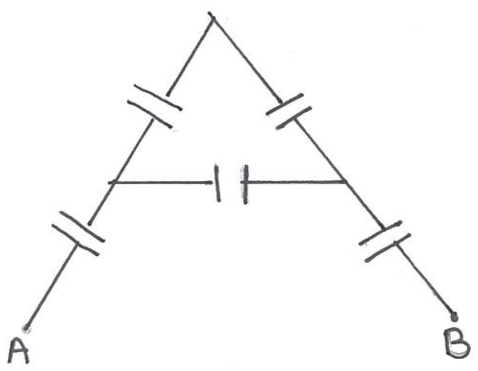
1.

2.

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

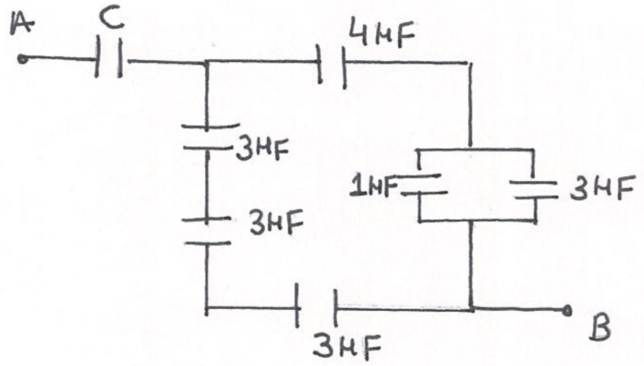
A.

Q.4 Find net capacitance across A and B ?

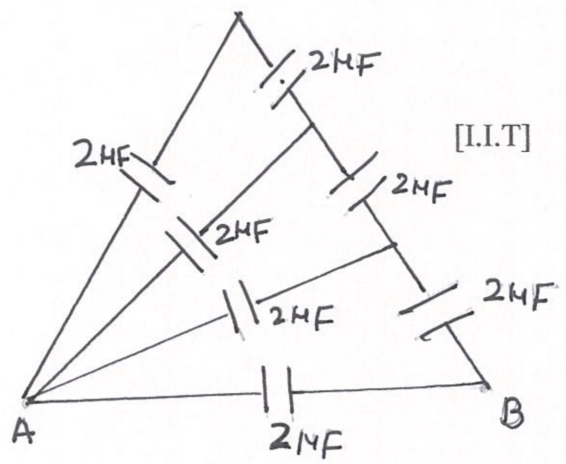


each Capacitor = $2 \mu F$

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

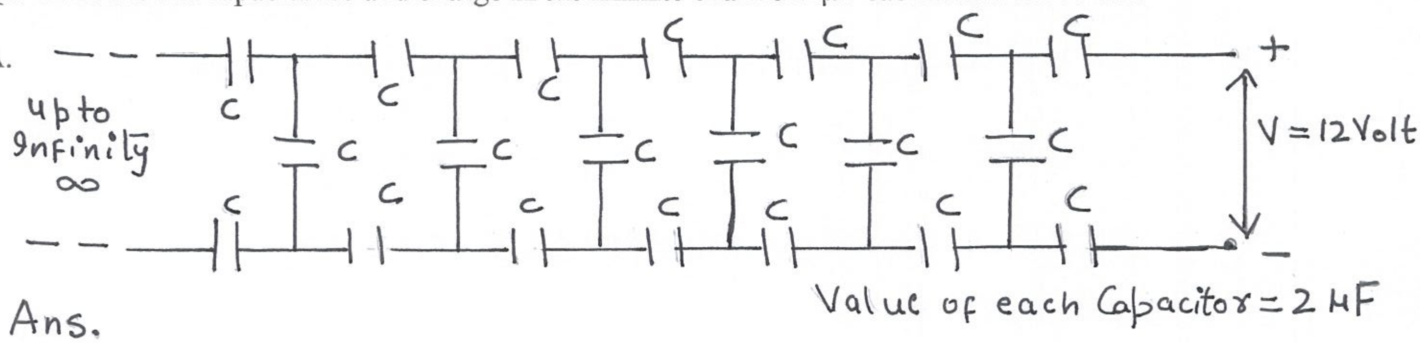


Q.6 find the net capacitance across A & B [I.I.T]



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

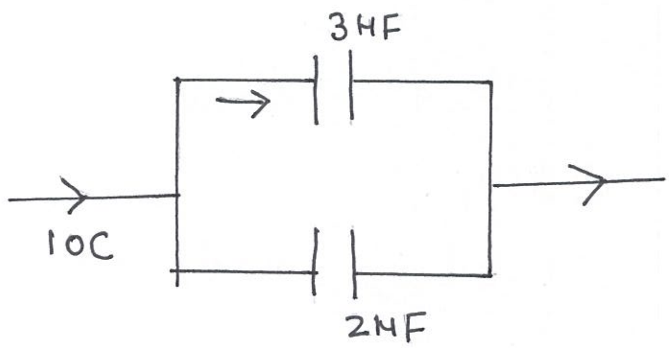
A.



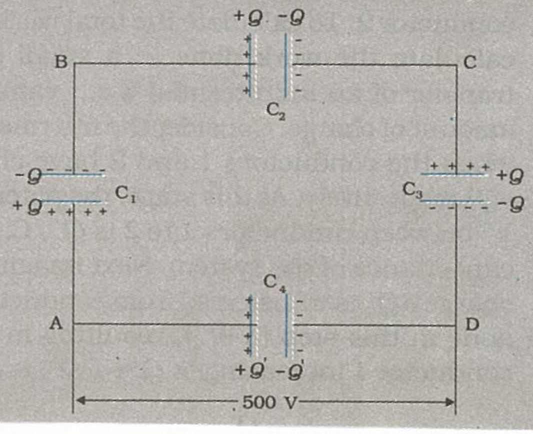
Ans.

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.)

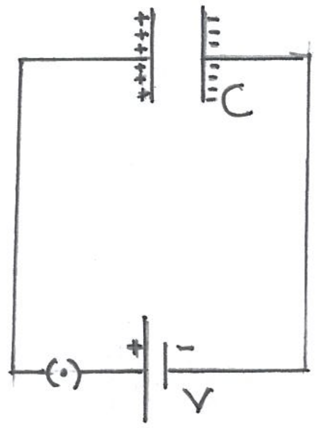


Solution:

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 ? [5—]

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?

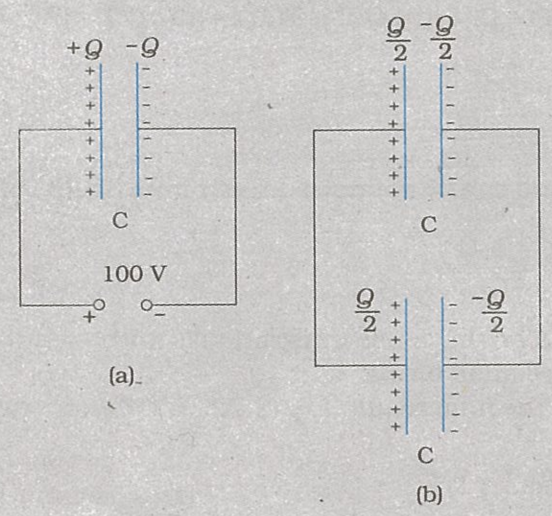


FIGURE 2.31

Solution :

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?

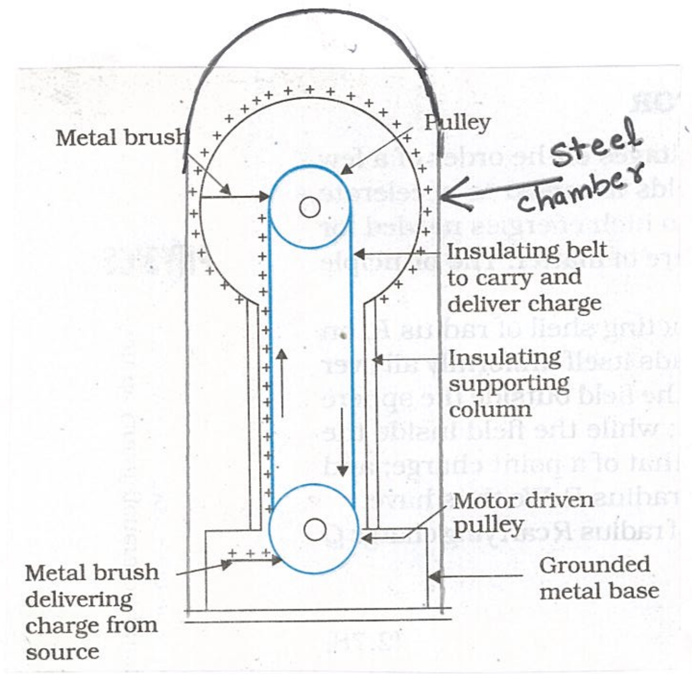
Ans. DEFINITION:

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:



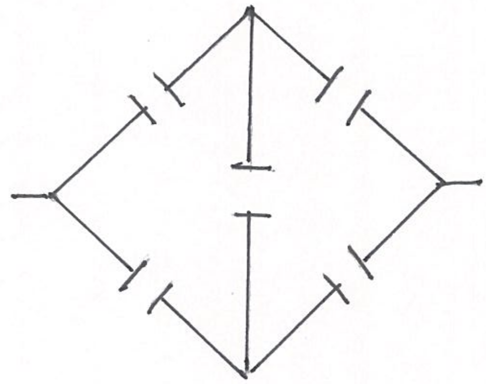
USES OF VAN DE GRAAFF GENERATOR:

ROLE OF CH_4 AND N_2 GAS IN GENERATOR

ADDITIONAL questions :

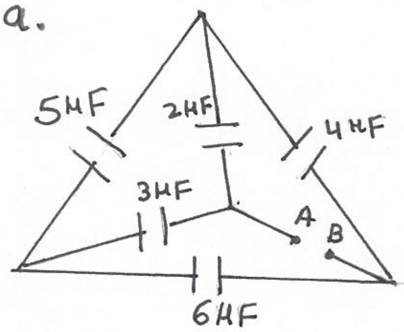
Q.1 How we can apply wheat stone bridge in capacitor circuit to find net capacitance, explain it by the help of an example?

A.

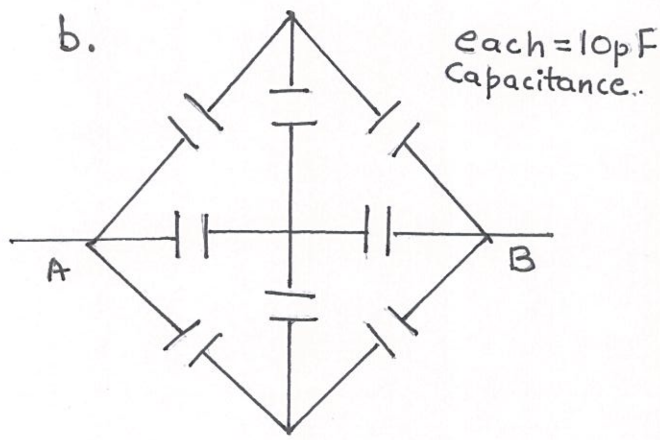


Q.2 find net capacitance across A & B in the given circuits?

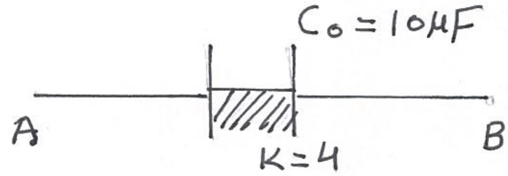
a.



b.

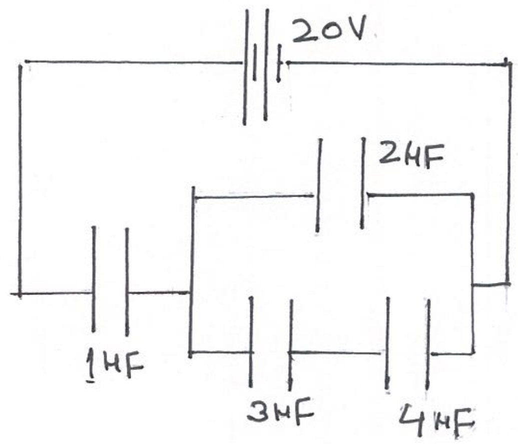


C.



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

A.



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.

Chapter wise Theoretical Important Questions in Physics for Class-XII
ELECTROSTATIC POTENTIAL AND CAPACITANCE

Electrostatics-

1. Derive an expression for the energy stored in a capacitor. Show that whenever two conductors share charges by bringing them into electrical contact, there is a loss of energy.
2. Derive an expression for the effective capacitance when capacitors are connected in (a) series and (b) parallel
3. Explain the principle of a capacitor and derive an expression for the capacitance of a parallel plate capacitor for the following cases:
   a. air filled
   b. dielectric medium filled
   c. filled with conducting slab
   d. filled with dielectric slab

4. Derive an expression for the electrostatic potential energy of a system of point charges

5. Define electric potential at a point. Derive an expression for the electric potential at a point due to (a) a point charge (b) a system of point charges (c) a dipole.

6. Show that the work done in an electric field is independent of path.

7. What are dielectrics? Distinguish polar and nonpolar dielectrics. Define the term Polarization vector.

8. What are equipotential surfaces write their important properties?
9. Explain the relation between V and E? also explain electrostatic shielding.

10. Describe the Principle, construction and working of Van de Graff generator.

N.C.E.R.T BACK EXERCISES

NCERT Question 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.

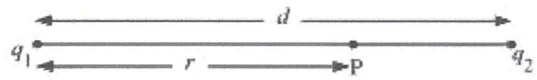
Answer

There are two charges,

$$q_1 = 5\times10^{-8}\text{C}$$
$$q_2 = -3\times10^{-8}\text{C}$$

Distance between the two charges, d = 16 cm = 0.16 m

Consider a point P on the line joining the two charges, as shown in the given figure.



r = Distance of point P from charge q_1

Let the electric potential (V) at point P be zero.

Potential at point P is the sum of potentials caused by charges q_1 and q_2 respectively.

$$\therefore V = \frac{q_1}{4\pi \in_0 r} + \frac{q_2}{4\pi \in_0 (d-r)} \quad \text{... (i)}$$

Where,

$\in_0$ = Permittivity of free space For

$V = 0$, equation (i) reduces to

$$\frac{q_1}{4\pi \in_0 r} = -\frac{q_2}{4\pi \in_0 (d-r)}$$
$$\frac{q_1}{r} = \frac{-q_2}{d-r}$$
$$\frac{5\times10^{-8}}{r} = -\frac{(-3\times10^{-8})}{(0.16-r)}$$
$$\frac{0.16}{r} - 1 = \frac{3}{5}$$
$$\frac{0.16}{r} = \frac{8}{5}$$

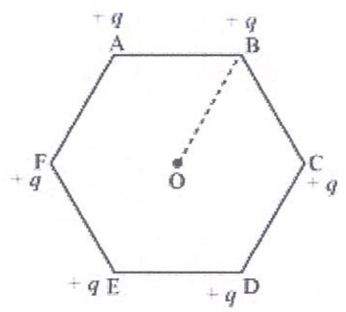
$\therefore r = 0.1\text{m} = 10\text{cm}$ Therefore, the potential is zero at a distance of 10 cm from the positive charge between the charges.

NCERT Question 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.

Answer

The given figure shows six equal amount of charges, q, at the vertices of a regular hexagon.

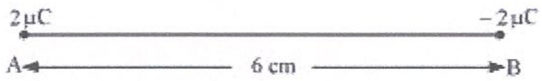


NCERT Question 2.3:

Two charges 2 μC and −2 μC are placed at points A and B 6 cm apart.
Identify an equipotential surface of the system.
What is the direction of the electric field at every point on this surface?

Answer

The situation is represented in the given figure.



An equipotential surface is the plane on which total potential is zero everywhere. This plane is normal to line AB. The plane is located at the mid-point of line AB because the magnitude of charges is the same.

The direction of the electric field at every point on this surface is normal to the plane in the direction of AB.

NCERT Question 2.4:

A spherical conductor of radius 12 cm has a charge of 1.6×10^{-7}C distributed uniformly on its surface. What is the electric field Inside the sphere
Just outside the sphere At a point 18 cm from the centre of the sphere?

Answer

Radius of the spherical conductor, $r = 12$ cm = 0.12 m

Charge is uniformly distributed over the conductor, $q = 1.6 \times 10^{-7}$ C

Electric field inside a spherical conductor is zero. This is because if there is field inside the conductor, then charges will move to neutralize it.

Electric field E just outside the conductor is given by the relation,

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

Where,

ϵ_0 = Permittivity of free space

$$\frac{1}{4\pi \epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

$$\therefore E = \frac{1.6 \times 10^{-7} \times 9 \times 10^{-9}}{(0.12)^2} = 10^5 \text{ NC}^{-1}$$

Therefore, the electric field just outside the sphere is $10^5\ \text{N C}^{-1}$.

Electric field at a point 18 m from the centre of the sphere = E_1

Distance of the point from the centre, d = 18 cm = 0.18 m

$$E_1 = \frac{q}{4\pi \in_0 d^2}$$
$$= \frac{9\times10^9 \times 1.6\times10^{-7}}{\left(18\times10^{-2}\right)^2}$$
$$= 4.4\times10^4\ \text{N/C}$$

Therefore, the electric field at a point 18 cm from the centre of the sphere is

4.4×10^4 N/C

NCERT Question 2.5:

A parallel plate capacitor with air between the plates has a capacitance of 8 pF (1pF = 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?

Answer

NCERT Question 2.6:

Three capacitors each of capacitance 9 pF are connected in series.

What is the total capacitance of the combination?

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

Answer

NCERT Question 2.7:

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

What is the total capacitance of the combination?

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

Answer

NCERT Question 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?

Answer

NCERT Question 2.9:

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

While the voltage supply remained connected.

After the supply was disconnected.

Answer

NCERT Question 2.10:

A 12 pF capacitor is connected to a 50V battery. How much electrostatic energy is stored in the capacitor?

Answer

Capacitor of the capacitance, $C = 12$ pF $= 12 \times 10^{-12}$ F

Potential difference, $V = 50$ V

Electrostatic energy stored in the capacitor is given by the relation,

$$E = \frac{1}{2}CV^2$$
$$= \frac{1}{2} \times 12 \times 10^{-12} \times (50)^2$$
$$= 1.5 \times 10^{-8} \text{ J}$$

Therefore, the electrostatic energy stored in the capacitor is 1.5×10^{-8} J.

NCERT Question 2.11:

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

Answer

Capacitance of the capacitor, $C = 600$ pF

Potential difference, $V = 200$ V

Electrostatic energy stored in the capacitor is given by,

$$E = \frac{1}{2}CV^2$$
$$= \frac{1}{2} \times (600 \times 10^{-12}) \times (200)^2$$
$$= 1.2 \times 10^{-5} \text{ J}$$

If supply is disconnected from the capacitor and another capacitor of capacitance $C = 600$ pF is connected to it, then equivalent capacitance (C') of the combination is given by,

$$\frac{1}{C'} = \frac{1}{C} + \frac{1}{C}$$
$$= \frac{1}{600} + \frac{1}{600} = \frac{2}{600} = \frac{1}{300}$$
$$\therefore C' = 300 \text{ pF}$$

New electrostatic energy can be calculated as

$$E' = \frac{1}{2} \times C' \times V^2$$
$$= \frac{1}{2} \times 300 \times (200)^2$$
$$= 0.6 \times 10^{-5} \text{ J}$$

Loss in electrostatic energy $= E - E'$

$$= 1.2 \times 10^{-5} - 0.6 \times 10^{-5}$$
$$= 0.6 \times 10^{-5}$$
$$= 6 \times 10^{-6} \text{ J}$$

Therefore, the electrostatic energy lost in the process is 6×10^{-6} J

NCERT Question 2.12:

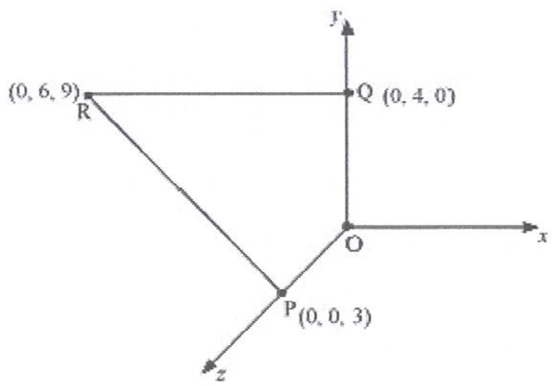
A charge of 8 mC is located at the origin. Calculate the work done in taking a small charge of -2×10^{-9} C from a point P (0, 0, 3 cm) to a point Q (0, 4 cm, 0), via a point R (0, 6 cm, 9 cm).

Answer

Charge located at the origin, $q = 8$ mC$= 8 \times 10^{-3}$ C

Magnitude of a small charge which is taken from a point P to point R to point Q, $q_1 = -2 \times 10^{-9}$ C

All the points are represented in the given figure.



Point P is at a distance, $d_1 = 3$ cm, from the origin along z-axis.

Point Q is at a distance, $d_2 = 4$ cm, from the origin along y-axis.

.Potential at point P, $V_1 = \frac{q}{4\pi \in_0 \times d_1}$

Potential at point Q, $V_2 = \frac{q}{4\pi \in_0 d_2}$

Work done (W) by the electrostatic force is independent of the path.

$$\therefore W = q_1 [V_2 - V_1]$$
$$= q_1 \left[\frac{q}{4\pi \in_0 d_2} - \frac{q}{4\pi \in_0 d_1}\right]$$
$$= \frac{qq_1}{4\pi \in_0}\left[\frac{1}{d_2} - \frac{1}{d_1}\right] \qquad \dots (i)$$

Where, $\frac{1}{4\pi \in_0} = 9\times10^9 \text{ N m}^2 \text{ C}^{-2}$

$$\therefore W = 9\times10^9 \times 8\times10^{-3} \times \left(-2\times10^{-9}\right)\left[\frac{1}{0.04} - \frac{1}{0.03}\right]$$
$$= -144\times10^{-3} \times \left(\frac{-25}{3}\right)$$
$$= 1.27 \text{ J}$$

Therefore, work done during the process is 1.27 J.

NCERT Question 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.

Answer

.

NCERT Question 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:
at the mid-point of the line joining the two charges, and
at a point 10 cm from this midpoint in a plane normal to the line and passing through the mid-point.

Answer

NCERT Question 2.15:

A spherical conducting shell of inner radius $r1$ and outer radius $r2$ has a charge Q.

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?

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

Answer

Charge placed at the centre of a shell is $+q$. Hence, a charge of magnitude $-q$ will be induced to the inner surface of the shell. Therefore, total charge on the inner surface of the shell is $-q$.

Surface charge density at the inner surface of the shell is given by the relation,

$$\sigma_1 = \frac{\text{Total charge}}{\text{Inner surface area}} = \frac{-q}{4\pi r_1^2} \quad \dots (i)$$

A charge of $+q$ is induced on the outer surface of the shell. A charge of magnitude Q is placed on the outer surface of the shell. Therefore, total charge on the outer surface of the shell is $Q + q$. Surface charge density at the outer surface of the shell,

$$\sigma_2 = \frac{\text{Total charge}}{\text{Outer surface area}} = \frac{Q+q}{4\pi r_2^2} \quad \dots (ii)$$

Yes

The electric field intensity inside a cavity is zero, even if the shell is not spherical and has any irregular shape. Take a closed loop such that a part of it is inside the cavity along a field line while the rest is inside the conductor. Net work done by the field in carrying a test charge over a closed loop is zero because the field inside the conductor is zero. Hence, electric field is zero, whatever is the shape.

NCERT Question 2.16:

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

$$\left(\overline{E_2} - \overline{E_1}\right).\hat{n} = \frac{\sigma}{\epsilon_0}$$

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 σ $\hat{n}/\epsilon_0$

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.]

Answer

Electric field on one side of a charged body is E_1 and electric field on the other side of the same body is E_2. If infinite plane charged body has a uniform thickness, then electric field due to one surface of the charged body is given by,

$$\overline{E_1} = -\frac{\sigma}{2\epsilon_0}\hat{n} \qquad \text{... (i)}$$

Where,

$\hat{n}$ = Unit vector normal to the surface at a point

σ = Surface charge density at that point

Electric field due to the other surface of the charged body,

$$\overline{E_2} = -\frac{\sigma}{2\epsilon_0}\hat{n} \qquad \text{... (ii)}$$

Electric field at any point due to the two surfaces,

$$\overline{E_2} - \overline{E_1} = \frac{\sigma}{2\epsilon_0}\hat{n} + \frac{\sigma}{2\epsilon_0}\hat{n} = \frac{\sigma}{\epsilon_0}\hat{n}$$

$$\left(\overline{E_2} - \overline{E_1}\right).\hat{n} = \frac{\sigma}{\epsilon_0} \qquad \text{... (iii)}$$

Since inside a closed conductor, $\overline{E_1} = 0$,

$$\therefore \quad \vec{E} = \overline{E_2} = -\frac{\sigma}{2\epsilon_0}\hat{n}$$

Therefore, the electric field just outside the conductor is $\frac{\sigma}{\epsilon_0}\hat{n}$.

When a charged particle is moved from one point to the other on a closed loop, the work done by the electrostatic field is zero. Hence, the tangential component of electrostatic field is continuous from one side of a charged surface to the other.

NCERT Question 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?

Answer

Charge density of the long c arged cylinder of length L and radius r is λ.

Another cylinder of same length surrounds the pervious cylinder. The radius of this cylinder is R.

Let E be the electric field produced in the space between the two cylinders.

Electric flux through the Gaussian surface is given by Gauss's theorem as,

$$\phi = E(2\pi d)L$$

Where, d = Distance of a point from the common axis of the cylinders

Let q be the total charge on the cylinder.

It can be written as

$$\therefore \phi = E(2\pi dL) = \frac{q}{\epsilon_0}$$

Where,

q = Charge on the inner sphere of the outer cylinder

ϵ_0 = Permittivity of free space

$$E(2\pi dL) = \frac{\lambda L}{\epsilon_0}$$

$$E = \frac{\lambda}{2\pi \epsilon_0 d}$$

Therefore, the electric field in the space between the two cylinders is $\frac{\lambda}{2\pi \epsilon_0 d}$

NCERT Question 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 eV, 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)?

What are the answers to (a) and (b) above if the zero of potential energy is taken at 1.06 Å separation?

Answer

The distance between electron-proton of a hydrogen atom, $d = 0.53\ \text{Å}$

Charge on an electron, $q_1 = -1.6 \times 10^{-19}$ C

Charge on a proton, $q_2 = +1.6 \times 10^{-19}$ C

Potential at infinity is zero.

Potential energy of the system, *p-e* = Potential energy at infinity − Potential energy at distance, *d*

$$= 0 - \frac{q_1 q_2}{4\pi \in_0 d}$$

Where,

$\in_0$ is the permittivity of free space

$$\frac{1}{4\pi \in_0} = 9\times10^9\ \text{Nm}^2\ \text{C}^{-2}$$

$$\therefore \text{Potential energy} = 0 - \frac{9\times10^9\times\left(1.6\times10^{-19}\right)^2}{0.53\times10^{10}} = -43.7\times10^{-19}\ \text{J}$$

Since $1.6\times10^{-19}\ \text{J} = 1\ \text{eV}$,

$$\therefore\ \text{Potential energy} = -43.7\times10^{-19} = \frac{-43.7\times10^{-19}}{1.6\times10^{-19}} = -27.2\ \text{eV}$$

Therefore, the potential energy of the system is −27.2 eV.

Kinetic energy is half of the magnitude of potential energy.

$$\text{Kinetic energy} = \frac{1}{2}\times(-27.2) = 13.6 \text{ eV}$$

Total energy = 13.6 − 27.2 = 13.6 eV

Therefore, the minimum work required to free the electron is 13.6 eV.

When zero of potential energy is taken, $d_1 = 1.06\,\text{Å}$

$\because$Potential energy of the system = Potential energy at d_1 − Potential energy at d

$$= \frac{q_1 q_2}{4\pi \epsilon_0 d_1} - 27.2 \text{ eV}$$

$$= \frac{9\times10^9\times\left(1.6\times10^{-19}\right)^2}{1.06\times10^{-10}} - 27.2 \text{ eV}$$

$$= 21.73\times10^{-19}\,\text{J} - 27.2 \text{ eV}$$

$$= 13.58 \text{ eV} - 27.2 \text{ eV}$$

$$= -13.6 \text{ eV}$$

NCERT Question 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.

Answer

NCERT Question 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 fields 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.

Answer

NCERT Question 2.21:

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

What is the electrostatic potential at the points?

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

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?

Answer

Charge $-q$ is located at $(0, 0, -a)$ and charge $+q$ is located at $(0, 0, a)$. Hence, they form a dipole. Point $(0, 0, z)$ is on the axis of this dipole and point $(x, y, 0)$ is normal to the axis of the dipole. Hence, electrostatic potential at point $(x, y, 0)$ is zero. Electrostatic potential at point $(0, 0, z)$ is given by,

$$V = \frac{1}{4\pi \in_0}\left(\frac{q}{z-a}\right) + \frac{1}{4\pi \in_0}\left(-\frac{q}{z+a}\right)$$
$$= \frac{q(z+a-z+a)}{4\pi \in_0 (z^2-a^2)}$$
$$= \frac{2qa}{4\pi \in_0 (z^2-a^2)} = \frac{p}{4\pi \in_0 (z^2-a^2)}$$

Where,

$\in_0$ = Permittivity of free space

p = Dipole moment of the system of two charges = $2qa$

Distance r is much greater than half of the distance between the two charges. Hence, the potential (V) at a distance r is inversely proportional to square of the distance i.e.,
$$V \propto \frac{1}{r^2}$$

Zero

The answer does not change if the path of the test is not along the x-axis.

A test charge is moved from point (5, 0, 0) to point (−7, 0, 0) along the x-axis.
Electrostatic potential (V_1) at point (5, 0, 0) is given by,
$$V_1 = \frac{-q}{4\pi \in_0}\frac{1}{\sqrt{(5-0)^2+(-a)^2}} + \frac{q}{4\pi \in_0}\frac{1}{(5-0)^2+a^2}$$
$$= \frac{-q}{4\pi \in_0 \sqrt{25^2+a^2}} + \frac{q}{4\pi \in_0 \sqrt{25+a^2}}$$
$$= 0$$

Electrostatic potential, V_2, at point (− 7, 0, 0) is given by,

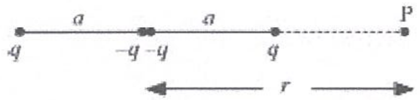
$$V_2 = \frac{-q}{4\pi \in_0}\frac{1}{\sqrt{(-7)^2+(-a)^2}} + \frac{q}{4\pi \in_0}\frac{1}{\sqrt{(-7)^2+(a)^2}}$$
$$= \frac{-q}{4\pi \in_0 \sqrt{49+a^2}} + \frac{q}{4\pi \in_0}\frac{1}{\sqrt{49+a^2}}$$
$$= 0$$

Hence, no work is done in moving a small test charge from point (5, 0, 0) to point (−7, 0, 0) along the x-axis.

The answer does not change because work done by the electrostatic field in moving a test charge between the two points is independent of the path connecting the two points.

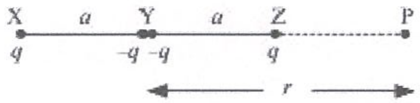
NCERT Question 2.22:

Figure 2.34 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).



Answer

Four charges of same magnitude are placed at points X, Y, Y, and Z respectively, as shown in the following figure.



A point is located at P, which is r distance away from point Y.

The system of charges forms an electric quadrupole.

It can be considered that the system of the electric quadrupole has three charges.

Charge $+q$ placed at point X

Charge $-2q$ placed at point Y

Charge $+q$ placed at point Z

$XY = YZ = a$

$YP = r$

$PX = r + a$

$PZ = r - a$

Electrostatic potential caused by the system of three charges at point P is given by,

$$V = \frac{1}{4\pi \epsilon_0}\left[\frac{q}{\text{XP}} - \frac{2q}{\text{YP}} + \frac{q}{\text{ZP}}\right]$$

$$= \frac{1}{4\pi \epsilon_0}\left[\frac{q}{r+a} - \frac{2q}{r} + \frac{q}{r-a}\right]$$

$$= \frac{q}{4\pi \epsilon_0}\left[\frac{r(r-a)-2(r+a)(r-a)+r(r+a)}{r(r+a)(r-a)}\right]$$

$$= \frac{q}{4\pi \epsilon_0}\left[\frac{r^2-ra-2r^2+2a^2+r^2+ra}{r(r^2-a^2)}\right] = \frac{q}{4\pi \epsilon_0}\left[\frac{2a^2}{r(r^2-a^2)}\right]$$

$$= \frac{2qa^2}{4\pi \epsilon_0 r^3\left(1-\frac{a^2}{r^2}\right)}$$

Since $\frac{r}{a} >> 1$,

$\therefore \frac{a}{r} << 1$

$\frac{a^2}{r^2}$ is taken as negligible.

$$\therefore V = \frac{2qa^2}{4\pi \epsilon_0 r^3}$$

It can be inferred that potential, $V \propto \frac{1}{r^3}$

However, it is known that for a dipole, $V \propto \frac{1}{r^2}$

And, for a monopole, $V \propto \frac{1}{r}$

NCERT Question 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.

Answer

NCERT Question 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 realize 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.

Answer

Capacitance of a parallel capacitor, $V = 2$ F

Distance between the two plates, $d = 0.5$ cm $= 0.5 \times 10^{-2}$ m

Capacitance of a parallel plate capacitor is given by the relation,

$$C = \frac{\epsilon_0 A}{d}$$

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

Where,

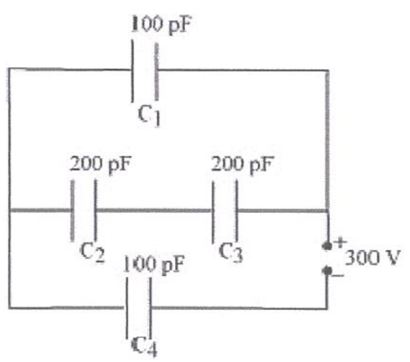
ϵ_0 = Permittivity of free space $= 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$

$$\therefore A = \frac{2 \times 0.5 \times 10^{-2}}{8.85 \times 10^{-12}} = 1130\ km^2$$

Hence, the area of the plates is too large. To avoid this situation, the capacitance is taken in the range of µF.

NCERT Question 2.25:

Obtain the equivalent capacitance of the network in Fig. 2.35. For a 300 V supply, determine the charge and voltage across each capacitor.



ANSWER

NCERT Question 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.

How much electrostatic energy is stored by the capacitor?

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.

Answer

Area of the plates of a parallel plate capacitor, $A = 90\text{ cm}^2 = 90 \times 10^{-4}\text{ m}^2$ Distance

between the plates, $d = 2.5\text{ mm} = 2.5 \times 10^{-3}\text{ m}$

Potential difference across the plates, $V = 400$ V

Capacitance of the capacitor is given by the relation,

$$C = \frac{\epsilon_0 A}{d}$$

Electrostatic energy stored in the capacitor is given by the relation, $E_1 = \frac{1}{2}CV^2$

$$= \frac{1}{2}\frac{\epsilon_0 A}{d}V^2$$

Where,

ϵ_0 = Permittivity of free space = $8.85 \times 10^{-12}\text{ C}^2\text{ N}^{-1}\text{ m}^{-2}$

$$\therefore E_1 = \frac{1 \times 8.85 \times 10^{-12} \times 90 \times 10^{-4} \times (400)^2}{2 \times 2.5 \times 10^{-3}} = 2.55 \times 10^{-6}\text{ J}$$

Hence, the electrostatic energy stored by the capacitor is 2.55×10^{-6} J.

Volume of the given capacitor,

$$V' = A \times d$$
$$= 90 \times 10^{-4} \times 25 \times 10^{-3}$$
$$= 2.25 \times 10^{-4}\text{ m}^3$$

Energy stored in the capacitor per unit volume is given by,

$$u = \frac{E_1}{V'}$$

$$= \frac{2.55\times10^{-6}}{2.25\times10^{-4}} = 0.113\ \text{J m}^{-3}$$

Again, $u = \frac{E_1}{V'}$

$$= \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{\epsilon_0 A}{2d}V^2}{Ad} = \frac{1}{2}\epsilon_0\left(\frac{V}{d}\right)^2$$

Where,

$\frac{V}{d}$ = Electric intensity = E

$$\therefore u = \frac{1}{2}\epsilon_0 E^2$$

NCERT Question 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?

Answer

NCERT Question 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.

Answer

Let F be the force applied to separate the plates of a parallel plate capacitor by a distance of Δx. Hence, work done by the force to do so = $F\Delta x$

As a result, the potential energy of the capacitor increases by an amount given as $uA\Delta x$

Where,
u = Energy density
A = Area of each plate
d = Distance between the plates
V = Potential difference across the plates

The work done will be equal to the increase in the potential energy i.e.,

$$F\Delta x = uA\Delta x$$

$$F = uA = \left(\frac{1}{2}\epsilon_0 E^2\right)A$$

Electric intensity is given by,

$$E = \frac{V}{d}$$

$$\therefore F = \frac{1}{2}\epsilon_0\left(\frac{V}{d}\right)EA = \frac{1}{2}\left(\epsilon_0 A\frac{V}{d}\right)E$$

However, capacitance, $C = \frac{\epsilon_0 A}{d}$

$$\therefore F = \frac{1}{2}(CV)E$$

Charge on the capacitor is given by,

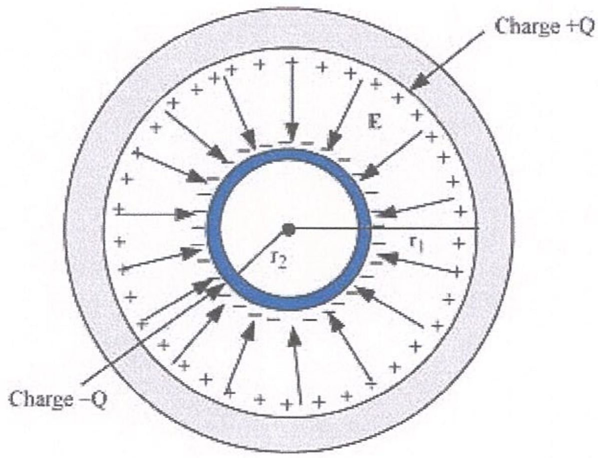
$$Q = CV$$

$$\therefore F = \frac{1}{2}QE$$

The physical origin of the factor, $\frac{1}{2}$, in the force formula lies in the fact that just outside the conductor, field is E and inside it is zero. Hence, it is the average value, $\frac{E}{2}$, of the field that contributes to the force.

NCERT Question 2.29:

A spherical capacitor consists of two concentric spherical conductors, held in position by suitable insulating supports (Fig. 2.36). Show



that the capacitance of a spherical capacitor is given by

$$C = \frac{4\pi \epsilon_0 r_1 r_2}{r_1 - r_2}$$

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

Answer

NCERT Question 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.

Determine the capacitance of the capacitor.

What is the potential of the inner sphere?

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

Answer

Capacitance of the capacitor is given by the relation,

$$C = \frac{4\pi \in_0 \in_r r_1 r_2}{r_1 - r_2}$$

Where,
$\in_0$ = Permittivity of free space = $8.85\times10^{-12}\ C^2\ N^{-1}\ m^{-2}$

$$\frac{1}{4\pi \in_0} = 9\times10^9\ N\,m^2\,C^{-2}$$

$$\therefore C = \frac{32\times0.12\times0.13}{9\times10^9\times(0.13-0.12)}$$
$$\approx 5.5\times10^{-9}\ F$$

Hence, the capacitance of the capacitor is approximately 5.5×10^{-9} F.

Potential of the inner sphere is given by,

$$V = \frac{q}{C}$$
$$= \frac{2.5\times10^{-6}}{5.5\times10^{-9}} = 4.5\times10^2\ V$$

Hence, the potential of the inner sphere is 4.5×10^2 V.

Radius of an isolated sphere, $r = 12 \times 10^{-2}$ m

Capacitance of the sphere is given by the relation,

$$C' = 4\pi \in_0 r$$
$$= 4\pi\times8.85\times10^{-12}\times12\times10^{-12}$$
$$= 1.33\times10^{-11}\ F$$

The capacitance of the isolated sphere is less in comparison to the concentric spheres. This is because the outer sphere of the concentric spheres is earthed. Hence, the potential difference is less and the capacitance is more than the isolated sphere

NCERT Question2.31:

Answer carefully:

1.Two large conducting spheres carrying charges Q_1 and Q_2 are brought close to each other.

2.Is the magnitude of electrostatic force between them exactly given by $Q_1 Q_2/4\pi\epsilon_0 r^2$, where r is the distance between their centres?

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

4.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?

5.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?

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

7.What meaning would you give to the capacitance of a single conductor?

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

Answer

NCERT Question 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).

Answer

Length of a co-axial cylinder, $l = 15$ cm $= 0.15$ m

Radius of outer cylinder, $r_1 = 1.5$ cm $= 0.015$ m

Radius of inner cylinder, $r_2 = 1.4$ cm $= 0.014$ m

Charge on the inner cylinder, $q = 3.5\ \mu C = 3.5 \times 10^{-6}$ C

Capacitance of a co-axial cylinder of radii r_1 and r_2 is given by the relation,

$$C = \frac{2\pi \in_0 l}{\log_e \frac{r_1}{r_2}}$$

Where,

$\in_0$ = Permittivity of free space = $8.85 \times 10^{-12}\ N^{-1}\ m^{-2}\ C^2$

$$\therefore C = \frac{2\pi \times 8.85 \times 10^{-12} \times 0.15}{2.3026 \log_{10}\left(\frac{0.15}{0.14}\right)}$$

$$= \frac{2\pi \times 8.85 \times 10^{-12} \times 0.15}{2.3026 \times 0.0299} = 1.2 \times 10^{-10}\ F$$

Potential difference of the inner cylinder is given by,

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

$$= \frac{3.5 \times 10^{-6}}{1.2 \times 10^{-10}} = 2.92 \times 10^4\ V$$

NCERT Question 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 pF?

Answer

Potential rating of a parallel plate capacitor, $V = 1$ kV = 1000 V

Dielectric constant of a material, $\epsilon_r = 3$

Dielectric strength = 10^7 V/m

For safety, the field intensity never exceeds 10% of the dielectric strength.

Hence, electric field intensity, E = 10% of $10^7 = 10^6$ V/m

Capacitance of the parallel plate capacitor, $C = 50$ pF $= 50 \times 10^{-12}$ F

Distance between the plates is given by,

$$d = \frac{V}{E}$$
$$= \frac{1000}{10^6} = 10^{-3} \text{ m}$$

Capacitance is given by the relation,

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

Where,
A = Area of each plate

ϵ_0 = Permittivity of free space = $8.85 \times 10^{-12}\ N^{-1} C^2 m^{-2}$

$$\therefore A = \frac{Cd}{\epsilon_0 \epsilon_r}$$
$$= \frac{50 \times 10^{-12} \times 10^{-3}}{8.85 \times 10^{-12} \times 3} \approx 19 \text{ cm}^2$$

Hence, the area of each plate is about 19 cm^2.

NCERT Question 2.34:

Describe schematically the equipotential surfaces corresponding to

1.a constant electric field in the *z*-direction,

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

3.a single positive charge at the origin, and

4.a uniform grid consisting of long equally spaced parallel charged wires in a plane.

Answer

1. Equidistant planes parallel to the *x-y* plane are the equipotential surfaces.

2.Planes parallel to the *x-y* plane are the equipotential surfaces with the exception that when the planes get closer, the field increases.

3.Concentric spheres centered at the origin are equipotential surfaces.

4.A periodically varying shape near the given grid is the equipotential surface. This shape gradually reaches the shape of planes parallel to the grid at a larger distance.

NCERT Question 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.)

Answer

NCERT Question 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.

Answer

NCERT Question 2.37:

Answer the following:

1.The top of the atmosphere is at about 400 kV with respect to the surface of the earth, corresponding to an electric field that decreases 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 steel cage so there is no field inside!)

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

3.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?

4.What are the forms of energy into which the electrical energy of the atmosphere is dissipated during a lightning? (Hint: The earth has an electric 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 occurring continually all over the globe pump an equal amount of negative charge on the earth.)

Answer

1.We do not get an electric shock as we step out of our house because the original equipotential surfaces of open air changes, keeping our body and the ground at the same potential.

2.Yes, the man will get an electric shock if he touches the metal slab next morning. The steady discharging current in the atmosphere charges up the aluminium sheet. As a result, its voltage rises gradually. The raise in the voltage depends on the capacitance of the capacitor formed by the aluminium slab and the ground.

3.The occurrence of thunderstorms and lightning charges the atmosphere continuously. Hence, even with the presence of discharging current of 1800 A, the atmosphere is not discharged completely. The two opposing currents are in equilibrium and the atmosphere remains electrically neutral.

4.During lightning and thunderstorm, light energy, heat energy, and sound energy are dissipated in the atmosphere.

1. Derive an expression for the electric potential at a point along the axial line of an electric dipole.
(Year : 2008) ***Marks allotted*** **: 2**

A. Refer to point no. 9 of *To The Point* Theory.

2. Two point charges, $q_1 = 10 \times 10^{-8}$ C and $q_2 = -2 \times 10^{-8}$ C are separated by a distance of 60 cm in air.
   (i) Find at what distance from the 1st charge, q_1, would the electric potential be zero.
   (ii) Also calculate the electrostatic potential energy of the system.

OR

Two point charges 4Q, Q are separated by 1 m in air. At what point on the line joining the charges is the electric field intensity zero?
Also calculate the electrostatic potential energy of the system of charges, taking the value of charge, $Q = 2 \times 10^{-7}$ C. **(2008) 2**

A. (i) $\frac{Kq_1}{x} + \frac{Kq_2}{(r-x)} = 0$ if $(x < r)$

or $\frac{Kq_1}{x} + \frac{Kq_2}{x-r} = 0$ if $(x > r)$ which gives, $x = 50$ cm (from $q_1 = 10 \times 10^{-8}$ C)

or $x = 75$ cm.

(ii) $U = \frac{Kq_1q_2}{r} = -3 \times 10^{-5}$ J

OR

(i) $\frac{K4Q}{x^2} = \frac{KQ}{(r-x)^2}$

$x = (2/3)$m or $x = 2$m (from 4Q)

(ii) $U = \frac{Kq_1q_2}{r} = 1.44 \times 10^{-3}$ J

3. A 500 μC charge is at the centre of a square of side 10 cm. Find the work done in moving a charge of 10 μC between two diagonally opposite points on the square. **(2008) 1**

A. $W = q \times$ Pot. difference between the two points $= q \times 0 = 0$

4. Derive an expression for the energy stored in a parallel plate capacitor.
On charging a parallel plate capacitor to a potential V, the spacing between the plates is halved, and a dielectric medium of $\varepsilon_r = 10$ is introduced between the plates, without disconnecting the d.c. source. Explain, using suitable expressions, how the (i) capacitance, (ii) electric field and (iii) energy density of the capacitor change. **(2008) 5**

A. Derivation for energy stored

$$dW = V.dq$$

$$W = \int_0^Q \frac{q}{C} dq = \frac{Q^2}{2C} = \text{Energy Stored}$$

Change of capacitance :

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

$$C_0 = \frac{\varepsilon_0 A}{d}$$
$$C' = 20\,C_0$$

Change of field :

$$E' = \frac{V}{d'}$$
$$E' = 2E_0 \;;\; E_0 = \frac{V}{d}$$

Change of energy density :

$$U_0 = \tfrac{1}{2} E_0^2 \varepsilon_0$$
$$U = \tfrac{1}{2} \varepsilon_0 4E_0^2 \times 10 = 40\,U_0$$

5. What is the electrostatic potential due to an electric dipole at an equatorial point ? **(2009) 1**

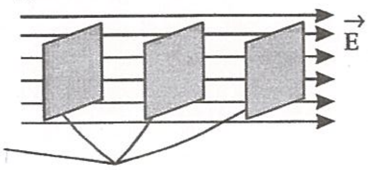
A. Zero.

6. What is the work done in moving a test charge q through a distance of 1 cm along the equatorial axis of an electric dipole ? **(2009) 1**

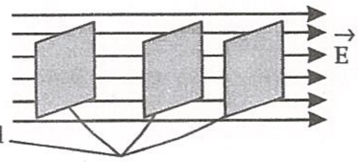
A. Zero.

7. Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along Z-direction. How are these surfaces different from that of a constant electric field along Z-direction ? **(2009) 2**

A.



For constant electric field



For increasing electric field

For constant electric field, equipotential surfaces are equidistant for same potential difference between these surfaces. For increasing field, separation between these surfaces decreases, in the direction of increasing field, for the same potential difference between them.

8. (i) Can two equipotential surfaces intersect each other ? Give reasons.

(ii) Two charges $-q$ and $+q$ are located at points A $(0, 0, -a)$ and B $(0, 0, +a)$ respectively. How much work is done in moving a test charge from point P(7, 0, 0) to Q(–3, 0, 0) ? **(2009) 2**

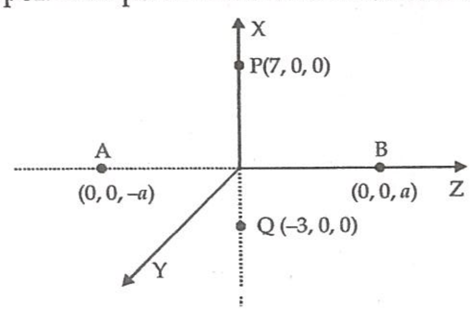
A. (i) No

Reason : At the point of intersection, there will be two values of electric potential which is not possible.

Alternatively

Electric field at the same point will point in two different directions which is not possible.

(ii)



Test charge is moved along the equipotential line of the dipole. Hence workdone in moving this charge is zero.

9. Define the term 'potential energy' of charge 'q' at a distance 'r' in an external electric field. **(2009) 1**

A. The amount of work done in bringing a charge q from ∞ to a distance 'r' in the electric field produced by another charge.

10. A parallel plate capacitor is charged by a battery. After some time the battery is disconnected and a dielectric slab of dielectric constant K is inserted between the plates. How would (i) the capacitance, (ii) the electric field between the plates and (iii) the energy stored in the capacitor, be affected ? Justify your answer. **(2009) 3**

A. Original capacitance $C_0 = \frac{Q}{V_0} = \varepsilon_0 \frac{A}{d}$

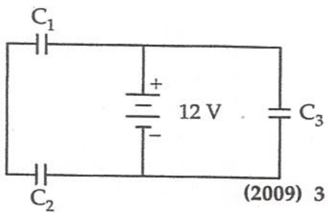
When a dielectric is inserted :

(i) Capacitance $\left(= K\varepsilon_0 \frac{A}{d} \right)$ increases.

(ii) Electric field $\left(= \frac{\sigma - \sigma_P}{\varepsilon_0} \right)$ decreases.

(iii) Energy stored $\left(W = \frac{1}{2} KC_0 . \frac{Q^2}{C_0 K^2} = \frac{1}{2} \frac{Q^2}{C_0} . \frac{1}{K} \right)$ decreases.

11. Three identical capacitors C_1, C_2 and C_3 of capacitance 6 μF each are connected to a 12 V battery as shown.



Find

(i) charge on each capacitor
(ii) equivalent capacitance of the network
(iii) energy stored in the network of capacitors. **(2009) 3**

A. (i) Charge on capacitors C_1 and C_2

$Q_1 = 36\ \mu C$; $Q_2 = 36\ \mu C$

$[\because\ Q = V \times C = ½ \times 12V \times 6\ \mu F = 36\ \mu C]$

Charge on capacitor C_3,

$$Q_3 = V \times C = 12V \times 6\ \mu F = 72\ \mu C$$

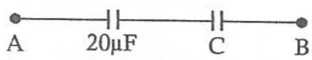
(ii) Equivalent capacitance

$$C = \frac{C_1 C_2}{C_1 + C_2} + C_3 = \frac{6 \times 6}{6 + 6} + 6 = 9 \mu F$$

(iii) Energy stored in network

$$W = \frac{1}{2} CV^2 = \frac{1}{2} \times 9 \times 10^{-6} \times (12)^2 J = 6.48 \times 10^{-4} J$$

12. The equivalent capacitance of the combination between A and B in the given figure is 4μF.



(i) Calculate capacitance of the capacitor C.
(ii) Calculate charge on each capacitor if a 12 V battery is connected across terminals A and B.
(iii) What will be the potential drop across each capacitor? **(2009) 3**

A. (i) Given : $\frac{1}{20} + \frac{1}{C} = \frac{1}{4}$

On solving, capacitance $C = 5\ \mu F$

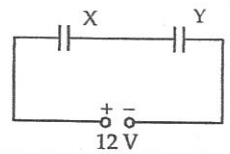
(ii) Charge on each capacitor

$$Q = C_{eq}V = 48\ \mu C$$

(iii) $V_1 = \dfrac{Q}{C_1} = 2.4\ V$

$V_2 = 9.6\ V$

13. Two parallel plate capacitor, X and Y, have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric medium of $\varepsilon_r = 4$.



(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.
(ii) Calculate the potential difference between the plates of X and Y.
(iii) What is the ratio of electrostatic energy stored in X and Y? **(2009) 3**

A. (i) $C_X = C \quad \therefore C_Y = 4C$

$$\frac{1}{C} + \frac{1}{4C} = \frac{1}{4}$$

$C = 5\ \mu F$

$\therefore$ $C_X = 5\ \mu F$ and $C_Y = 20\ \mu F$

(ii) $Q = V_X C_X = V_Y C_Y = VC = 4 \times 12\ \mu C = 48\ \mu C$

$\therefore$ $V_X = \dfrac{48}{5} V = 9.6\ V$

and $V_Y = \dfrac{48}{20} V = 2.4\ V$

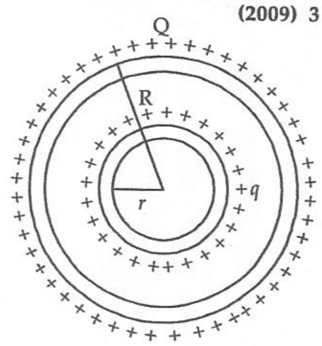
(iii) $W_X = \dfrac{Q^2}{2C}$ and $W_Y = \dfrac{Q^2}{8C}$

$$\frac{W_X}{W_Y} = 4.$$

14. (a) A charge +Q is placed on a large spherical conducting shell of radius R. Another small conducting sphere of radius *r* carrying charge '*q*' is introduced inside the large shell and is placed at its centre. Find the potential difference between two points, one lying on the sphere and the other on the shell.

(b) How would the charge between the two flow if they are connected by a conducting wire? Name the device which works on this fact. **(2009) 3**

A. (a) $V(R) = k\left[\dfrac{Q}{R} + \dfrac{q}{R}\right]$



$V(r) = k\left[\dfrac{Q}{R} + \dfrac{q}{r}\right]$

$V(r) - V(R) = kq\left[\dfrac{1}{r} - \dfrac{1}{R}\right]$

(b) Whole charge of inner shell will flow to outer shell.
Device : Van de Graff Generator.

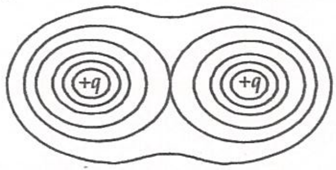
15. Name the physical quantity whose SI unit is joule/coulomb. **(2010) 1**

A. Electric potential.

16. (a) Depict the equipotential surfaces for a system of two identical positive point charges placed a distance 'd' apart.

(b) Deduce the expression for the potential energy of a system of two point charges q_1 and q_2 brought from infinity to the points $\vec{r_1}$ and $\vec{r_2}$ respectively in the presence of external electric field $\vec{E}$. **(2010) 3**

A. (a) Equipotential surfaces for a system of two identical positive charges:



(b) Expression for the potential energy of a system of two point charges in external field :
Work done in bringing the charge q_1 from infinity to $r_1 = q_1V(r_1)$
Work done in bringing the charge q_2 from infinity to $r_2 = q_2V(r_2)$
Work done = Work done against the external electric field + Work done on q_2 against the field due to q_1

$$= q_2V(r_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$$

Potential energy of the system = the total work done in assembling the configuration

$$= q_1V(r_1) + q_2V(r_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$$

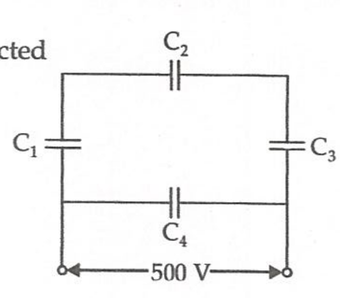
17. A parallel plate capacitor is charged by a battery. After sometime the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. How will (i) the capacitance of the capacitor, (ii) potential difference between the plates and (iii) the energy stored in the capacitor be affected?
Justify your answer in each case. **(2010) 3**

A. (i) Capacitance, $C = \frac{K\varepsilon_0 A}{d}$. Hence capacitance increases K times.

(ii) Potential difference, $V = \frac{V_0}{K}$. Hence potential difference decreases by a factor K.

(iii) Energy stored, $E = \frac{1}{2}CV^2$. As capacitance becomes K times and potential difference becomes 1/K times, therefore, energy stored becomes 1/K times.
Alternatively : Energy stored = $Q^2/2C$. As capacitance increases by a factor K, the energy stored will decrease by the same factor.

18. A network of four capacitors each of 12 μF capacitance is connected to a 500 V supply as shown in the figure. Determine
(a) equivalent capacitance of the network and
(b) charge on each capacitor. **(2010) 3**



A. (a) $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} = \frac{1}{4}$

$\Rightarrow$ $C = 4\,\mu F$

or simply $C_S = \frac{C}{3} = \frac{12}{3}\mu F = 4\mu F$

Equivalent Capacitance

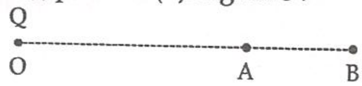
$$C_{eq} = C + C_4 = 12 + 4 = 16\ \mu F$$

(b) Calculation of charge on each capacitor :

Charge on capacitor C_4, *i.e.*, $Q_4 = C + V = 12 \times 500\ \mu C = 6000\ \mu C = 6 \times 10^{-3}$ C

Charge on capacitors C_1, C_2 & C_3, *i.e.*, $Q_{123} = 4\ \mu F \times 500\ V = 2 \times 10^{-3}$ C

19. A point charge Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative ? **(2011) 1**



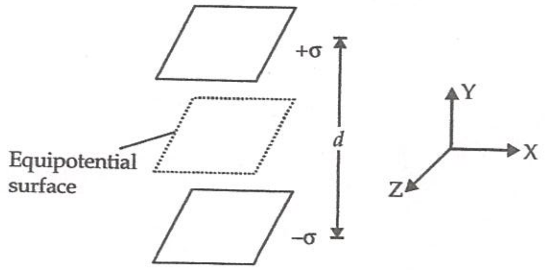
A. (i) Positive, (ii) Negative

20. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. What is the potential at the centre of the sphere? **(2011) 1**

A. 10 V

21. Two uniformly large parallel thin plates having charge densities $+\sigma$ and $-\sigma$ are kept in the X-Z plane at a distance '*d*' apart. Sketch an equipotential surface due to electric field between the plates. If a particle of mass *m* and charge '$-q$' remains stationary between the plates, what is the magnitude and direction of this field ? **(2011) 2**

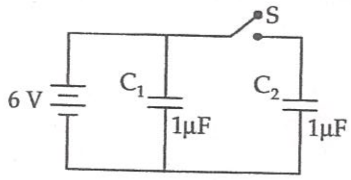
A. Depiction of equipotential surface (Parallel to the X-Z plane)



$qE = mg$

$\Rightarrow E = \frac{mg}{q}$; direction vertically downwards

22. Figure shows two identical capacitors, C_1 and C_2, each of 1 μF capacitance connected to a battery of 6 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ? **(2011) 2**



A. P.D. across $C_1 = 6V$

Final charge on $C_1 = 18\ \mu C$

P.D. across $C_2 = 2\ V$

Final charge on $C_2 = 6\ \mu C$

Alternatively,

$Q = CV$

$C' = KC$

Across C_1, V remains same but charge increases.

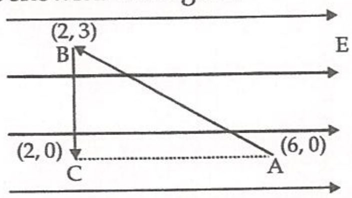
Across C_2, charge Q remains same but p.d. decreases.

23. Net capacitance of three identical capacitors in series is 1 μF. What will be their net capacitance if connected in parallel?

Find the ratio of energy stored in the two configurations if they are both connected to the same source. **(2011) 2**

A.
$$\frac{1}{C_S} = \frac{3}{C}$$
$$C = 3C_S$$
$$\therefore \quad C = 3\ \mu F$$
$$C_P = C_1 + C_2 + C_3 = 9\ \mu F$$
$$\frac{E_S}{E_P} = \frac{\frac{1}{2}C_S V^2}{\frac{1}{2}C_P V^2} = 1/9$$

24. A test charge 'q' is moved without acceleration from A to C along the path from A to B and then from B to C in electric field E as shown in the figure.



(i) Calculate the potential difference between A and C.

(ii) At which point (of the two) is the electric potential more and why? **(2012) 2**

A. Since $E = -dV/dr = (V_C - V_A)/4$

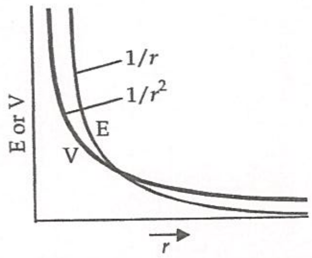
Therefore, $V_A - V_C = -4E$

At point C, potential is more.

Electric field is in the direction in which the potential decreases.

25. Draw a plot showing the variation of (i) electric field (E) and (ii) electric potential (V) with distance r due to a point charge Q. **(2012) 2**

A.



26. Why must electrostatic field be normal to the surface at every point of a charged conductor? **(2012) 1**

A. In the static situation, $\vec{E}$ has to ensure that the free charges on the surface do not experience any force.

27. Why is electrostatic potential constant throughout the volume of the conductor and has the same value (as inside) on its surface? **(2012) 1**

A. $\because |\vec{E}|$ is zero throughout the volume,

and potential, just inside, has to be equal to potential on surface.

28. Deduce the expression for the electrostatic energy stored in a capacitor of capacitance 'C' and having charge 'Q'.

How will the (i) energy stored and (ii) the electric field inside the capacitor be affected when it is completely filled with a dielectric material of dielectric constant 'K'? **(2012) 3**

A. Potential difference between the plates of capacitor

$$V = q / C$$

Work done to add additional charge dq on the capacitor

$$dw = V \times dq$$

$\therefore$ Total energy stored in the capacitor

$$U = \int dw = \int_0^Q \frac{q}{C} dq = \frac{1}{2}\frac{Q^2}{C}$$

When battery is disconnected,

(i) Energy stored will be decreased or energy stored = 1 /K times the initial energy.

(ii) Electric would decrease; $E' = E/K$

Or,

When battery remains connected,

(i) Energy stored will increase or becomes K times the initial energy.

(ii) Electric field will not change.

29. Explain the principle of a device that can build up high voltages of the order of a few million volts. Draw a schematic diagram and explain the working of this device.

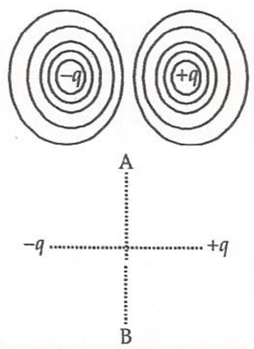
Is there any restriction on the upper limit of the high voltages set up in this machine? Explain. **(2012) 5**

A. Van de Graff generator : Refer Text

Yes, high voltages can be built up only upto the breakdown field of the surrounding medium.

30. Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero. **(2013) 2**

A.



Alternatively, any point on the equatorial plane (AB) of the dipole.

31. While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for thunderstorm to stop. Suddenly he noticed a child walking alone on the road. He asked the boy to come inside the car till the thunderstorm stopped. Dr. Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. pathak for his concern for safety of the child.

Answer the following questions based on the above information :

(a) Why is it safer to sit inside a car during a thunderstorm?
(b) Which two values are displayed by Dr. Pathak in his actions?
(c) Which values are reflected in parents' response to Dr. Pathak?
(d) Give an example of a similar action on your part in the past from everyday life.

(Value Based Question) (2013) 4

A. (a) Because during thunder storm, car would act as an electrostatic shield
(b) Dr. Pathak displayed values of concern for the safety of human life, helpfulness, empathy and scientific temper.
(c) Gratefulness, indebtedness
(d) Example of any similar action.

32. What is the geometrical shape of equipotential surfaces due to a single isolated charge? **(2013) 1**

A. Spherical.

33. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 360 μC. When potential across the capacitor is reduced by 120 V, the charge stored in it becomes 120 μC.

Calculate :

(i) The potential V and the unknown capacitance C.
(ii) What will be the charge stored in the capacitor, if voltage applied had increased by 120 V?

(2013) 3

A. (i)
$$Q = CV$$
$$360\ \mu C = CV$$
$$120\ \mu C = C(V-120) = CV - 120\,C = 360\ \mu C - 120\ \mu C$$
$$120\,C = 240\ \mu C$$
$\Rightarrow$ Capacitance, C = 2 μF

Substituting the value of C,

Potential V = 180 V

(ii) Charge stored when voltage is increased by 120 V

$Q' = 2\ \mu F \times (180 + 120)\ V = 600\ \mu C$.

34. A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness $d/2$, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

(2013) 2

A. $$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}} = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2K}} = \frac{2\varepsilon_0 AK}{d(K+1)}$$

35. A parallel plate capacitor of capacitance C is charged to a potential V. It is then connected to another uncharged capacitor having the same capacitance. Find out the ratio of the energy stored in the combined system to that stored initially in the single capacitor. **(2014) 2**

A. Energy stored in a capacitor $= \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

Capacitance of the (parallel) combination = C + C = 2C
Here, total charge, Q, remains the same

$\therefore$ initial energy $= \frac{1}{2}\frac{Q^2}{C}$

And final energy $= \frac{1}{2}\frac{Q^2}{2C}$

$\therefore \frac{\text{final energy}}{\text{initial energy}} = \frac{1}{2}$

(i) Parallel or (ii) Series combination
to remain constant (=V) and obtain the answers as (i) 2 : 1 or (ii) 1 : 2

36. "For any charge configuration, equipotential surface through a point is normal to the electric field." Justify. **(2014) 1**

A. If Electric field is not normal, it will have non-zero component along the surface and in that case, work would be done in moving a charge on an equipotential surface.

37. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has charge ±8 nC. **(2014) 2**

A. $\tau = pE\sin\theta$

$4\sqrt{3} = pE\sin 60° = pE\,\frac{\sqrt{3}}{2}$

$\Rightarrow \quad pE = 8$

Potential energy

$U = -pE\cos\theta = -8 \times \cos 60° = -4J$

38. An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole. If it has a charge of ± 4 nC. **(2014) 2**

A. $\tau = pE\sin\theta$

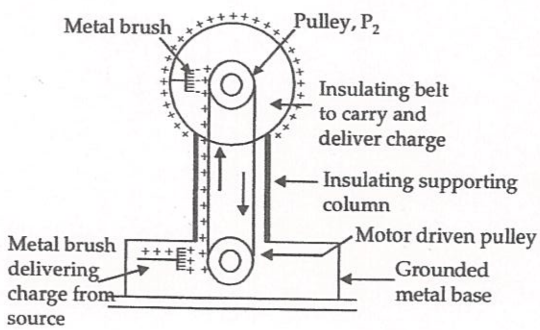
$8\sqrt{3} = pE\sin 60° = pE \times \frac{\sqrt{3}}{2}$

$\Rightarrow \quad pE = 16$

Potential energy, $U = -pE\cos\theta = -16 \times \cos 60° = -8J$

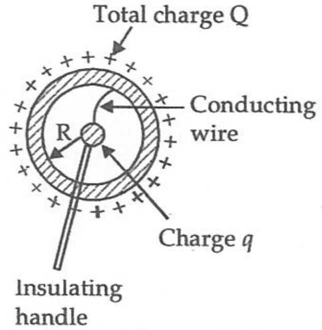
39. Draw a labelled diagram of Van de Graaff generator. State its working principle to show how by introducing a small charged sphere into a larger sphere, a large amount of charge can be transferred to the outer sphere. State the use of this machine and also point out its limitations. **(2014) 5**

A.



Principle & working.

Consider a set up of the type shown here



(i) Potential inside and on the surface, of the conducting sphere of radius 'R'.

$$V'_R = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{R}$$

(ii) Potential due to small sphere of radius 'r' carrying a charge 'q'.

At the surface of the smaller sphere : $V'_R = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r}$

At the surface of the large sphere : $V''_R = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{R}$

∴ The difference of potential between the smaller and the larger sphere :

$$= \Delta V = \frac{1}{4\pi\varepsilon_0}.\left[\left(\frac{Q}{R}+\frac{q}{r}\right)-\left(\frac{Q}{R}+\frac{q}{r}\right)\right] = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{R}\right)$$

When 'q' is positive, the inner sphere would always be at a higher potential with respect to outer sphere, irrespective of the amount of charges on the two.

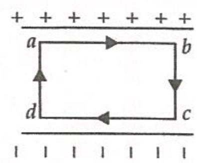
∴ When both the spheres are connected, charge will flow from the smaller sphere to the larger sphere. Thus for a set up of the type shown, charge would keep on pilling up on the larger sphere.

Use : This machine is used to accelerate charged particles (electron, protons, ions) to high energies.

Limitation : It can build up potentials upto a few million volts only.

40. (a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.

(b) The electric field inside a parallel plate capacitor is E.
Find the amount of work done in moving a charge q over a closed rectangular loop *a b c d a*.



OR

(a) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d.

(b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii. **(2014) 3**

A. (a) Work done by the source of potential, in storing an additional charge (dq), is

$$dW = V.dq$$

But $V = q/C$

$$\Rightarrow \quad dW = \frac{q}{C}dq$$

Total work done in storing the charge Q.

$$\int dW = \int_0^Q \frac{q}{C}dq$$

$$\left(\frac{q^2}{2}\right)_0^q = \frac{Q^2}{2C}$$

This work is stored as electrostatic energy in the capacitor.

$$Q = CV, \quad \therefore U = \frac{1}{2}CV^2$$

$$\text{Energy stored per unit volume} = \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2}{Ad} = \frac{1}{2}\varepsilon_0 E^2$$

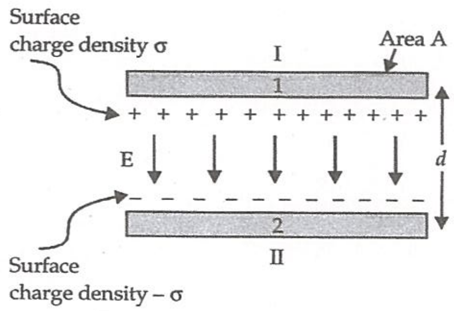
(b) Work done in moving the charge q from a to b, and from c to d is zero because Electric field is perpendicular to the displacement.

Work done from b to c = – Workdone from d to a

$\therefore$ Total work done in moving a charge q over a closed loop = 0

OR

(a)



Electric field between the plates of capacitor $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

$\therefore$ potential difference

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

Capacitance

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

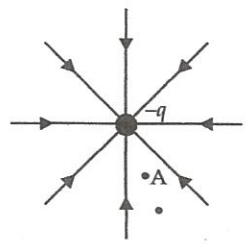
(b) When the two charged spherical-conductors are connected by a conducting wire, they acquire the same potential

i.e., $\frac{Kq_1}{R_1} = \frac{Kq_2}{R_2} \Rightarrow \frac{q_1}{q_2} = \frac{R_1}{R_2}$

Hence, ratio of surface charge densities

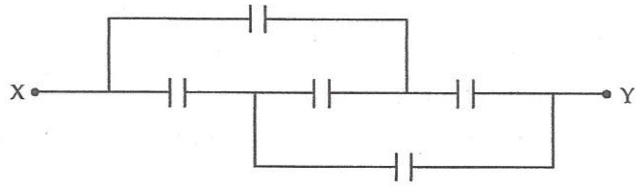
$$\frac{\sigma_1}{\sigma_2} = \frac{q_1/4\pi R_1^2}{q_2/4\pi R_2^2} = \frac{q_1 R_2^2}{q_2 R_1^2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$$

41. The field lines of a negative point charge are as shown in the figure. Does the kinetic energy of a small negative charge increase or decrease in going from B to A? **(2015) 1**

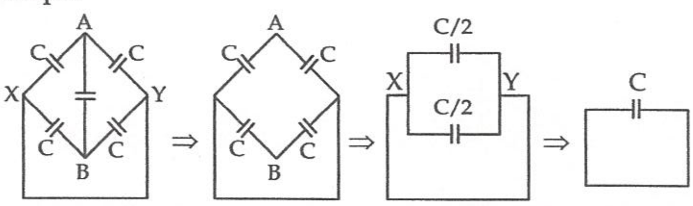


A. Decreases

42. Find the equivalent capacitance of the network shown in the figure, when each capacitor is of 1 μF. When the ends X and Y are connected to a 6 V battery, find out (i) the charge and (ii) the energy stored in the network. **(2015) 3**



A. The equivalent setup is



Here $V_A = V_B$ (A & B are at the same potential) so the bridge capacitor can be removed.

(i) $Q = CV = 6\ \mu C$

(ii) $U = \frac{1}{2} qV = 18\ \mu J$

43. Two capacitors of unknown capacitances C_1 and C_2 are connected first in series and then in parallel across a battery of 100 V. If the energy stored in the two combinations is 0.045 J and 0.25 J respectively, determine the value of C_1 and C_2. Also calculate the charge on each capacitor in parallel combination. **(2015) 3**

A. Energy stored in a capacitor

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

In series combination

$$0.045 = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}(100)^2$$

$$\Rightarrow \quad \frac{C_1C_2}{C_1+C_2} = 0.09 \times 10^4 \qquad ...(i)$$

In parallel combination

$$0.25 = \frac{1}{2}(C_1 + C_2)(100)^2$$

$\Rightarrow \; C_1 + C_2 = 0.5 \times 10^{-4}$ ...(ii)

On simplifying (i) and (ii)

$$C_1 C_2 = 0.045 \times 10^{-8}$$
$$(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2$$
$$= (0.5 \times 10^{-4})^2 - 4 \times 0.045 \times 10^{-8}$$
$$= 0.25 \times 10^{-8} - 0.180 \times 10^{-8}$$
$$(C_1 - C_2)^2 = 0.07 \times 10^{-8}$$
$$(C_1 - C_2) = 2.6 \times 10^{-5} = 0.26 \times 10^{-4}$$ ...(iii)

From (ii) and (iii) we have

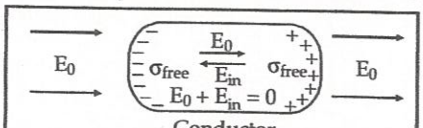
$\Rightarrow \; C_1 = 0.38 \times 10^{-4}$ F & $C_2 = 0.12 \times 10^{-4}$ F

Charges on capacitor C_1 and C_2 in parallel combination :

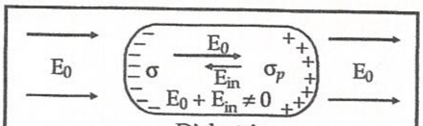
$$Q_1 = C_1V = (0.38 \times 10^{-4} \times 100) = 0.38 \times 10^{-2}\,C$$
$$Q_2 = C_2V = (0.12 \times 10^{-4} \times 100) = 0.12 \times 10^{-2}\,C$$

44. Explain, using suitable diagrams, the difference in the behaviour of a (i) conductor and (ii) dielectric in the presence of external electric field. Define the term polarization of a dielectric and write its relation with susceptibility. **(2015) 3**

A. In the presence of electric field, the free charge carriers in a conductor move. The charge distribution in the conductor readjusts itself so that the net electric field within the conductor becomes zero.



Conductor



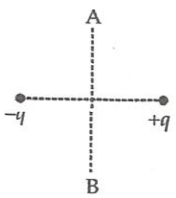
Dielectric

In a dielectric, the external electric field induces a net dipole moment, by stretching/reorienting the molecules. The dlectric field, due to this induced dipole moment, opposes but does not exactly cancel the external electric field.

Polarisation: Induced dipole moment, per unit volume, is called the polarization. For linear isotropic dielectrics having a susceptibility χ_e, we have

$$P = \chi_e E$$

45.



A charge 'q' is moved from a point A above a dipole of dipole moment 'p' to a point B below the dipole in equatorial plane without acceleration. Find the work done in the process. **(2016) 1**

A. No work is done/

$W = qV_{AB} = q \times 0 = 0$

46. Define an equipotential surface. Draw equipotential surfaces :

(i) in the case of a single point charge and

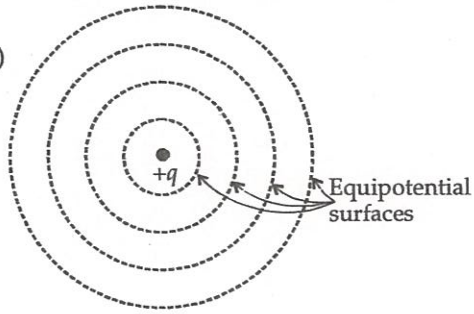
(ii) in a constant electric field in Z-direction.

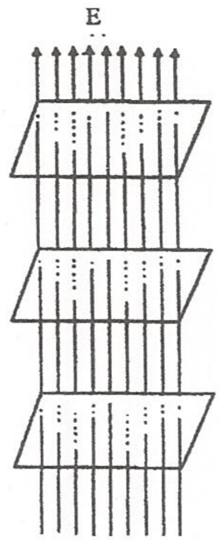
Why the equipotential surfaces about a single charge are not equidistant?

(iii) Can electric field exist tangential to an equipotential surface? Give reason **(2016) 3**

A. Surface with a constant value of potential at all points on the surface.

(i)





(ii) $V \propto \frac{1}{r}$

(iii) No

If the field lines are tangential, work will be done in moving a charge on the surface which goes against the definition of equipotential surface.

47. Find the ratio of the potential differences that must be applied across the parallel and series combination of two capacitors C_1 and C_2 with their capacitances in the ratio 1 : 2 so that the energy stored in the two cases becomes the same. **(2016) 3**

A. (ii) $U_s = \frac{1}{2} C_s V_s^2$

$$U_p = \frac{1}{2} C_p V_p^2$$

$$\Rightarrow \frac{V_{series}}{V_{parallel}} = \sqrt{\frac{C_{equivalent\ parallel}}{C_{equivalent\ series}}}$$

$$= \sqrt{\frac{C_1 + C_2}{\frac{C_1 C_2}{C_1 + C_2}}}$$

$$= \frac{C_1 + C_2}{\sqrt{C_1 C_2}} = \frac{3}{\sqrt{2}}$$

48. (i) If two similar large plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$ are separated by a distance d in air, find the expressions for

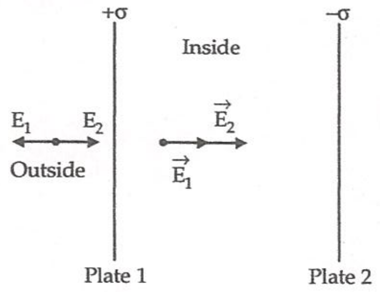
(a) field at points between the two plates and on outer side of the plates. Specify the direction of the field in each case.

(b) the potential difference between the plates.

(c) the capacitance of the capacitor so formed.

(ii) Two metallic spheres of radii R and 2R are charged so that both of these have same surface charge density σ. If they are connected to each other with a conducting wire, in which direction will the charge flow and why? **(2016) 5**

A. (i)



a. Inside

$$\vec{E} = \vec{E}_1 + \vec{E}_2$$

$$= \frac{\sigma+\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

Outside

$$\vec{E} = \vec{E}_2 - \vec{E}_1$$

$$= \frac{\sigma-\sigma}{2\varepsilon_0} = 0$$

b. Potential different between plates

$$V = Ed = \frac{1}{\varepsilon_0}\frac{Qd}{A}$$

c. Capacitance

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

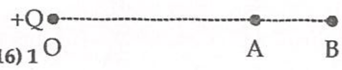
(ii) As potential on and inside a charged sphere is given

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{4\pi r^2\sigma}{r}$$

$\therefore$, $V \propto r$

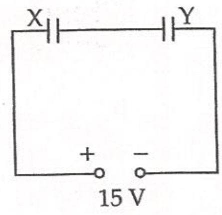
Hence, the bigger sphere will be at higher potential, so charge will flow from bigger sphere to smaller sphere.

49. A point charge +Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero? **(2016) 1**



A. Positive

50. Two parallel plate capacitors X and Y have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric medium of $\varepsilon_r = 4$.



(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.

(ii) Calculate the potential difference between the plates of X and Y.

(iii) Estimate the ratio of electrostatic energy stored in X and Y. **(2016) 3**

A. (i) Let $C_x = C$

$C_Y = 4C$ (as it has a dielectric medium of $\varepsilon_r = 4$)

For series combination of two capacitiors,

$$\frac{1}{C} = \frac{1}{C_X} + \frac{1}{C_Y}$$

$$\Rightarrow \quad \frac{1}{4\mu F} = \frac{1}{C} + \frac{1}{4C}$$

$$\frac{1}{4\mu F} - \frac{5}{4C}$$

$$\Rightarrow \quad C = 5\ \mu F$$

Hence $C_X = 5\ \mu F$

$C_Y = 20\ \mu F$

(ii) Total charge $Q = CV$

$$= 4\ \mu F \times 15\ V = 60\ \mu C$$

$$V_X = \frac{Q}{C_X} = \frac{60\mu C}{5\mu F} = 12V$$

$$V_Y = \frac{Q}{C_Y} = \frac{60\mu C}{20\mu F} = 3V$$

(iii) $$\frac{E_X}{E_Y} = \frac{\frac{Q^2}{2C_X}}{\frac{Q^2}{2C_Y}} = \frac{C_Y}{C_X} = \frac{20}{5} = 4:1$$

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PREVIOUS YEARS' MCQ'S FOR ENTRANCE EXAMS

QUESTIONS FOR : ENGINEERING ENTRANCE EXAM [J.E.E]

ELECTROSTATIC POTENTIAL AND CAPACITANCE

1. Which of the following statement(s) is/are correct?
   (a) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss law will still be valid.
   (b) The Gauss law can be used to calculate the field distribution around an electric dipole.
   (c) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same.
   (d) The work done by the external force in moving a unit positive charge from point A at potential V_A to point B at potential V_B is $(V_B - V_A)$.
   2011 *(IIT JEE)*

2. Two points P and Q are maintained at the potentials of 10 V and –4 V respectively. The work done in moving 100 electrons from P to Q is
   (a) -9.60×10^{-17} J (b) 9.60×10^{-17} J
   (c) -2.24×10^{-16} J (d) 2.24×10^{-16} J
   (AIEEE)

2008

3. The work done in bringing a unit positive charge from infinite distance to a point at distance x from a positive charge Q is W. Then the potential ϕ at that point is
   (a) $\frac{WQ}{x}$ (b) W
   (c) $\frac{W}{x}$ (d) WQ
   (J & K CET)

2007

4. The physical quantity in electrostatics analogous to temperature in heat
   (a) heat energy (b) capacity
   (c) resistance (d) potential
   (J & K CET)

5. The work done in moving an alpha particle between two points having potential difference 25 volt is
   (a) 8×10^{-18} J (b) 8×10^{-19} J
   (c) 8×10^{-20} J (d) 8×10^{-16} J
   (e) 4×10^{-18} J
   (Kerala PET)

6. A hollow metal sphere of radius R is charged with a charge Q. The electric potential and intensity inside the sphere are respectively
   (a) $\frac{Q}{4\pi\varepsilon_0 R^2}$ and $\frac{Q}{4\pi\varepsilon_0 R}$
   (b) $\frac{Q}{4\pi\varepsilon_0 R}$ and Zero
   (c) Zero and Zero
   (d) $\frac{4\pi\varepsilon_0 Q}{R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$
   2015 *(WB JEE)*

7. The velocity acquired by a charged particle of mass m and charge Q accelerated from rest by a potential of V is
   (a) $\frac{QV}{m}$ (b) $\sqrt{\frac{m}{QV}}$ (c) $\sqrt{mQV}$ (d) mQV
   (e) $\sqrt{\frac{2QV}{m}}$
   (Kerala PET)

2014

8. What is the electric potential at a distance of 9 cm from 3 nC ?
   (a) 300 V (b) 270 V
   (c) 30 V (d) 3 V *(Karnataka CET)*

9. An electric charge 10^{-3} μC is placed at the origin (0, 0) of (*X*-*Y*) co-ordinate system. Two points A and B are situated at $(\sqrt{2}, \sqrt{2})$ and (2,0) respectively. The potential difference between the points A and B will be
   (a) 4.5 volt (b) 9 volt
   (c) zero (d) 2 volt *(AIEEE)*

10. The electric field and the potential of an electric dipole vary with distance r as
    (a) $\frac{1}{r}$ and $\frac{1}{r^2}$ (b) $\frac{1}{r^2}$ and $\frac{1}{r}$
    (c) $\frac{1}{r^2}$ and $\frac{1}{r^3}$ (d) $\frac{1}{r^3}$ and $\frac{1}{r^2}$
    (J & K CET)

PREVIOUS YEARS' MCQ'S FOR ENTRANCE EXAMS

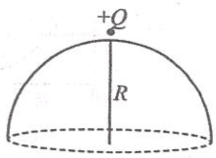
QUESTIONS FOR : ENGINEERING ENTRANCE EXAM [J.E.E]

TOPIC : POTENTIAL AND EQUIPOTENTIAL SURFACES

2017

11. There is a uniform electrostatic field in a region. The potential at various points on a small sphere centred at P, in the region, is found to vary between the limits 589.0 V to 589.8 V. What is the potential at a point on the sphere whose radius vector makes an angle of 60° with the direction of the field?
(a) 589.2 V (b) 589.6 V
(c) 589.5 V (d) 589.4 V
2017 *(JEE Main Online)*

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



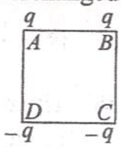
(a) The circumference of the flat surface is an equipotential.
(b) The component of the electric field normal to the flat surface is constant over the surface.
(c) Total flux through the curved and the flat surfaces is Q/ε_0.
(d) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$.
2017 *(JEE Advanced)*

2016

13. The potential (in volts) of a charge distribution is given by
$V(z) = 30 - 5z^2$ for $|z| \le 1$ m
$V(z) = 35 - 10|z|$ for $|z| \ge 1$ m.
$V(z)$ does not depend on x and y. If this potential is generated by a constant charge per unit volume ρ_0 (in units of ε_0) which is spread over a certai region, then choose the correct statement.
(a) $\rho_0 = 20\,\varepsilon_0$ in the entire region
(b) $\rho_0 = 10\,\varepsilon_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere
(c) $\rho_0 = 20\,\varepsilon_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere
(d) $\rho_0 = 40\,\varepsilon_0$ in the entire region *(JEE Main Online)*

14. Which of the following is a dielectric?
(a) Copper (b) Glass
(c) Antimony (Sb) (d) None of these
(UPSEAT)

15. Charges are placed on the vertices of a square as shown. Let $\vec{E}$ be the electric field and V the potential at the centre. If the charges on A and B are interchanged with those on D and C respectively, then



(a) $\vec{E}$ changes, V remains unchanged
(b) $\vec{E}$ remains unchanged, V changes
(c) both $\vec{E}$ and V change
(d) $\vec{E}$ and V remain unchanged *(AIEEE)*

16. Electric potential at the centre of a charged hollow metal sphere is
(a) zero
(b) twice as that on the surface
(c) half of that on the surface
(d) same as that on the surface *(J & K CET)*

17. N identical drops of mercury are charged simultaneously to 10 volt. When combined to form one large drop, the potential is found to be 40 volt, the value of N is
(a) 4 (b) 6 (c) 8 (d) 10
(e) 12 *(Kerala PET)*

18. A solid sphere of radius R is charged uniformly. At what distance from the centre is the potential half of its value at the centre?
(a) $R/2$ (b) $R/3$ (c) R (d) $4R/3$

19. For a polar molecule, which of the following statements is true ?
(a) The centre of gravity of electrons and protons coincide.
(b) The centre of gravity of electrons and protons do not coincide.
(c) The charge distribution is always symmetrical.
(d) The dipole moment is always zero. *(COMEDK)*

2013

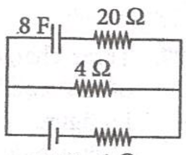
20. When a comb rubbed with dry hair attracts pieces of paper. This is because the
(a) comb polarizes the piece of paper
(b) comb induces a net dipole moment opposite to the direction of field
(c) electric field due to the comb is uniform
(d) comb induces a net dipole moment perpendicular to the direction of field
(e) paper acquires a net charge *(Kerala PET)*

TOPIC : CAPACITANCE

21. n identical capacitors are joined in parallel and charged to a potential V. The charged capacitors are disconnected and then connected in series using insulating handless such that the positive plate of one is connected to the negative plate of the other. The potential difference across the free plates of the combination is
(a) V (b) V/n
(c) nV (d) $(n+1)V$ *(J & K CET)*

2016

22. A capacitor of 8 F is connected as shown. Charge on the plates of the capacitor

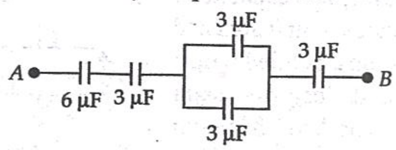


(a) 32 C
(b) 40 C
(c) 0 C
(d) 80 C
(Karnataka CET)

2015

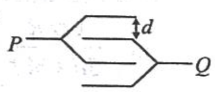
23. A 5 μF capacitor is fully charged by a 12 V battery and then disconnected. If it is connected now parallel to an uncharged capacitor, the voltage across it is 3 V. Then the capacity of the uncharged capacitor is
(a) 5 μF (b) 15 μF (c) 50 μF (d) 10 μF
(e) 25 μF *(Kerala PET)*

24. In this diagram, the P.D. between A and B is 60 V. The P.D. across 6 μF capacitor is ...V



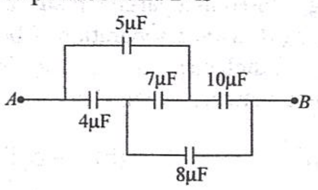
(a) 10 (b) 5
(c) 20 (d) 4 *(Karnataka CET)*

25. If A is plate area and d is distance between two plates, then effective capacitance between P and Q is



(a) $\frac{\varepsilon_0 A}{3d}$ (b) $\frac{3\varepsilon_0 A}{d}$ (c) $\frac{2\varepsilon_0 A}{d}$ (d) $\frac{\varepsilon_0 A}{2d}$
(UP GBTU)

26. In the circuit shown, the equivalent capacitance between the points A and B is



(a) 6 μF (b) 8 μF
(c) 2 μF (d) 4 μF *(UPSEAT)*

27. Which one of the following statements is correct?
(a) The balls will bounce back to the bottom plate carrying the opposite charge they went up with
(b) The balls will stick to the top plate and remain there
(c) The balls will execute simple harmonic motion between the two plates
(d) The balls will bounce back to the bottom plate carrying the same charge they went up with

The average current in the steady state registered by the ammeter in the circuit will be
(a) proportional to $V_0^{1/2}$
(b) zero
(c) proportional to V_0^2
(d) proportional to the potential V_0 *(JEE Advanced)*

2015

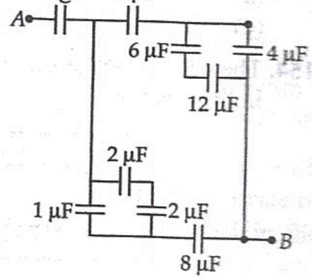
28. A parallel plate capacitor is charged and then isolated. The effect of increasing the plate separation on charge, potential and capacitance respectively are
(a) increases, decreases, decreases
(b) constant, increases, decreases
(c) constant, decreases, decreases
(d) constant, decreases, increases *(Karnataka CET)*

2013

29. A parallel plate capacitor of capacitance 5 μF is charged to 120 V and then connected to another uncharged capacitor. If the potential falls to 40 V, the capacitance of the second capacitor is
(a) 5 μF (b) 10 μF
(c) 15 μF (d) 20 μF *(J & K CET)*

30. A capacitor of capacitance C_1 is charged to a potential V and then connected in parallel to an uncharged capacitor of capacitance C_2. The final potential difference across each capacitor will be
(a) $\frac{C_1 V}{C_1 + C_2}$ (b) $\frac{C_2 V}{C_1 + C_2}$
(c) $1+\frac{C_2}{C_1}$ (d) $1-\frac{C_2}{C_1}$ *(J & K CET)*

31. In the given network, the value of C, so that an equivalent capacitance between A and B is 3 μF, is



(a) $\frac{1}{5}$ μF
(b) $\frac{31}{5}$ μF
(c) 48 μF
(d) 36 μF
(Karnataka CET)

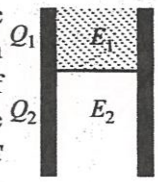
MASS PHYSICS

PREVIOUS YEARS' MCQ'S FOR ENTRANCE EXAMS

QUESTIONS FOR : ENGINEERING ENTRANCE EXAM [J.E.E]

TOPIC: CAPACITANCE & POTENTIAL ENERGY

32. 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 in the other portion is E_2. Choose 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) $\frac{C}{C_1} = \frac{2+K}{K}$

2014 (JEE Advanced)

33. Two capacitors of 10 pF and 20 pF are connected to 200 V and 100 V sources respectively. If they are connected by the wire, what is the common potential of the capacitors ?

(a) 300 volt (b) 133.3 volt

(c) 400 volt (d) 150 volt

(Karnataka CET)

34. Three capacitors 3 μF, 6 μF and 6 μF are connected in series to a source of 120 V. The potential difference, in volts, across the 3 μF capacitor will be

(a) 24 (b) 30

(c) 40 (d) 60 (WB JEE)

2013

35. Two identical capacitors are first connected in series and then in parallel. The ratio of equivalent capacitance is

(a) 1 : 1 (b) 1 : 2

(c) 1 : 3 (d) 1 : 4

(J & K CET 2013, WB JEE 2009)

36. Two capacitors C_1 and C_2 are charged to 120 V and 200 V respectively. It is found that by connecting them together the potential on each one can be made zero. Then

(a) $9C_1 = 4C_2$ (b) $5C_1 = 3C_2$

(c) $3C_1 = 5C_2$ (d) $3C_1 + 5C_2 = 0$

(JEE Main)

37. Two identical capacitors have the same capacitance C. One of them is charged to potential V_1 and the other V_2. The negative ends of the capacitors are connected together. When the positive ends are also connected, the decrease in energy of the combined system is

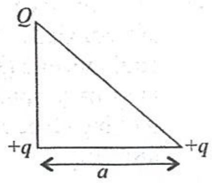
(a) $\frac{1}{4}C\left(V_1^2 - V_2^2\right)$ (b) $\frac{1}{4}C\left(V_1^2 + V_2^2\right)$

(c) $\frac{1}{4}C\left(V_1 - V_2\right)^2$ (d) $\frac{1}{4}C\left(V_1 + V_2\right)^2$.

38. A parallel combination of 0.1 MΩ resistor and a 10 μF capacitor is connected across a 1.5 V source of negligible resistance. The time required for the capacitor to get charged up to 0.75 V is approximately (in seconds)

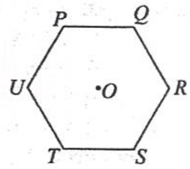
(a) ∞ (b) ln2 (c) $\log_{10}2$ (d) zero.

39. Three charges Q, $+q$ and $+q$ are placed at the vertices of a right-angled isosceles triangle as shown. The net electrostatic energy of the configuration is zero if Q is equal to



(a) $\frac{-q}{1+\sqrt{2}}$ (b) $\frac{-2q}{2+\sqrt{2}}$ (c) $-2q$ (d) $+q$.

40. Six charges of equal magnitude, 3 positive and 3 negative are to be placed on $PQRSTU$ corners of a regular hexagon, such that field at the centre is double that electric of what it would have been if only one +ve charge is placed at R.

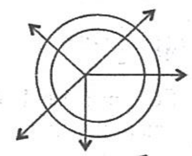


(a) +, +, +, −, −, − (b) −, +, +, −, −, +

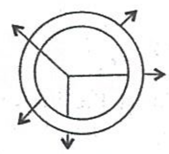
(c) −, +, +, −, +, − (d) +, −, +, −, +, −.

41. A metallic shell has a point charge q kept inside its cavity. Which one of the following diagrams correctly represents the electric lines of force?

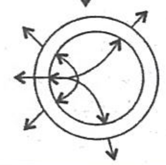
(a)



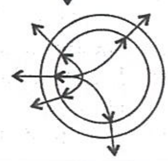
(b)



(c)



(d)



42. The energy stored in the electric field produced by a metal sphere is 4.5 J. If the sphere contains 4 μC charge, its radius will be [Take : $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2/C^2]

(a) 32 mm (b) 20 mm (c) 16 mm (d) 28 mm

(JEE Main Online)

2017

ELECTROSTATIC POTENTIAL AND CAPACITANCE

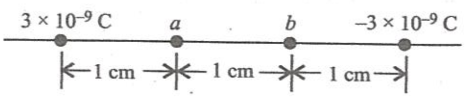
1. An electric charge 10^{-3} μC is placed at the origin (0, 0) of X-Y co-ordinate system. Two points A and B are situated at $(\sqrt{2}, \sqrt{2})$ and (2, 0) respectively. The potential difference between the points A and B will be
(a) 4.5 volt (b) 9 volt
(c) zero (d) 2 volt
(UP CPMT 2015, AIIMS 2010)

2014

2. What is the electric potential at a distance of 9 cm from 3 nC ?
(a) 300 V (b) 270 V (c) 30 V (d) 3 V
(Karnataka CET)

3. 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) $12\pi\varepsilon_0 Q \times 10^{22}$ V m^{-1}
(b) $4\pi\varepsilon_0 Q \times 10^{22}$ V m^{-1}
(c) $12\pi\varepsilon_0 Q \times 10^{20}$ V m^{-1}
(d) $4\pi\varepsilon_0 Q \times 10^{20}$ V m^{-1} *(JIPMER 2015, AIPMT 2008)*

4. In figure, a particle having mass m = 5 g and charge $q' = 2 \times 10^{-9}$ C starts from rest at point a and moves in a straight line to point b. What is its speed v at point b?

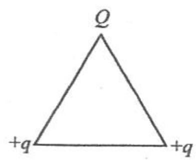


(a) 2.65 cm s^{-1} (b) 3.65 cm s^{-1}
(c) 4.65 cm s^{-1} (d) 5.65 cm s^{-1} *(AIIMS)*

2009

5. The mutual electrostatic potential energy between two protons which are at a distance of 9×10^{-15} m, in $_{92}U^{235}$ nucleus is
(a) 1.56×10^{-14} J (b) 5.5×10^{-14} J
(c) 2.56×10^{-14} J (d) 4.56×10^{-14} J
(J & K CET)

6. Three charges are placed at the vertex of an equilateral triangle as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) $-q$ (b) $q/2$
(c) $-2q$ (d) $-q/2$
(OJEE, Karnataka CET)

7. **Assertion:** If a conductor is given charge then no excess inner charge appears.
Reason: Electric field inside conductor is zero.
(a) Both assertion and reason are true and reason is the correct explanation of the assertion.
(b) Both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) Assertion is true but reason is false.
(d) Both assertion and reason are false. *(AIIMS)*

2012

8. Which of the following statements is false for a perfect conductor?
(a) The surface of the conductor is an equipotential surface.
(b) The electric field just outside the surface of a conductor is perpendicular to the surface.
(c) The charge carried by a conductor is always uniformly distributed over the surface of the conductor.
(d) None of these *(J & K CET)*

2010

9. Identify the false statement.
(a) Inside a charged or neutral conductor electrostatic field is zero.
(b) The electrostatic field at the surface of the charged conductor must be tangential to the surface at any point.
(c) There is no net charge at any point inside the conductor.
(d) Electrostatic potential is constant throughout the volume of the conductor.
(e) Electric field at the surface of a charged conductor is proportional to the surface charge density.
(Kerala PMT)

10. 1 volt is equivalent to
(a) $\frac{\text{newton}}{\text{second}}$ (b) $\frac{\text{newton}}{\text{coulomb}}$
(c) $\frac{\text{joule}}{\text{coulomb}}$ (d) $\frac{\text{joule}}{\text{second}}$
(AFMC, UGET (Manipal))

11. The electric field and the potential of an electric dipole vary with distance r as
(a) $\frac{1}{r}$ and $\frac{1}{r^2}$ (b) $\frac{1}{r^2}$ and $\frac{1}{r}$
(c) $\frac{1}{r^2}$ and $\frac{1}{r^3}$ (d) $\frac{1}{r^3}$ and $\frac{1}{r^2}$
(J & K CET)

MASS PHYSICS

PREVIOUS YEARS' MCQ'S FOR ENTRANCE EXAMS

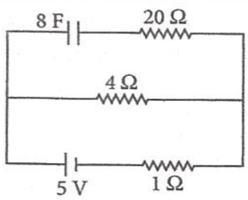
QUESTIONS FOR : MEDICAL ENTRANCE EXAM [N.E.E.T]

TOPIC : CAPACITANCE

12. A hexagon of side 8 cm has a charge 4 μC at each of its vertices. The potential at the centre of the hexagon is
(a) 2.7×10^6 V (b) 7.2×10^{11} V
(c) 2.5×10^{12} V (d) 3.4×10^4 V *(AIIMS)*

A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are
(a) zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (b) $\frac{Q}{4\pi\varepsilon_0 R}$ and zero
(c) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (d) both are zero
(AIPMT)

13. A capacitor of 8 F is connected as shown. Charge on the plates of the capacitor

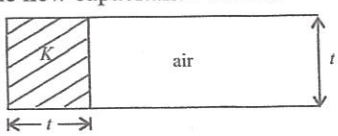


(a) 32 C
(b) 40 C
(c) 0 C
(d) 80 C
(Karnataka CET)

2014

14. The diameter of the plate of a parallel plate condenser is 6 cm. If its capacity is equal to that of a sphere of diameter 200 cm, the separation between the plates of the condenser is
(a) 4.5×10^{-4} m (b) 2.25×10^{-4} m
(c) 6.75×10^{-4} m (d) 9×10^{-4} m *(AIIMS)*

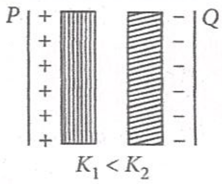
15. A parallel plate capacitor with air as a dielectric has capacitance C. A slab of dielectric constant K, having same thickness as the separation between the plates is introduced so as to fill one-fourth of the capacitor as shown in the figure. The new capacitance will be

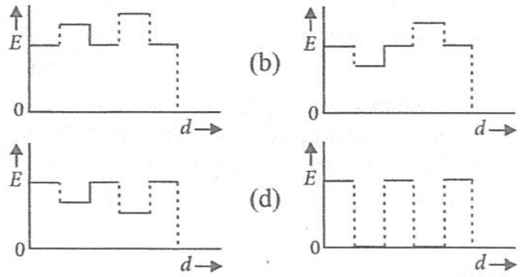


(a) $(K+3)\frac{C}{4}$
(b) $(K+2)\frac{C}{4}$
(c) $(K+1)\frac{C}{4}$ (d) $\frac{KC}{4}$ *(AIIMS)*

16. When three capacitors of equal capacities are connected in parallel and one of the same capacity is connected in series with its combination. The resultant capacity is 3.75 μF. The capacity of each capacitor is
(a) 5 μF (b) 6 μF (c) 7 μF (d) 8 μF
(MHT CET)

17. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between plates of a parallel plate capacitor, as shown in the figure. The variation of electric field E between the plates with distance d as measured from plate P is correctly shown by





(AIPMT)

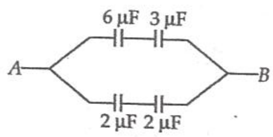
18. The region between the parallel plates of a capacitor is filled with parallel layers of air and paper (of dielectric constant 4). The space between the plates is 1 mm and the thickness of paper is 0.75 mm. The ratio of the voltages across air and paper is
(a) $\frac{1}{2}$ (b) $\frac{3}{4}$ (c) $\frac{4}{3}$ (d) $\frac{1}{3}$
(COMEDK)

19. A voltmeter reads 4 V when connected to a parallel plate capacitor with air as a dielectric. When a dielectric slab is introduced between plates for the same configuration, voltmeter reads 2 V. What is the dielectric constant of the material ?
(a) 8 (b) 0.5
(c) 10 (d) 2 *(Karnataka CET)*

2013

20. Two metal plate form a parallel plate capacitor. The distance between the plates is d. A metal sheet of thickness $d/2$ and of the same area is introduced between the plates. What is the ratio of the capacitances in the two cases?
(a) 4 : 1 (b) 2 : 1
(c) 3 : 1 (d) 5 : 1 *(JIPMER)*

21. The equivalent capacitance between A and B as shown in figure is



(a) $\frac{25}{26}$ μF
(b) 1 μF
(c) 3 μF (d) $\frac{3}{4}$ μF *(OJEE)*

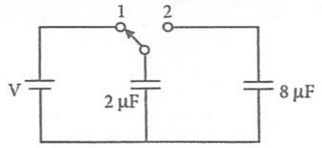
TOPIC : CAPACITOR AND CAPACITANCE

22. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system
(a) decreases by a factor of 2
(b) remains the same
(c) increases by a factor of 2
(d) increases by a factor of 4 *(NEET)*

. A parallel plate air capacitor has capacity C farad, potential V volt and energy E joule. When the gap between the plates is completely filled with dielectric
(a) both V and E increase
(b) Both V and E decrease
(c) V decreases, E increases
(d) V increases, E decreases *(MHT CET)*

2016

23. A capacitor of 2 μF is charged as shown in the diagram. When the switch S is turned to position 2, the percentage of its stored energy dissipated is

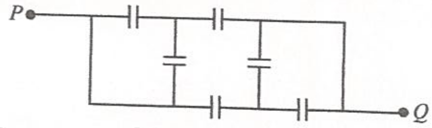


(a) 75% (b) 80%
(c) 0% (d) 20%
(NEET Phase-I)

24. The energy stored in a parallel plate capacitor of cross section area A with a separation d being filled with dielectric of dielectric constant ε_0 in terms of the electric field between them, E is

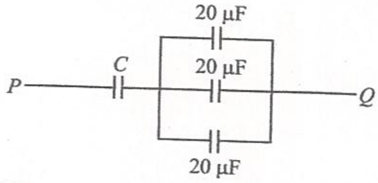
(a) $\frac{1}{2}\varepsilon_0 E^2$ (b) $\frac{1}{2}\varepsilon_0 E^2 Ad$
(c) $\frac{1}{2}\varepsilon_0 E^2 A/d$ (d) $\frac{1}{2}\varepsilon_0 E^2 d/A$
(J & K CET 2016, AIPMT 2012, 2008, AIIMS 2011)

25. A network of six identical capacitors, each of value C, is made as shown in the figure. The equivalent capacitance between the points P and Q is



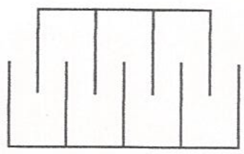
(a) $\frac{C}{4}$ (b) $\frac{3C}{4}$ (c) $\frac{3C}{2}$ (d) $\frac{4C}{3}$ *(BHU)*

26. If the equivalent capacitance between P and Q of the combination of the capacitors shown in figure below is 30 μF, the capacitor C is



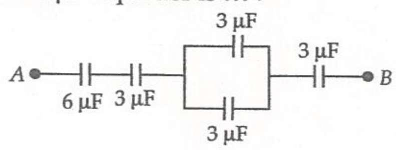
(a) 60 μF (b) 30 μF
(c) 10 μF (d) 5 μF *(J & K CET)*

27. A gang capacitor is formed by interlocking a number of plates as shown in the figure. The distance between the consecutive plates is 0.885 cm and the overlapping area of the plates is 5 cm^2. The capacity of the unit is



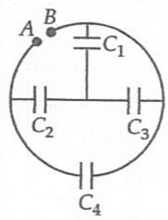
(a) 1.06 pF (b) 4 pF
(c) 6.36 pF (d) 12.72 pF *(BHU)*

28. In this diagram, the P.D. between A and B is 60 V. The P.D. across 6 μF capacitor is ...V



(a) 10 (b) 5
(c) 20 (d) 4 *(Karnataka CET)*

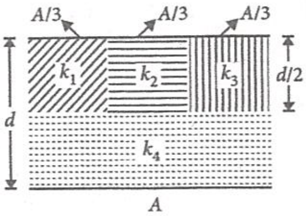
29. In the arrangement of capacitors shown in figure, each capacitor is of 9 μF, then the equivalent capacitance between the points A and B is



(a) 9 μF
(b) 18 μF
(c) 4.5 μF
(d) 15 μF
(UP CPMT)

TOPIC : CAPACITANCE AND VARIOUS CASES

30. A parallel-plate capacitor of area A, plate separation d and capacitance C is filled with four dielectric materials having dielectric constants k_1, k_2, k_3 and k_4 as shown in the figure. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant k is given by



(a) $k = k_1 + k_2 + k_3 + 3k_4$ (b) $k = \frac{2}{3}(k_1 + k_2 + k_3) + 2k_4$

(c) $\frac{2}{k} = \frac{3}{k_1 + k_2 + k_3} + \frac{1}{k_4}$

(d) $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{3}{2k_4}$ *(NEET Phase-II)*

31. Three parallel plate air capacitors are connected in parallel. Each capacitor has plate area $\frac{A}{3}$ and the separation between the plates is d, $2d$ and $3d$ respectively. The equivalent capacity of combination is (ε_0 = absolute permittivity of free space)

(a) $\frac{7\varepsilon_0 A}{18d}$ (b) $\frac{11\varepsilon_0 A}{18d}$

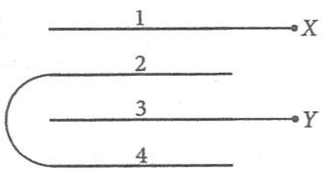
(c) $\frac{13\varepsilon_0 A}{18d}$ (d) $\frac{17\varepsilon_0 A}{18d}$ *(MHT CET)*

32. Two identical parallel plate air capacitors are connected in series to a battery of e.m.f. V. If one of the capacitor is completely filled with dielectric material of constant K, then potential differensce of the other capacitor will become

(a) $\frac{K}{V(K+1)}$ (b) $\frac{KV}{K+1}$

(c) $\frac{K-1}{KV}$ (d) $\frac{V}{K(K+1)}$ *(MHT CET)*

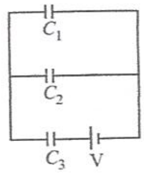
33. Four metal plates are arranged as shown. Capacitance between X and Y ($A \rightarrow$ Area of each plate, $d \rightarrow$ distance between the plates)



(a) $\frac{3}{2}\frac{\varepsilon_0 A}{d}$ (b) $\frac{2\varepsilon_0 A}{d}$ (c) $\frac{2}{3}\frac{\varepsilon_0 A}{d}$ (d) $\frac{3\varepsilon_0 A}{d}$

(Karnataka CET 2016, BHU 2010)

34. What would be the voltage across C_3?



(a) $\frac{(C_1 + C_2)V}{C_1 + C_2 + C_3}$

(b) $\frac{C_1 V}{C_1 + C_2 + C_3}$

(c) $\frac{C_2 V}{C_2 + C_2 + C_3}$ (d) $\frac{C_3 V}{C_1 + C_2 + C_3}$ *(AIIMS)*

35. Two conductors of capacities C_1 and C_2 are charged to potentials V_1 and V_2 respectively and then they are connected by a conducting wire. The common potential will be

(a) $C_1V_1 + C_2V_2$ (b) $\frac{C_1 + C_2}{C_1V_1 + C_2V_2}$

(c) $\frac{C_1V_1 + C_2V_2}{C_1 + C_2}$ (d) $(V_1 + V_2)(C_1 + C_2)$ *(BHU)*

36. n identical capacitors each of capacitance C when connected in parallel give the effective capacitance 90 μF and when connected in series give 2.5 μF. Then the values of n and C respectively are

(a) 6 and 15 μF (b) 5 and 18 μF

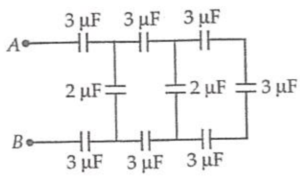
(c) 15 and 6 μF (d) 18 and 5 μF *(J & K CET)*

37. The number of ways one can arrange three identical capacitors to obtain distinct effective capacitances is

(a) 8 (b) 6

(c) 4 (d) 3 *(J & K CET)*

38. The equivalent capacitance between A and B is (in μF)



(a) 25

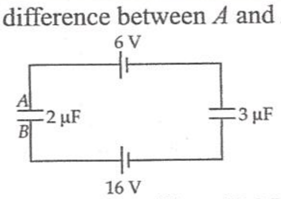
(b) $\frac{84}{25}$

(c) 9

(d) $\frac{25}{84}$

(e) 1 *(Kerala PMT)*

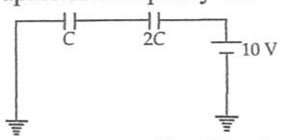
39. The potential difference between A and B is



(a) 13.2 V (b) –13.2 V

(c) –6 V (d) 6 V *(OJEE)*

40. In the circuit shown in figure, $C = 6$ μF. The charge stored in the capacitor of capacity C is



(a) zero (b) 90 μC

(c) 40 μC (d) 60 μC *(UP CPMT)*