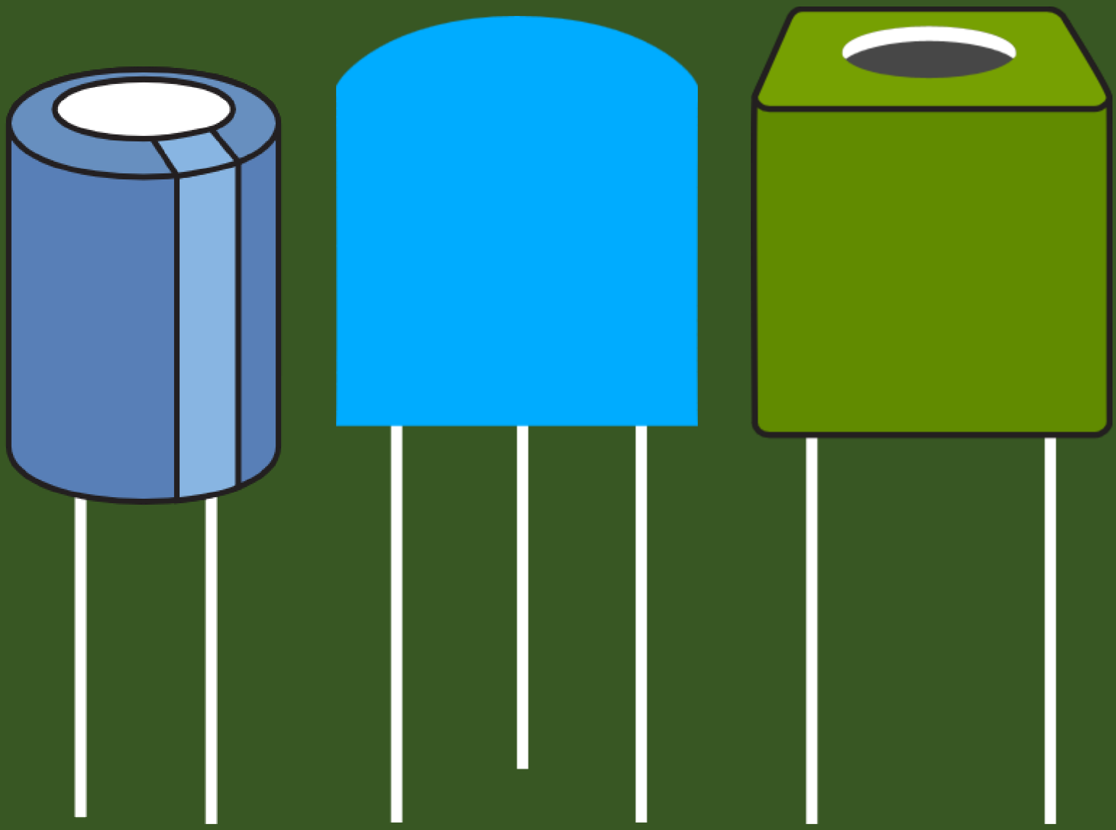
2.Electrostatic Potential and Capacitance



Physics Smart Booklet

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CAPACITOR

TYPES OF CAPACITANCE'S

- Capacitance of Spherical conductor:

$C = 4\pi\varepsilon r$

- Capacitance of Earth: $C = 4\pi\varepsilon r$: $r = 6.4\times10^{6}\,F$

$\therefore C = 4\pi\times8.854\times10^{-12}\times6.4\times10^{6} = 7.11\times10^{-6}\,F$

- Capacitance of Parallel Plate Capacitor:

$(C_0) = \dfrac{\varepsilon_0 A}{d}\,F$

where— ε_0 = Free Space permitivity

A = Plate Area

and d = Sepration between Plates

FORCE BETWEEN THE PLATES OF CAPACITOR

$F = \dfrac{\theta\sigma}{2\varepsilon_0} \Rightarrow F\dfrac{\theta^2}{2A\varepsilon_0} = \dfrac{1}{2}\varepsilon_0 AE^2$

F = Force: θ = charge

E = electric field between plates

σ = Surface charge density

ELECTROSTATIC PRESSURE

$(P) = \dfrac{F}{A} = \dfrac{\theta E}{A} = \dfrac{\sigma A}{A}\left(\dfrac{\sigma}{2\varepsilon}\right)$

$= \dfrac{1}{2}\dfrac{\sigma^2}{\varepsilon_0}$

KIRCHOFF'S LAW OF CAPACITOR'S

FIRST LAW: This law is basically law of conservation of charge which states that the sum of incoming charges at a function in equal to the sum of outgoing charges

$q_{\_} = q_1 + q_2 = q_3 + q_4$

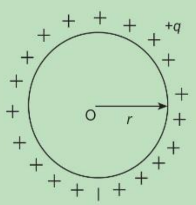
SECOND LAW: In a closed loop, the summation of all the potential differences must be zero.

$V - \dfrac{q_1}{C_1} - \dfrac{q_3}{C_3} = 0$

OTHER TYPES OF CAPACITOR'S

- Sphrical Capacitor outer Surface Earthed:

$C = \dfrac{\theta}{V} = \dfrac{4\pi\varepsilon_0}{\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)}$



- Cylindrical Capacitor:

$C = \dfrac{4\pi\varepsilon_0 L}{\ln\left(\dfrac{b}{a}\right)}$

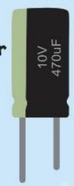
L, B and a - Parameters of Cyllinder

A capacitor is a device which can store more electric charge or potential energy compared to on isolated conductor

- Capacitance: Capacitance of a conductor measure of its ability to store charge.

$V \propto q \Rightarrow V = \dfrac{q}{c} \Rightarrow C = \dfrac{q}{V}$

S.I. Unit Farad $(F) = \dfrac{\text{Coulomb}}{\text{Volt}}$



DIELECTRIC

Dieletric is a material which behaves as non conductor upto certain value of External eletctric field. If the field crosses the limiting value (Called dielectric strogth) then it beging to conduct

Dielectric constant (k or E_R)

$E_r = K = \dfrac{E_m}{\varepsilon_0}$

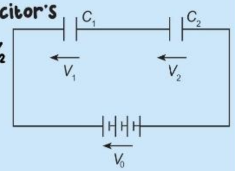
COMBINATION OF CAPACITOR'S

- Series Equivalent of Capacitor's

In Series— $\theta = C_1V_1 = C_2V_2$

$\because V_0 = V_1 + V_2$

$\therefore \dfrac{1}{C_{equi}} = \dfrac{1}{C_1} + \dfrac{1}{C_2}$

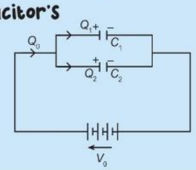


- Parallel Equivalent of Capacitor's

In Parallel— $V = V_1 = V_2$

$\theta = \theta_1 + \theta_2$

$C_{Equiv} = C_1 + C_2$



ENERGY STRORED IN A CHARGED CAPACITOR

$U = \dfrac{1}{2}\dfrac{\theta^2}{C} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}\theta V$

WORK DONE BY BATTERY DURING CHARGING OF A CAPACITOR

$\Rightarrow W_{Battery} = \theta C = CV^2 = \dfrac{\theta}{C}$

CHARGING & DISCHARGING OF A CAPACITOR

- CHARGING:

(i) Charging of a capacitor without Resistance Charging take no time when Switch closed

$q_0 = CV$

(ii) Charging of a Capacitor having Series Resistance:

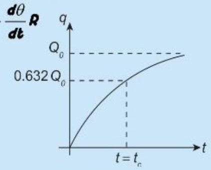
$V_0 = V_C + V_R = \dfrac{\theta}{C} + IR = \dfrac{\theta}{C} + \dfrac{d\theta}{dt}R$

$Q = CV_0\varepsilon^{\frac{t}{RC}} = Q_0 e^{\frac{t}{T}}$

I = Current

R = Resistance

T = Time Constant = RC



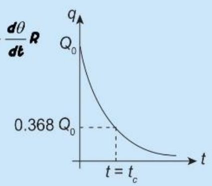
- Discharging of a capacitor through Serias resistance:

$V_0 = V_C + V_R = \dfrac{\theta}{C} + IR = \dfrac{\theta}{C} + \dfrac{d\theta}{dt}R$

$\theta = \theta_0(1 - e^{\frac{t}{T}})$

$\theta = 0.368\theta_0$

At time $t = RC$

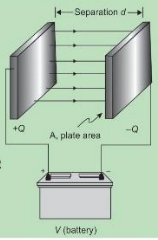


ENERGY DENSITY OF CAPACITOR

Energy Stored in the capacitor per unit volume.

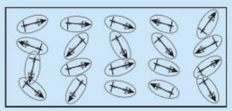
Energy density of capacitor $= \dfrac{dV}{dV}$

$\Rightarrow \left(\dfrac{U}{V}\right) = \dfrac{\dfrac{1}{2}CV^2}{A\times d} = \dfrac{1}{2}\varepsilon_0 F^2$



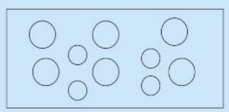
POLAR DIELECTRIC

- Centers of +ve and −ve charge do not coincide due to asymmetric shape of molecules.
- Each molecule has permanent dipole moment in presence of External electric field



NON-POLAR DIELECTRIC

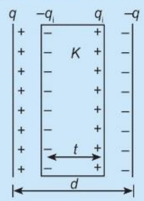
- Centers of +ve and −ve charge coincide due to symmetric shape of molecules.
- Each molecule has prmanent dipole moment only in presence of External electric field



CAPACITOR WITH DIELEATRIC

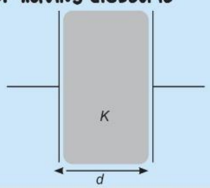
- Capacitance of capacitor having dielectric constant (k) and (t<d):

$C = \dfrac{A\varepsilon_0}{dd - t + \dfrac{t}{k}}$ t = thickness, k = Dieletric Constant



- Capacitance of Capacitor having diebctric constant (K) and (t = d):

$C = \dfrac{A\varepsilon_0}{d - d + \dfrac{d}{k}} = \dfrac{kA\varepsilon_0}{d} = kC_0$



Electrostatic Potential and Capacitance

Electrostatic Potential

It is the potential energy possessed by a unit positive charge at the given point in an electric field and is measured by the amount of work done in moving a unit positive charge from infinity to the given point against the field. It is a scalar quantity and is measured in volt.

$$V = -\int_{\infty}^{r} dW = -\int_{\infty}^{r} \vec{E}.d\vec{r}$$

The electric potential (V) at a distance r from a charge q is given by $V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r}\right]$.

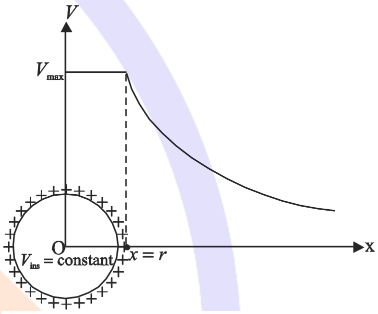
If ΔU is the change in potential energy of a system on a charge q move through a distance the against an electric field E, then $\Delta U = -qEd$.

Electrostatic potential at a point is $V = \frac{\Delta U}{q}$

The potential energy per unit positive charge at a point in an electric field is called the electric potential at that point.

Potential due to a point charge $= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Potential due to a charged spherical conductor is $= \frac{Q}{4\pi\varepsilon_0 x}$

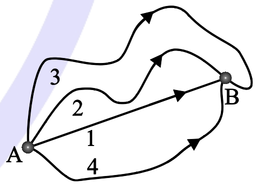


Potential due to a charged spherical conductor

where x is distance of the point from the center of charged sphere.

For points on the surface or inside the conductor the potential is $= \frac{Q}{4\pi\varepsilon_0 r}$

- The work done in moving a charged particle from one point to another in an electrostatic field depends only on the initial and final points, but not on the path between the two points. In figure the work done per unit charge in moving from A to B along all the paths 1, 2, 3 and 4 are equal. i.e., $W_1 = W_2 = W_3 = W_4 = W$ (say). The work done $W = V_A \sim V_B$.



Path independence of work done

- Work done in moving a charge over a closed path in an electric field is zero. Electric field is a conservative field.
- The electric potential at a point due to positive charges is positive and due to negative charges is negative. The net potential at a point is the algebraic sum of the potentials due to different charges. Electric potential is scalar additive. Only the potential difference between two points $V_A \sim V_B$ has a definite value. But, the absolute values of V_A and V_B are arbitrary and they have no physical significance. Only potential difference between two points is physically meaningful.
- The potential difference between two points is the work done in moving one coulomb of positive charge from one point to the other. It is measured in volt.
- Electric potential at a point due to a short dipole is given by $V = \frac{q(2a)\cos\theta}{4\pi\varepsilon_0 r^2} = \frac{\vec{p}\cdot\hat{r}}{4\pi\varepsilon_0 r^2}$, where p = electric dipole moment.
- Potential at a point due to a dipole on the axial line is inversely proportional to the square of the distance from the dipole. At large distances, $V \propto \frac{1}{r^2}$, whereas, for a point charge, $V \propto \frac{1}{r}$.

- Potential is maximum ($\theta = 0$ or π and $\cos\theta = \pm 1$), along the axis of the dipole.
- At any point on the equatorial line, potential is zero (Thus, equatorial line of a dipole is equipotential).
- Electric potential due to a system of charges is given by $V = \frac{1}{4\pi\varepsilon_0}\sum \frac{q_i}{r_i}$.
- For a continuous distribution of charge, $V = \int \frac{dQ}{4\pi\varepsilon_0 r}$
- $dQ = \lambda\, dl$, for linear distribution of charge.
- $dQ = \sigma dS$, for surface distribution of charge.
- $dQ = \rho dv$, for volume distribution of charge.

Equipotential surface

An equipotential surface is a surface passing through points at the same electric potential.

- Equipotential surfaces around a point charge are concentric spherical surfaces.
- Equipotential surfaces around a charged cylinder or line of charge are concentric cylindrical surfaces.
- Equipotential surfaces due to a large charged plane are planes parallel to the surface.
- For a uniform spherical distribution of charges (like a spherical shell or a sphere), the equipotential outside the spheres are concentric spheres around the centre of distribution of charges.
- All the lines in a plane passing through the centre of a dipole and perpendicular to the axis of the dipole lie on an equipotential surface of zero potential. If the dipole lies along *x*-axis, the *y*-*z* plane ($x = 0$) is an equipotential surface with V = 0.
- Electric field lines are perpendicular to an equipotential surface and hence work done in moving a charge on an equipotential surface is zero.

Potential energy

- Potential energy of a system of two charges is given by $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$
- Potential energy of a system of three charges is given by $U = \left(\frac{1}{4\pi\varepsilon_0}\right)\left[\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_3 q_1}{r_{31}}\right]$
- Energy of a system of several point charges is given by $U = \sum_{i\neq j} U_{ij} = \sum_{i\neq j}\left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{q_i q_j}{r_{ij}}\right)$

Capacitors

When a conductor is charged, the charge spreads on its surface. If the conductor is smooth, it retains the charge for considerable time. Thus, a conductor can be used to store charge. The ability of a conductor to store charge is called its capacitance.

The capacitance of a conductor is defined as its ability to store charge and is measured by the ratio of the charge added to the conductor to the rise in its potential.

i e., $C = \frac{Q}{V}$

The unit of capacitance in SI is farad (*F*). One farad is the capacitance of a conductor if its potential rises by 1 volt when a charge of 1 coulomb is added to it.

Capacitance of a Spherical Conductor

Consider a spherical conductor of radius *r*. Its capacitance, $C = 4\pi\varepsilon_0 r$.

If the capacitor is filled with a dielectric of relative permittivity $\varepsilon_r, C = 4\pi\varepsilon_0\varepsilon_r r$.

> ☞ When *C* = 1 F, r = 9 × 10^9, m = 9 × 10^6 km, i.e. the size of conductor needed to have a conductor of capacitance of 1 C is 9 × 10^6 km.

Principle of a capacitor

An earthed conductor kept close to a charged conductor decreases the potential of the charged conductor. Hence for a given Q, the corresponding V is small; hence the ratio $C = \frac{Q}{V}$ is large. i.e., the *capacitance of the* conductor *increases.*

Capacitor

It is an arrangement of two conductors separated by a dielectric. One important use of a capacitor is to store charge.

Capacitance of some simple capacitors

(a) Spherical capacitor

$R = n^{1/3} r$, where ε_r is the relative permittivity of the medium between the outer sphere of radius *b* and inner sphere of radius *a*.

> ☞ *C* can be increased by
> - decreasing (b – a) i.e., by bringing the spheres as close as possible, introducing a medium of higher ε_r.

(b) Parallel plate capacitor

$C = \frac{\varepsilon_0\varepsilon_r A}{d}$, where ε_r is the relative permittivity of the medium between two parallel plates of area *A* and separated by a distance *d*.

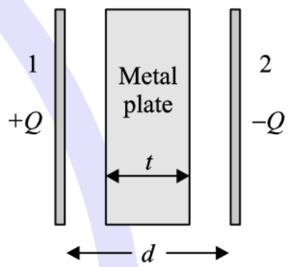
(c)Cylindrical capacitor: $C = \frac{2\pi\varepsilon_0\varepsilon_r L}{2.303 \log_{10}\frac{b}{a}}$, where *L* is the length, *b* is the radius of the outer cylinder and *a* is the radius of the inner cylinder.

> ☞
> - Suppose there are *n* charged drops, each of capacitance *C*, charged to potential *V* with charge *q*, surface density *σ* and potential energy *U* coalesce to form a single drop. For such a drop,
> - Total charge = *n q*
> - Total capacitance = n$^{1/3}$ *C*
> - Potential = n$^{2/3}$*V*
> - Surface density of charge = n$^{1/3}$ *σ*, and
> - Total potential energy = n$^{2/3}$ *U*.
> - Capacitance of a parallel plate capacitor with a dielectric slab of thickness *t* is given by: $E' = \frac{V'}{d}$
> - For a conducting slab, *K* = ∞ $\therefore\ Q' = Q$
> - If dielectric slab fills the entire space between the plates (instead of filling it partially), then *t* = *d*. In that case, $\frac{V}{K+1}$

- Clearly, capacitance increase on introducing a conducting slab as well as dielectric slab between the plates of an air capacitor.
- The capacitance of a parallel plate capacitor having a number of slabs of thickness t_1, t_2, t_3, … and dielectric constants K_1, K_2, K_3, … respectively in between the plates is $C = \dfrac{\varepsilon_0 A}{\left[\dfrac{t_1}{K_1} + \dfrac{t_2}{K_2} + \dfrac{t_3}{K_3} + ...\right]}$
- Obviously, distance between the plates in this case is $d = t_1 + t_2 + t_3 + \ldots$
- When a number of dielectric slabs of same thickness (d) and different areas of cross-section A_1, A_2, A_3, … having dielectric constants K_1, K_2, K_3, … respectively are placed between the plates of a parallel plate capacitor, its capacitance is given by $C = \dfrac{\varepsilon_0 (K_1A_1 + K_2A_2 + K_3A_3 + ...)}{d}$

Effect of introducing a metal plate

If a metal plate of thickness '*t*' is held parallel in between the plates of a parallel plate capacitor, the electric field inside the metal will be zero. Work done in moving a unit charge from negative to positive plate is $V = E(d - t)$. The distance between the plates effectively decreases. Hence the potential difference decreases and capacitance increases.



Since $E = \dfrac{Q}{A\varepsilon_0}$, potential difference, $V = \dfrac{Q}{A\varepsilon_0}(d - t)$.

Hence, $C = \dfrac{Q}{V} = \dfrac{\varepsilon_0 A}{d - t}$

Series combination

A number of capacitors connected end to end such that each capacitor acquires the same charge is called a series combination. If C is the equivalent capacitance,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \text{............} \quad \text{or} \quad \frac{1}{C} = \sum \frac{1}{C_n} \quad \text{and} \quad V = V_1 + V_2 + V_3 + \ldots + V_n$$

- For a series combination of two capacitors $C = \dfrac{C_1 C_2}{C_1 + C_2}$
- If $C_1 = C_2$, then $C = \dfrac{C_1}{2} = \dfrac{C_2}{2}$
- The equivalent capacitance of *n* number of identical capacitors, each of capacitance *C*, in series is equal to (*C*/*n*).

Parallel combination

A number of capacitors are said to be in parallel if they are connected between two points such that the potential difference between each of them is the same.

In such a case $C = C_1 + C_2 + C_3 \ldots$ and $C_p = \sum C_n$

Also $Q = Q_1 + Q_2 + Q_3 + \ldots$

The equivalent capacitance of *n* number of identical capacitors, each of capacitance *C*, in parallel is equal to *nC*.

Energy stored in a capacitor

Work done in charging a capacitor is stored in it in the form of **electrostatic energy,** given by $E = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$ when Q is in coulomb, V is in volt and C is in farad, energy E is in joule.

When two capacitors charged to different potentials are connected by a conducting wire, charge flows from the one at higher potential to the other at lower potential till their potentials become equal. The equal potential is called **common potential** (V), where $V = \frac{\text{total charge}}{\text{total capacitance}} = \frac{q_1 + q_2}{C_1 + C_2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$

Loss in energy due to sharing of charges is given by $E_1 - E_2 = \frac{C_1C_2(V_1 - V_2)^2}{2(C_1 + C_2)}$.

Dielectrics

Dielectrics are of two types: non polar and polar. The non polar dielectrics (like N_2, O_2, benzene, methane) etc., are made up of non polar atoms/molecules, in which the centre of mass of positive charge coincides with the centre of mass of positive charge. And for polar molecules, the centre of mass of positive charge does not coincide with the centre of mass of negative charge of the atom/molecule.

Dielectric constant and capacitance

Consider two identical capacitors A and B. A has a medium of relative permittivity ε_r and B has air or vacuum in between the plates. C_A and C_B are the capacitances. Then $\varepsilon_r = \frac{C_A}{C_B}$

☞

- It can be shown that the ratio of the fields $(E_B / E_A) = \varepsilon_r$ or $E_B = (E_A / \varepsilon_r)$.

Since $C = \frac{\varepsilon_0 A}{d}(K_1 + K_2)$ i.e., the dielectric medium decreases the field and hence, the potential of a capacitor also decreases.

- A non polar dielectric can be polarized by applying an external electric field on the dielectric.

The effective electric field $(\vec{E})$ in a polarized dielectric is given by $\vec{E} = \vec{E}_0 - \vec{E}_p$ where $\vec{E}_0$ is strength of external field applied and $\vec{E}_p$ is intensity of induced electric field set up due to polarization. It is equal to surface density of induced charge. The ratio (E_0 / E) = K, dielectric constant.

- When a dielectric slab is placed in between the plates of a parallel plate capacitor, the charge induced on its sides due to polarization of dielectric is $q_i = q\frac{(K-1)}{K}$.
- When an insulating slab of dielectric constant K is introduced between the plates of a parallel plate capacitor and

(a) the charging battery is on:

(i) potential difference V remains constant

(ii) electric field E remains constant,

(iii) capacitance C becomes K times

(iv) potential energy U becomes K times

(v) charge q becomes K times

(vi) surface density of charge σ becomes K times.

(b) the charging battery is disconnected:

(i) capacitance C becomes K times

(ii) charge q remains constant

	(iii) σ remains constant (iv) V becomes 1/K times (v) E becomes 1/K times (vi) potential energy becomes 1/K times.

Types of capacitors in use

Type	Application
Variable air core capacitor	Tuning circuits
Mica capacitors	High frequency circuits
Paper capacitors	General purpose
Ceramic capacitors	General purpose
Electrolytic capacitors	Rectifier circuits

Van De Graff generator

It is an electrostatic machine used to produce very high potential of the order of few million volts. It is based on the following principles:

(a) discharge action at sharp points

(b) charges given to the inner surface of a sphere move to the outer surface and the field inside is always zero.

(c) for a given sphere, increase of charges increases the potential.

Illustration

1. A proton moves in the direction of the electric field. Let ΔU represent the change in its potential energy and ΔW represent the work done by the electric field. Then

(A) both ΔU and ΔW are positive (B) both ΔU and ΔW are negative

(C) ΔU is negative but ΔW is positive (D) ΔU is positive but ΔW is negative

Ans (C)

As the proton moves in the direction of the electric field, both its displacement and the electric force acting on it are in the same direction. Hence, ΔW is positive. Since $\Delta U = -\Delta W$, its potential energy decreases. Hence, ΔU is negative.

2. Suppose the electric potential outside a living cell is higher than that inside by 0.05 V. The work done by the electric force when a sodium ion moves from outside to inside is

(A) $+8\times10^{-20}$ J (B) -8×10^{-20} J (C) $+8\times10^{-19}$ J (D) -8×10^{-19} J

Ans (A)

Sodium ion has a positive charge, $q = 1.6\times10^{-19}$ C

Work done by the electric force is given by, $dW = qdV$

$dW = 1.6\times10^{-19}\times0.05 = 8\times10^{-20}$ J

3. The number of electrons passing through a 40 W bulb which is connected to a 24 V car battery in one hour is

(A) 4.75×10^{13} (B) 1.75×10^{23} (C) 2.75×10^{23} (D) 3.75×10^{23}

Ans (D)

Energy = power × time = 40 × 60 × 60 J.

Charge passing through the bulb, $q = \frac{\Delta U}{\Delta V} = \frac{40\times60\times60}{24}$

The number of electrons passing through the bulb, $n = \frac{q}{e} = \frac{40\times60\times60}{24\times1.6\times10^{-19}} = 3.75\times10^{23}$

4. A proton, a deuteron and an α-particle are accelerated through the same potential. The ratio of their velocities will be

(A) $1:\sqrt{2}:1$ (B) $\sqrt{2}:1:\sqrt{2}$ (C) $\sqrt{2}:1:1$ (D) $1:1:\sqrt{2}$

Ans (C)

The kinetic energy gained by a charged particle is equal to the potential energy lost by the charged particle. ∴ $\frac{1}{2}mv^2 = qV$

$$\therefore\ v = \sqrt{\frac{2qV}{m}}\ ;\ v \propto \sqrt{\frac{q}{m}}$$

$$\therefore\ v_p : v_d : v_\alpha = \sqrt{\frac{q}{m}} : \sqrt{\frac{q}{2m}} : \sqrt{\frac{2q}{4m}} = 1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{2}} = \sqrt{2}:1:1$$

5. The electric potential decreases uniformly from 150 V to 50 V as one moves along the x-axis from a point at x = – 1 cm to x = 1 cm. The electric field at the origin.

(A) is greater than 50 V cm^{-1} (B) is less than 50 V cm^{-1}

(C) is equal to 50 V cm^{-1} (D) is equal to greater than 50 V cm^{-1}

Ans (D)

$$E_x = -\frac{\Delta V}{\Delta x} = -\frac{50-150}{1-(-1)} = \frac{100}{2} = 50\,V\ cm^{-1}$$

As E_y and E_z are not known, E at the origin can be either equal to or greater than 50 V cm^{-1}.

6. Three charges each of magnitude 1 μC are placed at the vertices of an equilateral triangle of side 10 cm. The electric potential at the centre O of the triangle is

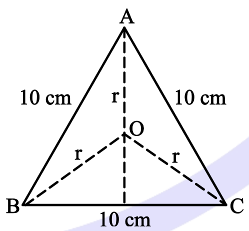
(A) $27\sqrt{3}\times10^{+4}$ V (B) $27\sqrt{3}\times10^{+5}$ V (C) 5.4×10^{5} V (D) zero

Ans (A)

Since each charge is at the same distance from the centre O of the triangle, the net potential at O is the three times the potential due to each charge.

$$V_0 = 3\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\right),$$

since $r\cos30 = 5\times10^{-2}$, $r = \frac{5\times10^{-2}}{\cos30} = \frac{10\times10^{-2}}{\sqrt{3}}$



$$\therefore\ V_0 = 3\times9\times10^9\left(\frac{1\times10^{-6}\times\sqrt{3}}{10\times10^{-2}}\right) = 27\sqrt{3}\times10^{+4}\ V$$

7. In infinite number of charges each equal to q are placed on the x-axis of a coordinate system at x = 1 m, x = 2 m, x = 4 m, x = 8 m ….. and so on. The potential at the origin due to the infinite set of charges is

(A) $\frac{q}{4\pi\varepsilon_0}$ (B) $\frac{2q}{4\pi\varepsilon_0}$ (C) $\frac{3q}{4\pi\varepsilon_0}$ (D) infinite

Ans (B)

Potential at the origin is the sum of potentials due to each charge.

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{1}+\frac{q}{2}+\frac{q}{4}+........\right]$$

$$\frac{q}{4\pi\varepsilon_0}\left[1+\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+......\right]$$

$$=\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{1-\frac{1}{2}}\right]=\frac{2q}{4\pi\varepsilon_0}$$

8. An amount of charge Q is distributed uniformly along an insulating ring of radius R. The electric potential on the axis of the ring at a distance r from the centre of the ring is

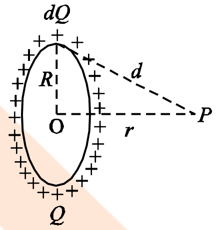
(A) $\frac{1}{4\pi\varepsilon_0}\frac{Qr}{(R^2+r^2)^{3/2}}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{(R^2+r^2)^{3/2}}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{(R^2+r^2)^{1/2}}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{(R^2+r^2)}$

Ans (C)

Consider an element of charge dQ. The potential due to this charge at P is given by

$$dV=\frac{1}{4\pi\varepsilon_0}\frac{dQ}{d}=\frac{1}{4\pi\varepsilon_0}\frac{dQ}{\sqrt{(R^2+r^2)}}$$



The potential at P due to the entire ring is given by

$$V=\int dV=\frac{1}{4\pi\varepsilon_0\sqrt{R^2+r^2}}\int dQ=\frac{Q}{4\pi\varepsilon_0\sqrt{R^2+r^2}}$$

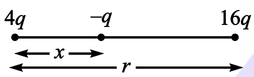
9. Two point charges 4q and 16q are placed at a distance r apart. Suppose a third charge –q is placed in between, on the line joining 4q and 16q, so that the electric potential energy of the system of charges is minimum. The position of the third charge is

(A) $\frac{r}{3}$ from 4q (B) $\frac{r}{3}$ from 16q (C) $\frac{2r}{3}$ from 4q (D) $\frac{2r}{3}$ from 16q

Ans (A)

Let the charge –q be placed at a distance x from the charge 4q as shown in the figure. The potential energy of the system of charges is given by

$$U=\frac{1}{4\pi\varepsilon_0}\left[\frac{(4q)(16q)}{r}+\frac{(4q)(-q)}{x}+\frac{(16q)(-q)}{r-x}\right]$$



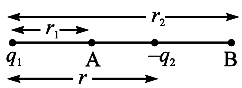
For U to be minimum, $\frac{dU}{dx}=0\Rightarrow\frac{d}{dx}\left[\frac{4}{x}+\frac{16}{r-x}\right]=0$

i.e., $-\frac{4}{x^2}+\frac{16}{(r-x)^2}=0\Rightarrow\frac{4}{x^2}=\frac{16}{r-x}\Rightarrow\frac{2}{x}=\frac{2}{r-x}$

$\Rightarrow x=\frac{r}{3}$

Note: The system will have minimum potential energy when the third charge is placed at the neutral point produced by the other two charges.

10. Let q_1 and $-q_2$ are two charges separated by a distance d apart. Let A and B be two points at distances r_1 and r_2 from the charge q_1 where the net electric potential due to the two charges is zero as shown in the figure. Then



(A) $r_1=\left(\frac{q_1}{q_1+q_2}\right)d;\ r_2=\left(\frac{q_2}{q_1+q_2}\right)d$ (B) $r_1=\left(\frac{q_2}{q_1+q_2}\right)d;\ r_2=\left(\frac{q_2}{q_1+q_2}\right)d$

(C) $r_1=\left(\frac{q_1}{q_1+q_2}\right)d;\ r_2=\left(\frac{q_2}{q_1-q_2}\right)d$ (D) $r_1=\left(\frac{q_1}{q_1-q_2}\right)d;\ r_2=\left(\frac{q_1}{q_1+q_2}\right)d$

Ans (C)

For the potential at A to be zero,

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1}+\frac{1}{4\pi\varepsilon_0}\frac{(-q_2)}{(d-r_1)}=0$$

i.e., $\frac{q_1}{r_1}=\frac{q_2}{d-r_1}\therefore r_1=\left(\frac{q_1}{q_1+q_2}\right)d$

For the potential at B to be zero.

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_2}+\frac{1}{4\pi\varepsilon_0}\frac{(-q_2)}{(r_2-d)}=0$$

i.e., $\frac{q_1}{r_2}=\frac{q_2}{r_2-d}\therefore r_2=\left(\frac{q_1}{q_1-q_2}\right)d$

11. A metallic sphere of radius R_1 is charged to a potential V. If it is enclosed by a spherical conducting shell of radius R_2 and connected to it, its new potential will be

(A) zero (B) $V\left(\frac{R_1}{R_2}\right)$ (C) $V\left(\frac{R_2}{R_1}\right)$ (D) $V\left(\frac{R_1}{R_1+R_2}\right)$

Ans (B)

If Q is the charge on the metallic sphere, its potential is given by $V=\frac{1}{4\pi\varepsilon_0}\frac{Q}{R_1}$. When it is surrounded by a spherical conducting shell of radius R_2 and connected to it, the charge on the sphere is completely transferred to the spherical shell. The potential of the spherical shell is given by $V'=\frac{1}{4\pi\varepsilon_0}\frac{Q}{R_2}$. All points inside the spherical shell will be at this potential. Hence, the new potential of the metallic sphere will also be V′.

$\therefore \frac{V'}{V}=\frac{R_1}{R_2}$ $\qquad \therefore V'=V\left(\frac{R_1}{R_2}\right)$

12. Three concentric metallic spherical shells A, B and C of radii a, b and c with a < b < c, have surface charge densities σ, –σ and σ respectively. The potential of the spherical shell A is

(A) $\frac{\sigma}{\varepsilon_0}(a-b+c)$ (B) $\frac{\sigma}{\varepsilon_0}(a+b+c)$ (C) $\frac{\sigma}{\varepsilon_0}(b-a+c)$ (D) $\frac{\sigma}{\varepsilon_0}(c-b+a)$

Ans (A)

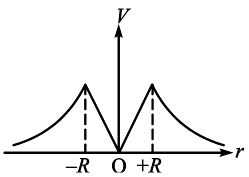
The potential at any point inside a spherical shell is the same as that on its surface. Since the shell A is enclosed within the shells B and C, its potential is the sum of its own potential and the potentials due to B and C.

Hence $V_A=\frac{1}{4\pi\varepsilon_0}\frac{Q_A}{a}+\frac{1}{4\pi\varepsilon_0}\frac{Q_B}{b}+\frac{1}{4\pi\varepsilon_0}\frac{Q_C}{c}$

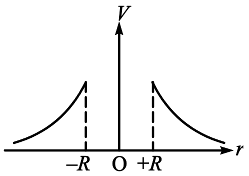
$$=\frac{1}{4\pi\varepsilon_0}\left[\frac{\sigma(4\pi a^2)}{a}-\frac{\sigma(4\pi b^2)}{b}+\frac{\sigma(4\pi c^2)}{c}\right]$$

$$=\frac{\sigma}{\varepsilon_0}(a-b+c)$$

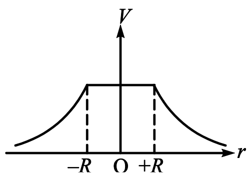
13. Of the following graphs the variation of electric potential (V) due to a hollow charged conducting sphere of radius R with distance r from its centre is represented in



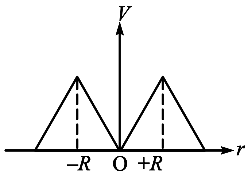
(A)



(B)



(C)



(D)

Ans (C)

The potential inside a charged hollow conducting sphere is a constant which is equal to the potential on the surface. The potential outside the charged sphere varies inversely as the distance from the centre of the sphere.

14. Two metal spheres A and B of radii 1 mm and 2 mm are initially charged with 20 nC and 10 nC respectively. They are brought in contact and then moved back to their initial positions. The common potential is

(A) 112.5 kV (B) 180 kV (C) 45 kV (D) 90 kV

Ans (D)

When two charged metal bodies (spheres) are brought in contact, charge flows from one to the other until the two conductors acquire the same potential.

Since, $V_1 = V_2, \frac{1}{4\pi\varepsilon_0}\frac{q_1'}{r_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_2'}{r_2}$

where q_1' and q_2' are charges on the metal spheres after distribution of charges.

$$\therefore \frac{q_1'}{q_2'} = \frac{r_1}{r_2} = \frac{1\times10^{-3}}{2\times10^{-3}} = \frac{1}{2}$$

$$\therefore q_2' = 2q_1'$$

$$q_1' + q_2' = q_1 + q_2 = 20\text{ nC} + 10\text{ nC}$$

$$q_1' + 2q_1' = 30\text{nC} \Rightarrow q_1' = 10\text{nC},\ q_2' = 20\text{ nC}$$

$$V_1' = \frac{1}{4\pi\varepsilon_0}\frac{q'}{r_1} = 9\times10^9\frac{10\times10^{-9}}{1\times10^{-3}} = 90\text{ kV}$$

V_1' is also 90 kV. Thus the correct choice is (D)

15. A small metal sphere is attached to a wooden handle. Holding the wooden handle the metal sphere is introduced into the space between two oppositely charged metal plate of a capacitor. Then

(A) The metal spheres acquires a net positive charge when held closer to the + ve plate and retains when brought out the region.

(B) The metal acquires a net negative charge when held closer to the + ve plate and retains when brought out the region.

(C) The two hemispherical surfaces of the metal sphere will have been oppositely charged when placed between the metal plates but no net charge on being taken out.

(D) The sphere will have no net charge when placed in between the plates but acquires a net charge on being taken out of the electric field.

Ans (C)

Due to induction, the surface of the conducting sphere closer to the positive plate becomes negatively charged while the opposite hemisphere acquires positive charged. However the net charge on the sphere is zero both when put in between the plates or outside the two plates.

16. A parallel plate air capacitor has a capacitance of 1.3 pF. The separation between the plates is doubled and wax fills the space between them. The new capacitance is 2.6 pF. The dielectric constant of wax used is

(A) 3.5 (B) 7 (C) 4 (D) 5

Ans (C)

The situations arising in the problem is introduction of a dielectric. On introducing a dielectric of relative permittivity ε_r (or dielectric constant K), C increases.

$$C \propto K$$

The capacitance C_1 of the parallel plate capacitor of area of cross-section A and separation distance d is, $C_1 = \frac{\varepsilon_0 A}{d}$.

If the separation distance is doubled and the space is filled by wax, the new capacitance is $C_2 = \frac{\varepsilon_0 KA}{2d}$ where K is the dielectric constant of wax.

So $\frac{C_2}{C_1} = \frac{K}{2}$ or $K = 2\left(\frac{C_2}{C_1}\right)$

i.e., $K = 2\left[\frac{2.6\text{ pF}}{1.3\text{ pF}}\right]$ i.e., K = 4.

17. When a metal plate is introduced between the plates of a parallel plate capacitor its capacitance increases to 4.5 times the initial value. If d is the separation between the two plates of the capacitor, the thickness of the metal plate introduced is

(A) d/3 (B) 5d/9 (C) 7d/9 (D) d

Ans (C)

Initial capacitance $C = \frac{\varepsilon_0 A}{d}$.

When a metal plate of thickness t is introduced, the new capacitance $C' = \frac{\varepsilon_0 A}{(d-t)}$.

Given $C' = 4.5\,C \Rightarrow \frac{\varepsilon_0 A}{(d-t)} = 4.5\frac{\varepsilon_0 A}{d}$ Solving, we get $t = \frac{7d}{9}$

18. A capacitor of capacitance C is charged to a potential V and then disconnected from the battery. The air in between the plates of the capacitor is replaced by a dielectric constant K. The fractional decrease in the energy of the capacitor is

(A) $\frac{1}{K}$ (B) K (C) $1-\frac{1}{K}$ (D) $\frac{1}{K^2}$

Ans (C)

On introducing a dielectric slab between the plates of a capacitor which is already charged Q remains unaltered while V and C change. Thus, expressions containing both V and C should be avoided namely $\left(U = \frac{1}{2}CV^2\right)$.

Before the dielectric is introduced, Energy stored, $U_i = \frac{1}{2}\cdot\frac{Q^2}{C_{air}}$

After the introduction of the dielectric, with the battery disconnected,

Energy stored, $U_f = \frac{1}{2}\cdot\frac{Q^2}{C_{diel}} = \frac{1}{2}\frac{Q^2}{KC_{air}}$. Fractional decrease in energy

$$= \frac{U_i - U_f}{U_i} = 1 - \frac{U_f}{U_i} = 1 - \frac{1}{K}.$$

Aliter

$$U = \frac{1}{2}QV$$

$$\frac{U_i - U_f}{U_i} = \frac{\frac{1}{2}QV_i - \frac{1}{2}QV_f}{\frac{1}{2}QV_i} = \frac{V_i - V_f}{V_i}$$

But $V_f = \frac{V_i}{K}$ $\therefore \frac{U_f - U_f}{U_i} = \frac{V_i - (V_i/K)}{V_i} = 1 - \frac{1}{K}$

19. Two parallel plate capacitors of capacitance C and 2 C are connected in parallel and charged to a potential difference V. The battery is then disconnected and the space between the plates of capacitance C is completely filled with a material of dielectric constant K. The potential difference across the capacitors now becomes

(A) $\frac{V}{K+1}$ (B) $\frac{2V}{K+2}$ (C) $\frac{3V}{K+2}$ (D) $\frac{3V}{K+3}$

Ans (C)

When the capacitors are in parallel the pd across both capacitors are equal. On introducing a dielectric (dielectric constant K) the capacitance of the capacitor increases to K times.

Initial charge on the system is $Q = CV + (2C)V = 3CV$. On introducing a dielectric slab into the smaller (first) capacitor its new capacitance is KC.

Thus, $C_{eff} = KC + 2C = (+2)C$

Q remains constant.

$$Q_{in} = Q_{fin} \quad ; \quad 3CV = C_{eff}V_{eff} \quad ; \quad 3CV = (K+2)C\,V_{eff} \quad ; \quad \therefore V_{eff} = \frac{3V}{K+2}$$

Aliter

$$V_{eff} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{CV + 2CV}{(KC + 2C)} \; ; \quad V_{eff} = \frac{3V}{K+2}$$

20. A parallel plate air capacitor is charged to a potential difference V. After disconnecting the battery, the distance between the plates of the capacitor is increased using an insulating handle. As a result, the potential difference between the plates,

(A) does not change (B) becomes zero (C) increases (D) decreases

Ans (C)

$c = \frac{\varepsilon_0 A}{d}$. On increasing d, c decreases. In the given problem, V is fixed. Thus in the expression $V = \frac{Q}{C}$, Q remain unaltered and C decreases. Thus, V increases.

21. When a capacitor remains connected to a battery, a dielectric slab is introduced between the plates. Then,

(A) potential difference between the plates increases

(B) energy stored in the capacitor increases

(C) electric field between the plates decreases

(D) charge on the plates decreases

Ans (B)

When a dielectric slab is introduced with the battery still connected, we know that V remains constant. $V_{air} = V_{diel} =$ constant.

$E_{air} \times d = E_{diel} \times d$

where d = separation between the plates of the capacitor.

$\therefore E_{air} = E_{diel}$

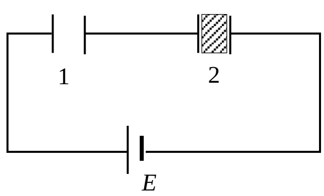
From this it is clear that charges (A) and (C) are wrong.

$$\frac{U_i}{U_f} = \frac{(1/2)C_{air}V^2}{(1/2)C_{diel}V^2} = \frac{C_{air}}{C_{die}} = \frac{1}{K}$$

$\therefore U_f = KU_i$. K being always > 1, $U_f > i_i$ and hence the choice (B).

Also $U = \frac{1}{2}QV$ since $U_f > U_i$ and V is constant $Q_f > Q_i$ and choice (D) is also wrong.

22. Two identical capacitors 1 and 2 are connected in series to a battery as shown in figure. Capacitor 2 contains a dielectric slab of dielectric constant K as shown. If Q_1 is the charge on each capacitor before removing the slab and Q_2 is the charge on each capacitor after removing the slab, then the correct relation between Q_1 and Q_2.



(A) $\frac{Q_1}{Q_2} = \frac{K}{K+1}$ (B) $\frac{Q_1}{Q_2} = \frac{K+1}{K}$ (C) $\frac{Q_1}{Q_2} = \frac{2K}{K+1}$ (D) $\frac{Q_1}{Q_2} = \frac{K+1}{2K}$

Ans (C)

Since the two capacitors are in series both have equal charges. Let Q_1 be the charge on the system.

Then charge on the system is

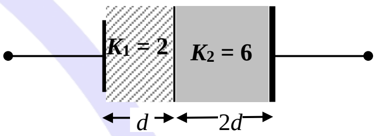
$$Q_1=\left(\frac{C\times KC}{C+KC}\right)V_1=\left(\frac{K}{K+1}\right)CV_1 \quad \therefore V_1=\frac{Q_1(K+1)}{KC} \qquad \ldots(1)$$

On removing the dielectric slab the charge on the system is

$$Q_2=\left(\frac{C\times C}{C+C}\right)V_2=\frac{CV_2}{2} \qquad \therefore V_2=\frac{2Q_2}{C} \qquad \ldots(2)$$

The battery being the same $V_1=V_2$ from Eqs. (1) and (2) we get $\dfrac{Q_1}{Q_2}=\dfrac{2K}{K+1}$

23. A parallel plate capacitor has two layers of dielectric as shown in the figure. This capacitor is connected across a battery. The ratio of potential difference across the dielectric layers (order K_1 and K_2) is



(A) 2/3 (B) 3/2 (C) 4 (D) 1/4

Ans (B)

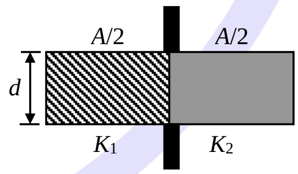
We have, $C=\dfrac{\varepsilon_0\varepsilon_r A}{d}$ $\quad C_1=\dfrac{2\varepsilon_0 A}{d}$ $\quad C_2=\dfrac{6\varepsilon_0 A}{2d}$

Thus, since the capacitors are in series the charge q on each capacitor is the same.

$V_1=\dfrac{q}{C_1}$ and $V_2=\dfrac{q}{C_2}$

$$\therefore \frac{V_1}{V_2}=\frac{C_2}{C_1}=\frac{6\varepsilon_0 A}{2d}\times\frac{d}{2\varepsilon_0 A} \qquad \therefore \frac{V_1}{V_2}=\frac{3}{2}$$

24. A parallel plate capacitor of area A is filled with two dielectrics of dielectric constants K_1 and K_2 as shown in figure. The equivalent capacitance is



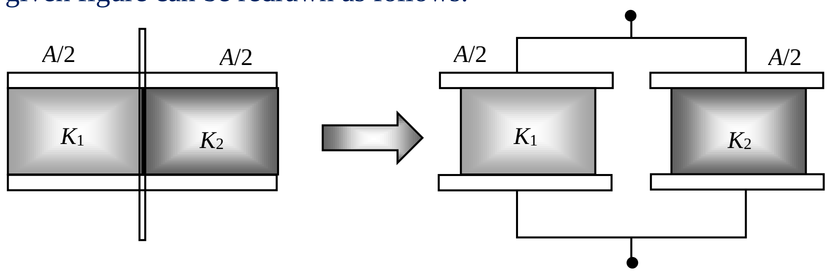
(A) $C=\dfrac{\varepsilon_0 A}{d}\left(\dfrac{K_1K_2}{K_1+K_2}\right)$ (B) $C=\dfrac{\varepsilon_0 A}{d}(K_1+K_2)$

(C) $C=\dfrac{\varepsilon_0 A}{d}\left(\dfrac{K_1+K_2}{2}\right)$ (D) $C=\dfrac{\varepsilon_0 A}{d}\left(\dfrac{K_1}{2}\right)$

Ans (C)

When two dielectric slabs are placed as shown in the figure, we can imagine a metal plate of negligible thickness separating the two dielectrics. Then, the system is equidistant to two capacitors C_1 and C_2 in series.

The given figure can be redrawn as follows.



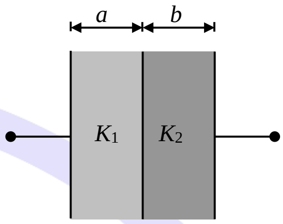
The capacitor system with two dielectric slabs placed side by side as shown is equivalent to two capacitors of capacitances C_1 and C_2 in parallel.

Thus, the effective capacitance $C=C_1+C_2$.

But, $C_1 = \dfrac{\varepsilon_0 K_1 (A/2)}{d}$ and $C_2 = \dfrac{\varepsilon_0 K_2 (A/2)}{d}$

$$C = \left[\frac{\varepsilon_0 (A/2)}{d} K_1\right] + \left[\frac{\varepsilon_0 (A/2)}{d} K_2\right] \text{ or } C = \frac{\varepsilon_0 A}{d}\left[\frac{K_1 + K_2}{2}\right].$$

25. A parallel plate capacitor has two layers of dielectrics as shown in the figure. Then the ratio of potential differences across the dielectric layers when connected to a battery is



(A) $\dfrac{K_1}{K_2}$ (B) $\dfrac{K_1 a}{K_2 b}$

(C) $\dfrac{K_2 b}{K_1 a}$ (D) $\dfrac{K_2 a}{K_1 b}$

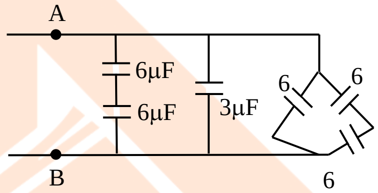
Ans (D)

The arrangement is equivalent to two capacitors in series.

$\therefore$ Ratio of potential differences = inverse ratio of capacitances

i.e., $V_1 : V_2 = C_2 : C_1 = \dfrac{\varepsilon_0 K_2 A}{b} : \dfrac{\varepsilon_0 K_1 A}{a} \Rightarrow \dfrac{V_1}{V_2} = \dfrac{K_2 a}{K_1 b}$

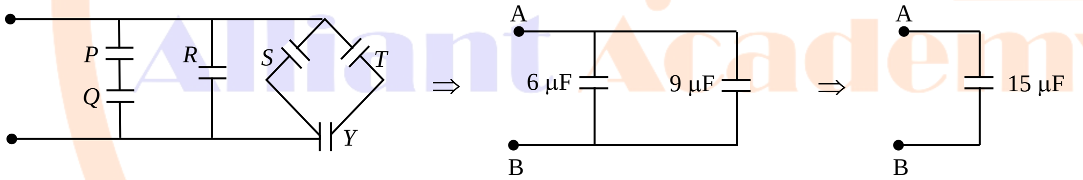
26. The equivalent capacitance of the given circuit is



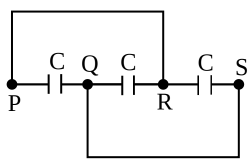
(A) $\dfrac{18}{5}\mu F$ (B) $\dfrac{5}{18}\mu F$

(C) 15 μF (D) $\dfrac{1}{15}\mu F$

Ans (C)



27. Three capacitors, each of capacitance C = 3 μF, are connected as shown in figure. The equivalent capacitance between points P and S is



(A) 1 μF

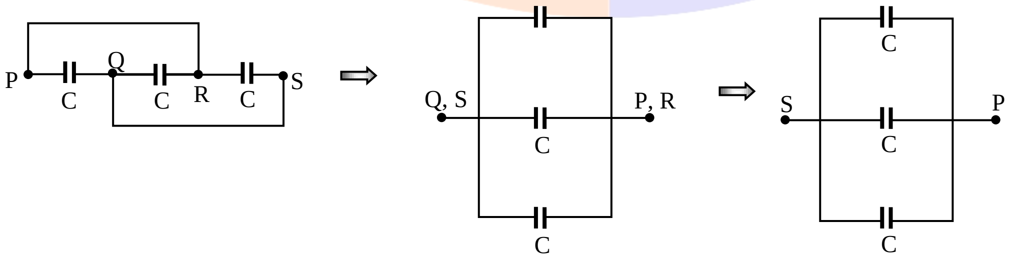
(B) 3 μF

(C) 6 μF

(D) 9 μF

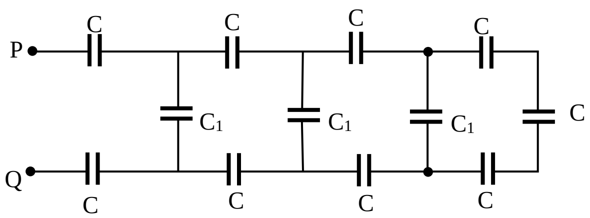
Ans (D)

The given circuit can be redrawn as shown.



So the capacitance across P and S is C + C + C = 3 C = 3 (3 μF) = 9 μF

28. In the network shown, C_1 = 6 μF and C = 9 μF. The equivalent capacitance between points P and Q is



(A) 3 μF

(B) 6 μF

(C) 9 μF
(D) 12 μF

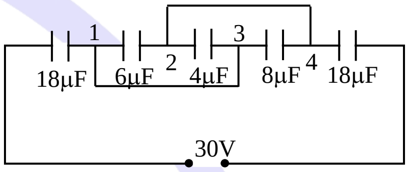
Ans (A)

The last three capacitors on the right, each of capacitance C = 9 μF, are in series, and are equivalent to a capacitance C′ given by $C' = \frac{c}{n} = \frac{9}{3} = 3\mu F$.

Since C′ is in parallel with C_1, the equivalent capacitance of the last part of the network is $C'' = C' + C_1 = 3 + 6 = 9$ μF.

Continuing this process of calculation towards the left, we notice that we are finally left with the combination whose equivalent capacitance is 3 μF.

29. Five capacitors are connected to each other as shown. What is the potential drop and charge across 4 μF capacitor?



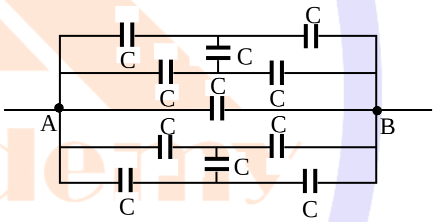
(A) 3 V, 10 μC (B) 10 V, 30 μC
(C) 3 V, 20 μC (D) 10 V, 40 μC

Ans (D)

Capacitors 6 μF, 4 μF and 8 μF are in parallel and their effective capacitance 6 + 4 + 8 = 18 μC. Across the power supply we have three capacitors 18 μF each in series. The voltage is divides equally across the three 18 μF. Hence, voltage across each unit in series is $\left(\frac{30}{3}\right) = 10\,V$

∴ charge an 4 μF = 10 V × 4 μF = 40 μC

30. The effective capacitance between A and B is



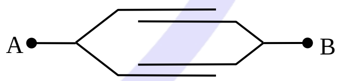
(A) C (B) C/2
(C) 3C (D) 4C

Ans (C)

The capacitor network enclosed by the dotted loop is a balanced Wheatstone net of equivalent capacitance C.

∴ $C_{eff} = C + C + C = 3\,C$

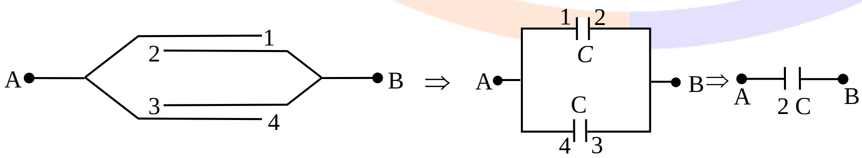
31. The equivalent capacitance between A and B in the given diagram is



(A) $2\frac{\varepsilon_0 A}{d}$ (B) $\frac{\varepsilon_0 A}{d}$
(C) $\frac{\varepsilon_0 A}{2d}$ (D) $\frac{3\varepsilon_0 A}{d}$

Ans (A)

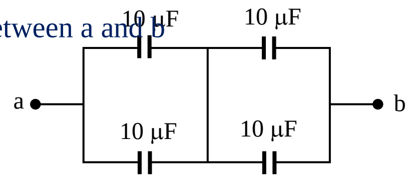
The arrangement can be analysed as shown in the given figure.



$C_{12} = C_{43} = C$

$C_p = C + C = 2C = 2\frac{\varepsilon_0 A}{d}$

32. In the circuit shown in figure, the equivalent capacitance between a and b is



(A) 20 μF (B) 40 μF
(C) 10 μF (D) 5 μF

Ans (C)

The circuit given in the figure can be redrawn as

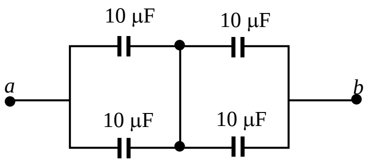


Fig 1

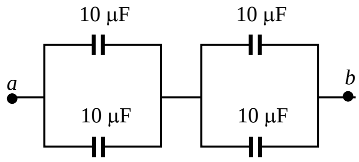


Fig 2

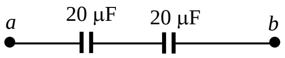


Fig 3

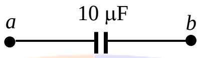
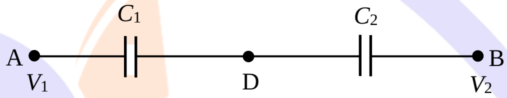


Fig 4

33. Figure shows a part of an electrical circuit with two capacitors of capacitances C_1 and C_2. The points A and B are at potentials V_1 and V_2 respectively. The potential at the point D will be

(A) $\frac{1}{2}(V_1+V_2)$ (B) $\frac{C_1V_1+C_2V_2}{C_1+C_2}$

(C) $\frac{C_1V_2+C_2V_1}{C_1+C_2}$ (D) $\frac{C_2V_1-C_1V_2}{C_1+C_2}$



Ans (B)

Let q be the charge on each capacitor. If V is the potential at point D, then,

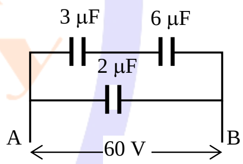
$V_1 - V = q/C_1$ ... (1)

and $V - V_2 = q/C_2$ ... (2)

Dividing Eqn. (1) by Eqn. (2), we get

$\frac{V_1-V}{V-V_2}=\frac{C_2}{C_1}$ or $V=\frac{(C_1V_1+C_2V_2)_1}{(C_1+C_2)}$

34. In the circuit shown, the potential difference across the 3 μF capacitor is V and the equivalent capacitance between A and B is C_{AB}. Then



(A) C_{AB} = 4 μF, V = 40 V (B) C_{AB} = 8 μF, V = 80 V

(C) C_{AB} = 8 μF, V = 40 V (D) C_{AB} = 4 μF, V = 80 V

Ans (A)

3 μF and 6 μF are in series and their equivalent capacitor is in parallel with 2 μF.

$\therefore C_{AB}=\frac{3\times6}{3+6}+2=4\mu F$; Potential difference across 3 μF is $V=\frac{60}{3}\times2=40\,V$

35. A capacitor has a capacitance C_1 = 1.0 μF. It can withstand a maximum voltage of V_1 = 6.0 kV. A second capacitor of capacitance C_2 = 2.0 μF can withstand a maximum voltage of V_2 = 4.0 kV. If the capacitors are connected in series, the combination can withstand a maximum voltage of

(A) 10 kV (B) 9 kV (C) 8 kV (D) 6 kV

Ans (B)

The maximum charge the first capacitor can hold is $Q_1 = C_1 V_1 = 1 \times 10^{-6} \times 6000 = 6 \times 10^{-3}$ C

The maximum charge that the second capacitor can hold is $Q_2 = C_2V_2 = 2 \times 10^{-6} \times 4000 = 8 \times 10^{-3}$ C

We know that in a series combination, the charge on each capacitor is the same. Now the first capacitor cannot hold a charge of 8×10^{-3} C; it can hold a maximum charge of 6×10^{-3} C. Therefore, the charge on the second capacitor must also be 6×10^{-3} C. Hence, the voltage across the second capacitor is $V_2=\frac{6\times10^{-3}C}{2\times10^{-6}F}=3000$ volt = 3 kV.

Thus, the maximum voltage the system can withstand = $V_1 + V_2$ = 6 kV + 3 kV = 9 kV.

36. A parallel plate capacitor of capacitance C is charged to a potential difference V by connecting it to a battery. Another capacitor of capacitance 2C is similarly charged to a potential difference 2V. The charging battery is then disconnected and the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of the other. The final energy of the configuration is

(A) zero (B) $\frac{3}{2}CV^2$ (C) $\frac{25}{6}CV^2$ (D) $\frac{9}{2}CV^2$

Ans (B)

$Q_1 = CV$ and $Q_2 = (2C) \times (2V) = 4CV$. Since the capacitors are connected in parallel such that the plates of opposite polarities are connected together, the common potential is

$$V' = \frac{Q_2 - Q_1}{C_1 + C_2} = \frac{4CV - CV}{C + 2C} = V$$

Equivalent capacitance $C' = C + 2C = 3C$. Therefore, the final energy of the configuration is

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

37. The additional energy required to increase the charge from 5 μC to 10 μC of a 20 pF capacitor is

(A) 2.5 J (B) 0.625 J (C) 1.875 J (D) –0.625 J

Ans (C)

The potential energy of 20 pF when its charge is 5 μC is found using $U = \frac{1}{2}\frac{Q^2}{C}$

i.e., $$U_1 = \left(\frac{1}{2}\right)\frac{(5\ \mu C)^2}{(20\ pF)} = \frac{1}{2}\frac{(5 \times 10^{-6} C)^2}{(20 \times 10^{-12} F)} = 0.625\ J.$$

The potential energy of 20 pF capacitor when the charge is 10 μC is

$$U_2 = \left(\frac{1}{2}\right)\frac{(10\ \mu C)^2}{(20\ pF)} = \frac{1}{2}\left[\frac{(10 \times 10^{-6} C)^2}{(20 \times 10^{-12} F)}\right] = 2.5\ J.$$

So the additional energy required is $U_2 - U_1 = 2.5\ J - 0.625\ J = 1.875\ J$

38. Two capacitors C_1 and C_2 are charged to potentials 300 V and 100 V and then they are connected in parallel. The potential difference of the parallel combination is 250 V. The ratio of C_2 to C_1 is

(A) $C_2 : C_1 = 1 : 3$ (B) $C_2 : C_1 = 3 : 1$ (C) $C_2 : C_1 = 1 : \sqrt{3}$ (D) $C_2 : C_1 = \sqrt{3} : 1$

Ans (A)

If capacitors C_1 and C_2 are charged to potentials V_1 and V_2, and then they are connected in parallel, the common potential V_{com} is given by $V_{com} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$

Dividing the numerator and the denominator of the RHS by C_1 we get $V_{com} = \frac{V_1 + (C_2/C_1)V_2}{1 + (C_2/C_1)}$

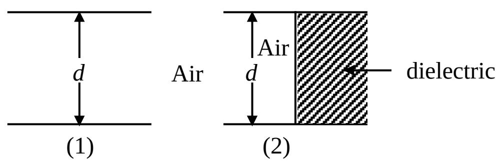
Letting $V_{comm} = 250$ V, $V_1 = 300$ V and $V_2 = 100$ V

$$250\ V = \frac{(300\ V) + (C_2/C_1)(100\ V)}{1 + (C_2/C_1)}$$; Simplifying for $\frac{C_2}{C_1}$, $\frac{C_2}{C_1} = \frac{1}{3}$ or $C_2 : C_1 = 1:3$

39. A parallel plate air filled capacitor has a capacitance of 2 μF. It is half filled with a dielectric with K = 3. Its capacitance is,

(A) 4 μF (B) 3 μF

(C) 1.5 μF (D) 0.5 μF



Ans (A)

If A is the area of each plate, the capacitance of the air-filled capacitor shown in figure (1) is

$C_0 = \frac{\varepsilon_0 A}{d}$ where $C_0 = 2$ μF (given).

The capacitance of air capacitor in figure (2) is $C_1 = \frac{\varepsilon_0 A/2}{d} = \frac{\varepsilon_0 A}{2d} = \frac{C_0}{2}$

The capacitance of dielectric filled capacitor in figure (2) is $C_2 = \frac{k\varepsilon_0 A/2}{d} = \frac{k\varepsilon_0 A}{2d} = \frac{kC_0}{2}$

Since C_1 and C_2 are in parallel, the capacitance C of the capacitor shown in figure (2) is

$$C = C_1 + C_2 = \frac{C_0}{2} + \frac{KC_0}{2} = \frac{C_0}{2}(1+K) = \frac{2\mu F}{2}(1+3) = 4\ \mu F.$$

40. A capacitor has a capacitance 2 μF. It is initially charged to a potential difference of 5 V, and the battery is disconnected. If a dielectric slab of dielectric constant K = 6 is inserted completely between the plates what is the final electrostatic potential energy?

(A) 4.17 μJ (B) 3.17 μJ (C) 2.17 μJ (D) 1.17 μJ

Ans (A)

The initial charge on the capacitor will be $Q_0 = C_0V_0$ = (2 μF) (5 V) = 10 μC.

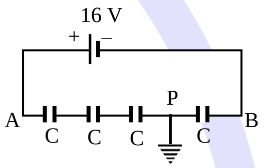
After the dielectric slab is introduced between the plates, the capacitance becomes K times the original value.

∴ The new capacitance is, $C = C_0K$ = (2 μF) 6 = 12 μF

Since, the battery is disconnected, the charge on the capacitor plates will remain the same.

∴ Electrostatic potential energy is $U = \frac{1}{2}\frac{Q_0^2}{C} = \frac{1}{2}\frac{(10\ \mu C)^2}{(12\ \mu F)} = 4.17\ \mu J$

41. Four identical capacitors are connected in series with a battery of 16 V between A and B as shown in figure. If the point P is earthed, then the potential at A and B is



(A) 16 V, 0 (B) 12 V, –12 V

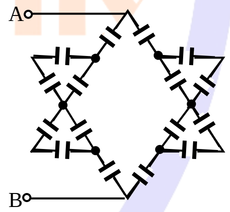
(C) 12 V, –4 V (D) 8 V, –8 V

Ans (C)

The potential difference across each capacitor is 4 V. Since, there are three capacitors between the point A and the ground, the potential difference between A and ground is = 12 V, the potential difference between ground and the point B is 0 – 4 = –4 V

∴ The potential at A is 12 V and that at B is –4 V

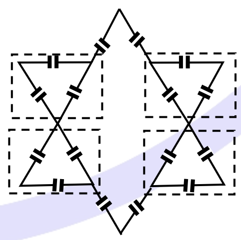
42. In the figure shown, each capacitor is of capacitance 4 μF. The equivalent capacitance between A and B is



(A) 1 μF (B) 2.4 μF

(C) 2 μF (D) 4 μF

Ans (B)

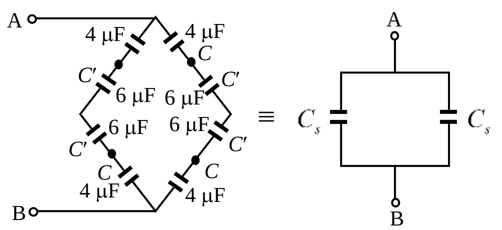


The given circuit can be rewritten as shown in the figure.

Let C′ be the capacitance of each part of the network covered under the dotted lines $C' = C + \frac{C}{2} = \frac{3}{2}C$

$C = \frac{3}{2} \times 4\ \mu F = 6\ \mu F$

The circuit can be rewritten as shown in the figure



$$\frac{1}{C_S} = \frac{1}{4} + \frac{1}{4} + \frac{1}{6} + \frac{1}{6}$$

$$C_S = \frac{6}{5}\ \mu F$$

$$\frac{1}{C_{AB}} = 2\frac{1}{C_s} = 2 \times \frac{6}{5}\ \mu F \Rightarrow C_{AB} = 2.4\ \mu F$$

43. Nine metallic plates are arranged so as to get the maximum capacitance. The separation between the adjacent plates is such that the maximum value of capacitance is 8 μF. The capacitance of capacitor formed by the adjacent plates is

(A) 2 μF (B) 4 μF (C) 1 μF (D) 0.5 μF

Ans (C)

In order to get maximum capacitance, the capacitors must be connected in parallel. For this, the alternate plates must be connected together. If n plates are connected in the above said manner, then the effective capacitance becomes (n – 1) C, where C is the capacitance between the adjacent plates.

In the given problem, nine plates are connected to get maximum capacitance. Therefore, the effective capacitance C′ = (n – 1) C = 8C.

But, C′ = 8 μF ⇒ C = 1 μF.

44. Five identical capacitors connected in series have a equivalent capacitance of 4 μF. The total energy stored in them when they are connected in parallel and charged to 400 V is

(A) 10 J (B) 8 J (C) 4 J (D) 21 J

Ans (B)

The equivalent capacitance of the series combination C_S = C/5 = 4 μF where C is the capacitance of each capacitor. When these capacitors are connected in parallel, the effective capacitance becomes C_p = 5 × C = 100 μF. The energy stored by the combination,

$$E = \frac{1}{2} C_p V^2 = \frac{1}{2} \times 100\times10^{-6} \times (400)^2 = 8\text{ J}$$

45. n identical charged water drops, combine to form a big single drop. If energy of each drop is E, then the energy of the combined drop is

(A) n^2E (B) $n^{\frac{1}{3}}E$ (C) $n^{\frac{5}{3}}E$ (D) nE

Ans (C)

The energy of a charged drop $E = \frac{1}{2}\frac{q^2}{C}$ where C is the capacitance of each drop. Let C' be the capacitance of the big drop. The energy stored in the big drop $E' = \frac{1}{2}\frac{(nq)^2}{C'}$.

$$\frac{E'}{E} = n^2 \times \frac{C}{C'} = n^2 \times \frac{4\pi\varepsilon_0 \times r}{4\pi\varepsilon_0 \times R} \Rightarrow \frac{E'}{E} = n^2 \times \frac{r}{R}$$

Volume of the big drop = n × volume of one drop

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

$$\therefore \frac{E'}{E} = n^2 \times \frac{r}{n^{1/3} r} \Rightarrow E' = n^{5/3} E$$

46. Two electrons each moving with a velocity of 10^6 ms^{-1} are released towards each other. The distance of closest approach will be

Solution

$$2\left[\frac{1}{2}mV^2\right] = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_0} = 9\times10^{-31}\times10^{12} = \frac{9\times10^9\times2.56\times10^{-38}}{r_0}$$

⇒ $r_0 = 2.56 \times 10^{-10}$ m

⇒ r_0 = 2.56 Å

47. Two point charges ± 3.2 × 10^{-19} C are at 2.4 Å and are situated in uniform electric field of 4 × 10^5 Vm^{-1}. The work done in rotating this dipole from stable equilibrium to unstable equilibrium is

Solution

For stable equilibrium, θ_1 = 0° and for unstable equilibrium, θ_2 = 180°

W = PE [cos θ_1 – cos θ_2]

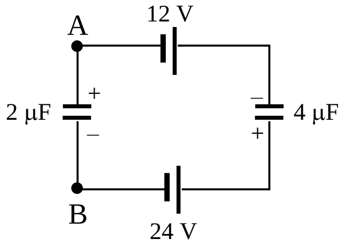
= 3.2 × 10^{-19} × 2.4 × 10^{-10} × 4× 10^5 [cos 0° – cos 180°]

= 2 × 3.2 × 2.4 × 4 × 10^{-24}

= 61.4 × 10^{-24} J

48. The potential difference between the points A and B is

Solution

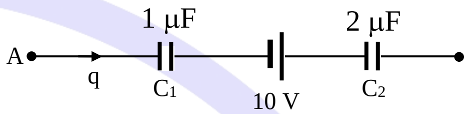


$$\frac{q}{4}+\frac{q}{2}=24-12$$

$$\frac{3q}{4}=12 \Rightarrow q=16\ \mu C$$

$$V_{AB}=\frac{q}{2}=\frac{16\times10^{-6}}{2\times10^{-6}}=8\ \text{Volt}$$

49. In the given circuit, if potential at 'A' is 10 V higher than at 'B' then potential and charge of each capacitor are



Solution

According to KVL, $V_A-\frac{q}{1\times10^{-6}}+10-\frac{q}{2\times10^{-6}}-V_B=0$

$\Rightarrow\ 20=\frac{q}{10^{-6}}\left[1+\frac{1}{2}\right]\ \Rightarrow\ q=\frac{40}{3}\ \mu C$, charge on each capacitor.

$\therefore\ V_1=\frac{q}{C_1}=\frac{40}{3}$ volt

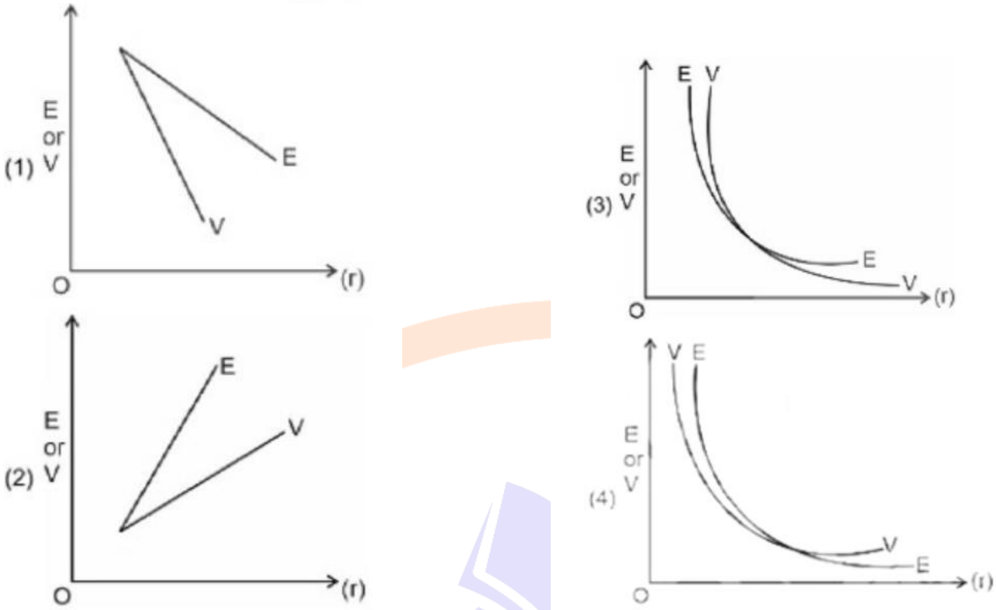
$V_2=\frac{q}{C_2}=\frac{20}{3}$ Volt

NCERT LINE BY LINE QUESTIONS

1. An electric point charge q = 6 μC is placed at origin of x - y Co-ordinate axis. Calculate electric potential due to the charge at point P(12m, 16m) in free space. [NCERT Pg. 54]

   (a) 1.2 kV (b) 2.3 kV (c) 3.7 kV (d) 2.7 kV

2. The comparative graph of potential and electric field due to a point charge at a distance r from it is best shown by graph. [NCERT Pg. 55)



3. A point charge $Q = 4\times10^{-7}C$ is placed at a point in free space. How much work is required to bring a charge 2nC from infinity to a point 9cm from charge Q ? [NCERT Pg. 55)

a) 3×10^{-4} J b) 8×10^{-5} J c) 2×10^{-5} J d) 5×10^{-5} J

4. Which among the following statements is an incorrect statement ? [NCERT Pg. 57)

(a) The electric dipole potential falls off, at large distance, as $1/r^1$

(b) The electric potential due to dipole in the equatorial position is zero

(c) The electric potential due to dipole has axial symmetry about dipole moment vector p

(d) Electric potential on dipole axis is maximum.

5. Two charges 6 nC and -4 nC are located 15 cm apart. At what point on line joining two charges is electric potential zero? [NCERT Pg. 58]

(a) 6 cm from 6 nC charge (b) 45 cm from 6 nC charge

(c) 38 cm from 6 nC charge (d) 9 cm from -4 nC charge

6. The incorrect statement regarding equipotential surface is [NCERT Pg. 60]

(a) Equipotential surface through a point is normal to electric field at that point

(b) An equipotential surface is a surface with a constant value of potential at all points on the surface

(c) Equipotential surfaces of a single point charge are concentric spherical surfaces centred at the charge

(d) For uniform electric field along x-axis, equipotential surfaces are planes parallel x - y plane

7. Work done by external agent in assembling three identical charges from infinity to given locations is [NCERT Pg. 62]

a) $\frac{5}{8\varepsilon_0}\frac{q^2}{r}$ b) $\left(\frac{5}{8\pi\varepsilon_0}\frac{q^2}{r}\right)$ c) $\frac{5}{2\pi\varepsilon_0}\frac{q^2}{r}$ d) $\frac{3q^2}{8\pi\varepsilon_0 r}$

8. Two point charges $7\,\mu C$ and $-2\,\mu C$ are placed at position (–9cm, 0) and (9cm, 0) respectively. How much work is required to separate two charges infinitely away from each other ? [NCERT Pg. 66]

a) 0.2 J b) 0.5 J c) 0.6 J d) 0.7 J

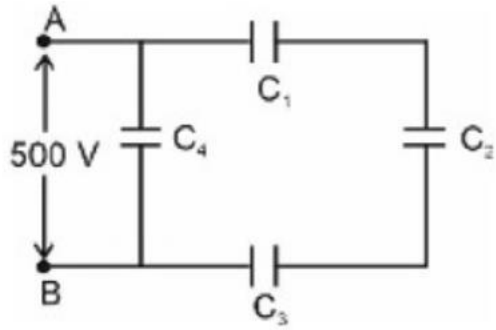
9. A dipole with dipole moment 310^{-9} C m is placed in external uniform field of E = $4\,10^{5}$ N C^{-1} . Calculate amount of work done by field in rotating the dipole from $\theta = 60°$ to 0°. (θ is angle between electric field E and dipole moment vector) [NCERT Pg. 66]
(a) 200 μ J (b) 600 μ J (c) 300 μ J (d) 90 μ J

10. When a conductor is placed inside uniform electric field. Then [NCERT Pg. 68]
(a) At the surface of conductor, electrostatic field is normal to the surface at every point.
(b) Inside the conductor, electrostatic field is zero.
(c) The electrostatic potential is constant throughout the volume of conductor and has the same value on its surface
(d) All of above are correct

11. Two conductors are separated by distance of 1 cm in air. The dielectric strength of air is about 310^{6} Vm^{-1}. What maximum safe potential difference can be applied across conductors? [NCERT Pg. 68]
(a) 3×10^{4} V (b) 6×10^{4} V (c) 3×10^{6} V (d) 1.5×10^{4} V

12. A slab of material having dielectric constant K = 1.5 has the same area as of a plates of parallel plate capacitor but has thickness $\frac{3}{4}$ of plate separation is introduced between the plates of the capacitor having capacitance C. On introducing slab, capacity becomes factor of [NCERT Pg. 78]
a) $\frac{12}{7}C$ b) $\frac{5}{7}C$ c) $\frac{6}{7}C$ d) $\frac{4}{3}C$

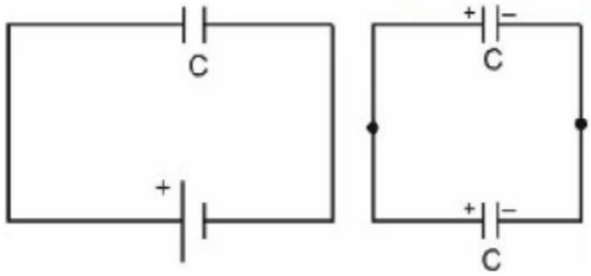
13. A network of four capacitors each 10 μF are connected as shown with 500V supply. Calculate the ratio of charges stored on C_4 and C_2 [NCERT Pg. 80]



(a) 1 (b) $\frac{1}{2}$ (c) $\frac{1}{3}$ (d) 3

14. A 900 pF parallel plate capacitor is charged by 100 V ideal battery. The space between the plates is 1cm. How much electrostatic energy is stored per unit volume of empty space of capacitor? [NCERT Pg. 82]
(a) $4.42\times10^{-4} Jm^{-3}$ (b) $8.85\times10^{-6} Jm^{-3}$
(c) $2.21\times10^{-7} Jm^{-3}$ (d) $6.2\times10^{-6} Jm^{-3}$

15. A 90 pF capacitor is charged by a 10 V battery. The capacitor is then disconnected from battery and connected to another charged 90 pF capacitor. Final electrostatic energy stored by the system is [NCERT Pg. 82]



(a) 225 pJ (b) 2.25 nJ (c) 4.5 pJ (d) 4.5 nJ

16. A parallel plate capacitor is charged by a battery. Now battery is removed and medium between the plates of the capacitor is filled with an insulating material of dielectric constant K, then [NCERT Pg. 85)

(a) Electric field due to charged plates induces a net dipole moment in the dielectric (insulating material)

(b) Net potential difference between the plates is reduced

(c) Capacitance C decreases from initial value C_o to (C_o/K)

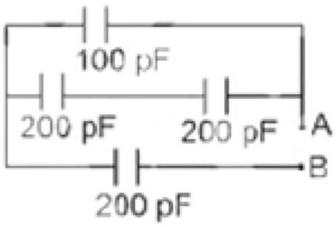
(d) Both (a) and (b) are correct

17. A parallel plate capacitor with each plate of area $6\times10^{-3}m^2$ has plate separation of 3 mm. A 3 mm thick mica sheet of dielectric constant K = 6 was inserted between the plates. If this capacitor is connected to 100 volt supply, what is charge on positive plate of capacitor? (NCERT Pg. 87]

(a) $1.92\times10^{-9}C$ (b) $1.06\times10^{-8}C$

(c) $4.2\times10^{-8}C$ (d) $4.36\times10^{-7}C$

18. Equivalent capacitance of the network across points A and B is [NCERT Pg. 90]



(a) 200pF (b) 150pF (c) 100 pF (d) 700 pF

19. A spherical capacitor consists of two concentric spherical conductors held in position by filling insulating material of dielectric constant 6. The inner sphere has radius of 10 cm and outer has 40 cm. The capacitance of spherical capacitor is [NCERT Pg. 91]

(a) 100 pF (b) 108 pF (c) 88.8 pF (d) 73.3 pF

20. A parallel plate capacitor is to be designed with a voltage rating of 2 kV, using a material of dielectric constant 3 and dielectric strength about 12 x 10^6 Vm^{-1}, for safety we should like the field never exceed 20% of dielectric strength. What minimum area of plate is required to have capacitance of 60 pF? [NCERT Pg. 91]

(a) $1.2\times10^{-6}m^2$ (b) $4.75\times10^{-4}m^2$ (c) $1.88\times10^{-3}m^2$ (d) $5.65\times10^{-3}m^2$

21. The electric potential inside a conducting sphere

(a) increases from centre to surface

(b) decreases from centre to surface

(c) remains constant from centre to surface

(d) is zero at every point inside

22. It becomes possible to define potential at a point in an electric field because electric field

(a) is a conservative field

(b) is a non-conservative field

(c) is a vector field
(d) obeys principle of superposition

23. Which of the following about potential at a point due to a given point charge is true ?
The potential at a point P due to a given point charge
(a) is a function of distance from the point charge.
(b) varies inversely as the square of distance from the point charge.
(c) is a vector quantity.
(d) is directly proportional to the square of distance from the point charge.

24. Which of the following quantities do not depend on the choice of zero potential or zero potential energy?
(a) Potential at a point
(b) Potential difference between two points
(c) Potential energy of a two-charge system
(d) None of these

25. A cube of a metal is given a positive charge Q. For this system, which of the following statements is true?
(a) Electric potential at the surface of the cube is zero
(b) Electric potential within the cube is zero
(c) Electric field is normal to the surface of the cube
(d) Electric field varies within the cube

26. A unit charge moves on an equipotential surface from a point A to point B, then
(a) $V_A - V_B = +$ ve (b) $V_A - V_B = 0$
(c) $V_A - V_B = -$ ve (d) it is stationary

27. The electric potential at a point on the equatorial line of an electric dipole is
(a) directly proportional to distance
(b) inversely proportional to distance
(c) inversely proportional to square of the distance
(d) None of these

28. The potential energy of a system of two charges is negative when
(a) both the charges are positive
(b) both the charges are negative
(c) one charge is positive and other is negative
(d) both the charges are separated by infinite distance

29. An electric dipole of moment $\vec{p}$ is placed normal to the lines of force of electric intensity , $\vec{E}$ then the work done in deflecting it through an angle of 180° is
(a) pE (b) $+2pE$ (c) $-2pE$ (d) zero

30. Which of the following about potential difference between any two points is true?
I. It depends only on the initial and final position.
II. It is the work done per unit positive charge in moving from one point to other.
III. It is more for a positive charge of two units as compared to a positive charge of one unit.
(a) I only (b) II only
(c) I and II (d) I, II and III

31. An electric dipole of moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. Then which of the following is/are correct?
I. The torque on the dipole is $\vec{p} \times \vec{E}$
II. The potential energy of the system is $\vec{p}.\vec{E}$

III. The resultant force on the dipole is zero.
(a) I, II and II (b) I and III

32. Match the entries of Column I and Column II

Column I	**Column II**
(A) Inside a conductor placed in an external electric field.	(1) Potential energy = 0
(B) At the centre of a dipole	(2) Electric field = 0
(C) Dipole in stable equilibrium	(3) Electric potential = 0
(D) Electric dipole perpendicular to uniform electric field.	(4) Torque = 0

(a) (A) → (2); (B) → (4); (C) → (3); (D) → (1)
(b) (A) → (2); (B) → (3); (C) → (4); (D) → (1)
(c) (A) → (2); (B) → (3); (C) → (1); (D) → (4)
(d) (A) → (1); (B) → (3); (C) → (4); (D) → (2)

33. If a unit positive charge is taken from one point to another over an equipotential surface, then
(a) work is done on the charge (b) work is done by the charge
(c) work done is constant (d) no work is done

34. On decreasing the distance between the plates of a parallel plate capacitor, its capacitance
(a) remains unaffected (b) decreases
(c) first increases then decreases. (d) increases

35. Energy is stored in a capacitor in the form of
(a) electrostatic energy (b) magnetic energy
(c) light energy (d) heat energy

36. If in a parallel plate capacitor, which is connected to a battery, we fill dielectrics in whole space of its plates, then which of the following increases?
(a) Q and V (b) V and E (c) E and C (d) Q and C

37. When air in a capacitor is replaced by a medium of dielectric constant *K*, the capacity
(a) decreases *K* times (b) increases *K* times
(c) increases K^2 times (d) remains constant

38. A conductor carries a certain charge. When it is connected to another uncharged conductor of finite capacity, then the energy of the combined system is
(a) more than that of the first conductor
(b) less than that of the first conductor
(c) equal to that of the first conductor
(d) uncertain

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Electrostatic Potential and Equipotential Surfaces

1. The electric potential inside a conducting sphere
(a) increases from centre to surface (b) decreases from centre to surface
(c) remains constant from centre to surface (d) is zero at every point inside

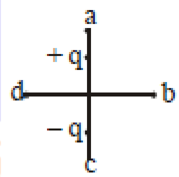
2. A unit charge moves on an equipotential surface from a point A to point B, then
(a) $V_A - V_B = +$ ve (b) $V_A - V_B = 0$ (c) $V_A - V_B = -$ ve (d) it is stationary

3. Consider a finite insulated, uncharged conductor placed near a finite positively charged conductor. The uncharged body must have a potential :
(a) less than the charged conductor and more than at infinity.
(b) more than the charged conductor and less than at infinity.
(c) more than the charged conductor and more than at infinity.
(d) less than the charged conductor and less than at infinity.

4. Two concentric spheres of radii R and r have similar charges with equal surface charge densities (σ). What is the electric potential at their common centre?
(a) σ / ε_0 (b) $\frac{\sigma}{\varepsilon_0}(R-r)$ (c) $\frac{\sigma}{\varepsilon_0}(R+r)$ (d) None of these

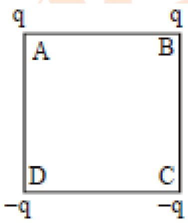
5. From a point charge, there is a fixed point A. At A, there is an electric field of 500 V/m and potential difference of 3000 V. Distance between point charge and A will be
(a) 6 m (b) 12 m (c) 16 m (d) 24 m

6. Four points a, b, c and d are set at equal distance from the centre of a dipole as shown in a figure. The electrostatic potential V_a, V_b, V_c, and V_d would satisfy the following relation:



(a) $V_a > V_b > V_c > V_d$ (b) $V_a > V_b = V_d > V_c$ (c) $V_a > V_c = V_b = V_d$ (d) $V_b = V_d > V_a > V_c$

7. Charges are placed on the vertices of a square as shown. Let $\bar{E}$ 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



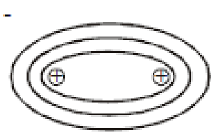
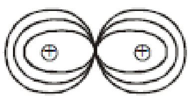
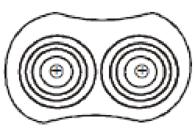
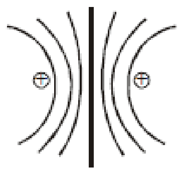
(a) $\bar{E}$ changes, *V* remains unchanged (b) $\bar{E}$ remains unchanged, *V* changes
(c) both $\bar{E}$ and *V* change (d) $\bar{E}$ and *V* remain unchanged

8. Two metal pieces having a potential difference of 800 V are 0.02 m apart horizontally. A particle of mass 1.96×10^{-15} kg is suspended in equilibrium between the plates. If e is the elementary charge, then charge on the particle is
(a) 8 (b) 6 (c) 0.1 (d) 3

9. The electric potential V (in Volt) varies with x (in metres) according to the relation $V = (5 + 4x^2)$. The force experienced by a negative charge of 2×10^{-6} C located at x = 0.5 m is
(a) 2×10^{-6} N (b) 4×10^{-6} N (c) 6×10^{-6} N (d) 8×10^{-6} N

10. The 1000 small droplets of water each of radius r and charge Q, make a big drop of spherical shape. The potential of big drop is how many times the potential of one small droplet?
(a) 1 (b) 10 (c) 100 (d) 1000

11. Which of the following figure shows the correct equipotential surfaces of a system of two positive charges?

(a) 
(b) 
(c) 
(d) 

12. Four charges $q_1 = 2 \times 10^{-8}$ C, $q_2 = -2 \times 10^{-8}$ C, $q_3 = -3 \times 10^{-8}$ C, and $q_4 = 6 \times 10^{-8}$ C are placed at four corners of a square of side $\sqrt{2}$ m. What is the potential at the centre of the square?
(a) 270 V (b) 300 V (c) Zero (d) 100 V

13. The electric potential at point A is 1V and at another point B is 5V. A charge 3 μC is released from B. What will be the kinetic energy of the charge as it passes through A?
(a) 8×10^{-6} J (b) 12×10^{-6} J (c) 12×10^{-9} J (d) 4×10^{-6} J

14. A thin spherical conducting shell of radius R has a charge q. Another charge Q is placed at the centre of the shell. The electrostatic potential at a point P, a distance R/2 from the centre of the shell is
(a) $\frac{2Q}{4\pi\varepsilon_0 R}$ (b) $\frac{2Q}{4\pi\varepsilon_0 R} - \frac{2Q}{4\pi\varepsilon_0 R}$ (c) $\frac{2Q}{4\pi\varepsilon_0 R} + \frac{q}{4\pi\varepsilon_0 R}$ (d) $\frac{(q+Q)^2}{4\pi\varepsilon_0 R}$

15. A large insulated sphere of radius r charged with Q units of electricity is placed in contact with a small insulated uncharged sphere of radius r' and is then separated. The charge on the smaller sphere will now be
(a) $\frac{Q(r'+r)}{r'}$ (b) $\frac{Q(r'+r)}{r}$ (c) $\frac{Qr}{r'+r}$ (d) $\frac{Qr'}{r'+r}$

16. Electrical field intensity is given as $\vec{E} = (2x+1)y\hat{i} + x(x+1)\hat{j}$. The potential of a point (1, 2) if potential at origin is 2 volt is,
(a) 2 V (b) 4 V (c) – 2 V (d) 0 V

17. The electric potential due to a small electric dipole at a large distance r from the centre of the dipole is proportional to
(a) r (b) 1/r (c) $1/r^2$ (d) $1/r^3$

18. Two small identical metal balls of radius *r* are at a distance *a* from each other and are charged, one with a potential V_1 and the other with a potential V_2. The charges on the balls are :
(a) $q_1 = V_1 a, q_2 = V_2 a$
(b) $q_1 = V_1 r, q_2 = V_2 r$
(c) $q_1 = \left(\frac{V_1+V_2}{2}\right)a, q_2 = \left(\frac{V_1+V_2}{2}\right)r$
(d) $q_1 = -\frac{r}{a}(rV_2 - aV_1), q_2 = -\frac{r}{a}(rV_1 - aV_2)$

19. Choose the wrong statement about equipotential surfaces.
(a) It is a surface over which the potential is constant
(b) The electric field is parallel to the equipotential surface
(c) The electric field is perpendicular to the equipotential surface
(d) The electric field is in the direction of steepest decrease of potential

Topic 2: Electrostatic Potential Energy and Work Done in Carrying a Charge

20. When a positive charge q is taken from lower potential to a higher potential point, then its potential energy will
(a) increase (b) decrease (c) remain unchanged (d) become zero

21. A square of side 'a' has charge Q at its centre and charge 'q' at one of the corners. The work required to be done in moving the charge 'q' from the corner to the diagonally opposite corner is
(a) zero (b) $\frac{Qq}{4\pi\epsilon_0 a}$ (c) $\frac{Qq\sqrt{2}}{4\pi\epsilon_0 a}$ (d) $\frac{Qq}{2\pi\epsilon_0 a}$

22. An alpha particle is accelerated through a potential difference of 10^6 volt. Its kinetic energy will be
(a) 1 MeV (b) 2 MeV (c) 4 MeV (d) 8 MeV

23. A and B are two points in an electric field. If the work done in carrying 4.0C of electric charge from A to B is 16.0 J, the potential difference between A and B is

(a) zero (b) 2.0 V (c) 4.0 V (d) 16.0 V

24. A conductor carries a certain charge. When it is connected to another uncharged conductor of finite capacity, then the energy of the combined system is

(a) more than that of the first conductor (b) less than that of the first conductor
(c) equal to that of the first conductor (d) uncertain

25. If a unit charge is taken from one point to another over an equipotential surface, then

(a) work is done on the charge (b) work is done by the charge
(c) work done on the charge is constant (d) no work is done

26. A ball of mass 1 g carrying a charge 10^{-8} C moves from a point A at potential 600 V to a point B at zero potential. The change in its K.E. is

(a) -6×10^{-6} erg (b) -6×10^{-6} J (c) 6×10^{-6} J (d) 6×10^{-6} erg

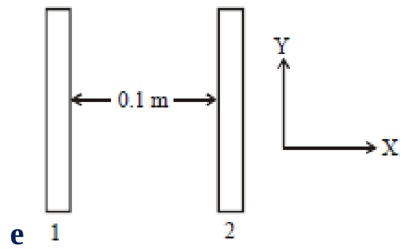
27. A positive point charge q is carried from a point B to a point A in the electric field of a point charge + Q at O. If the permittivity of free space is e0, the work done in the process is given by

(a) $\frac{qQ}{4\pi \epsilon_0}\left(\frac{1}{a}+\frac{1}{b}\right)$ (b) $\frac{qQ}{4\pi \epsilon_0}\left(\frac{1}{a}-\frac{1}{b}\right)$ (c) $\frac{qQ}{4\pi \epsilon_0}\left(\frac{1}{a^2}-\frac{1}{b^2}\right)$ (d) $\frac{qQ}{4\pi \epsilon_0}\left(\frac{1}{a^2}+\frac{1}{b^2}\right)$

28. There exists a uniform electric field $E = 4 \times 10^5$ Vm^{-1} directed along negative x-axis such that electric potential at origin is zero. A charge of – 200 μC is placed at origin, and a charge of + 200 μC is placed at (3m, 0). The electrostatic potential energy of the system is

(a) 120 J (b) – 120 J (c) – 240 J (d) zero

29. Two insulating plates are both uniformly charged in such a way that the potential difference between them is $V_2 - V_1 = 20$ V. (i.e., plate 2 is at a higher potential). The plates are separated by $d = 0.1$ m and can be treated as infinitely large. An electron is released from rest on the inner surface of plate 1. What is its speed when it hits plate 2? ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg)



(a) 2.65×10^6 m/s (b) 7.02×10^{12} m/s (c) 1.87×10^6 m/s (d) 32×10^{-19} m/s

30. Two positive charges of magnitude '*q*' are placed, at the ends of a side (side 1) of a square of side '2*a*'. Two negative charges of the same magnitude are kept at the other corners. Starting from rest, if a charge *Q* moves from the middle of side 1 to the centre of square, its kinetic energy at the centre of square is

(a) zero (b) $\frac{1}{4\pi \epsilon_0}\frac{2qQ}{a}\left(1+\frac{1}{\sqrt{5}}\right)$ (c) $\frac{1}{4\pi \epsilon_0}\frac{2qQ}{a}\left(1-\frac{2}{\sqrt{5}}\right)$ (d) $\frac{1}{4\pi \epsilon_0}\frac{2qQ}{a}\left(1-\frac{1}{\sqrt{5}}\right)$

31. 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) -2.24×10^{-16} J (c) 2.24×10^{-16} J (d) -9.60×10^{-17} J

32. Two identical thin rings each of radius *R* meters are coaxially placed at a distance *R* meters apart. If Q_1 coulomb and Q_2 coulomb are respectively the charges uniformly spread on the two rings, the work done in moving a charge *q* from the centre of one ring to that of other is

(a) zero (b) $\frac{q(Q_1-Q_2)(\sqrt{2}-1)}{\sqrt{2}.4\pi\varepsilon_0 R}$ (c) $\frac{q\sqrt{2}(Q_1+Q_2)}{4\pi\varepsilon_0 R}$ (d) $\frac{q(Q_1+Q_2)(\sqrt{2}+1)}{\sqrt{2}.4\pi\varepsilon_0 R}$

Topic 3: Charge and Capacitance of a Capacitor

33. The capacity of parallel plate capacitor depends on
(a) metal used to make plates (b) thickness of plate
(c) potential applied across the plate (d) area of plate

34. We increase the charge on the plates of a capacitor, it means,
(a) increasing the capacitance (b) increasing P.D. between plates
(c) decreasing P.D. between plates (d) no change in field between plates

35. If in a parallel plate capacitor, which is connected to a battery, we fill dielectrics in whole space of its plates, then which of the following increases?
(a) Q and V (b) V and E (c) E and C (d) Q and C

36. A dielectric slab is inserted between the plates of an isolated charged capacitor. Which of the following quantities remain unchanged ?
(a) The charge on the capacitor (b) The stored energy in the Capacitor
(c) The potential difference between the plates (d) The electric field in the capacitor

37. A cylindrical capacitor has charge Q and length L. If both the charge and length of the capacitors are doubled by keeping other parameters fixed, the energy stored in the capacitor:
(a) remains same (b) increases two times (c) decreases two times (d) increases four times

38. To establish an instantaneous current of 2 A through a 1 mF capacitor ; the potential difference across the capacitor plates should be charged at the rate of :
(a) 2×10^4 V/s (b) 4×10^6 V/s (c) 2×10^6 V/s (d) 4×10^4 V/s

39. Two identical metal plates are given positive charges Q_1 and Q_2 ($< Q_1$) respectively. If they are now brought close together to form a parallel plate capacitor with capacitance C, the potential difference between them is
(a) $\frac{Q_1+Q_2}{2C}$ (b) $\frac{Q_1+Q_2}{C}$ (c) $\frac{Q_1-Q_2}{C}$ (d) $\frac{Q_1-Q_2}{2C}$

40. A parallel plate capacitor with air between the plates has a capacitance of 8 pF. Calculate 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. ($\varepsilon_r = 6$)
(a) 72 pF (b) 81 pF (c) 84 pF (d) 96 pF

41. A parallel plate air capacitor has a capacitance of 100 mF. The plates are at a distance d apart. If a slab of thickness t ($t < d$) and dielectric constant 5 is introduced between the parallel plates, then the capacitance will be
(a) 50 mF (b) 100 mF (c) 200 mF (d) 500 mF

42. A uniform electric field $\vec{E}$ exists between the plates of a charged condenser. A charged particle enters the space between the plates and perpendicular to $\vec{E}$. The path of the particle between the plates is a :
(a) straight line (b) hyperbola (c) parabola (d) circle

43. Force between two plates of a capacitor is
(a) $\frac{Q}{\varepsilon_0 A}$ (b) $\frac{Q^2}{2\varepsilon_0 A}$ (c) $\frac{Q^2}{\varepsilon_0 A}$ (d) None of these

44. An air capacitor of capacity C = 10 mF is connected to a constant voltage battery of 12 volt. Now the space between the plates is filled with a liquid of dielectric constant 5. The (additional) charge that flows now from battery to the capacitor is
(a) 120 μC (b) 600 μC (c) 480 μC (d) 24 μC

45. A parallel plate capacitor with air between the plates is charged to a potential difference of 500V and then insulated. A plastic plate is inserted between the plates filling the whole gap. The potential difference between the plates now becomes 75V. The dielectric constant of plastic is

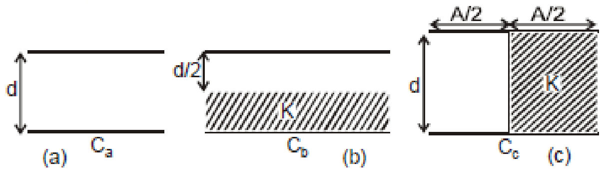
(a) 10/3 (b) 5 (c) 20/3 (d) 10

46. The gap between the plates of a parallel plate capacitor of area A and distance between plates d, is filled with a dielectric whose permittivity varies linearly from $\in_1$ at one plate to $\in_2$ at the other. The capacitance of capacitor is:

(a) $\in_0 (\in_1 + \in_2) A/d$ (b) $\in_0 (\in_2 + \in_1) A/2d$

(c) $\in_0 A/\left[d \ln(\in_2/\in_1)\right]$ (d) $\in_0 (\in_2 - \in_1) A/\left[d \ln(\in_2/\in_1)\right]$

47. The capacitance of a parallel plate capacitor is C_a (Fig. a). A dielectric of dielectric constant K is inserted as shown in fig (b) and (c). If C_b and C_c denote the capacitances in fig (b) and (c), then



(a) both C_b, $C_c > C_a$ (b) $C_c > C_a$ while $C_b > C_a$ (c) both C_b, $C_c < C_a$ (d) $C_a = C_b = C_c$

48. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates

(a) does not change (b) becomes zero (c) increases (d) decreases

49. 'n' identical drops, each of capacitance C and charged to a potential V, coalesce to form a bigger drop. Then the ratio of the energy stored in the big drop to that in each small drop is

(a) $n^{5/3}:1$ (b) $n^{4/3}:1$ (c) $n:1$ (d) $n^3:1$

50. When a dielectric is introduced between the plates of a condenser, the capacity of condenser

(a) increases (b) decreases (c) remains same (d) None of these

51. An unchanged parallel plate capacitor filled with a dielectric constant K is connected to an air filled identical parallel capacitor charged to potential V_1. If the common potential is V_2, the value of K is

(a) $\frac{V_1 - V_2}{V_1}$ (b) $\frac{V_1}{V_1 - V_2}$ (c) $\frac{V_2}{V_1 - V_2}$ (d) $\frac{V_1 - V_2}{V_2}$

Topic 4: Grouping of Capacitors and Energy Stored in a Capacitor

52. If there are *n* capacitors in parallel connected to *V* volt source, then the energy stored is equal to

(a) CV (b) $\frac{1}{2}nCV^2$ (c) CV^2 (d) $\frac{1}{2n}CV^2$

53. A sheet of aluminium foil of negligible thickness is introduced between the plates of a capacitor. The capacitance of the capacitor

(a) decreases (b) remains unchanged (c) becomes infinite (d) increases

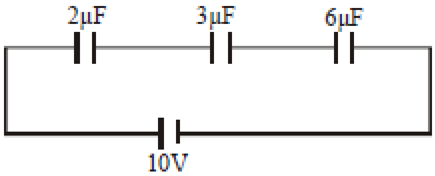
54. The work done in placing a charge of 8×10^{-18} coulomb on a condenser of capacity 100 micro-farad is

(a) 16×10^{-32} joule (b) 3.1×10^{-26} joule (c) 4×10^{-10} joule (d) 32×10^{-32} joule

55. Two capacitors of capacitances C_1 and C_2 are connected in parallel across a battery. If Q_1 and Q_2 respectively be the charges on the capacitors, then $\frac{Q_1}{Q_2}$ will be equal to

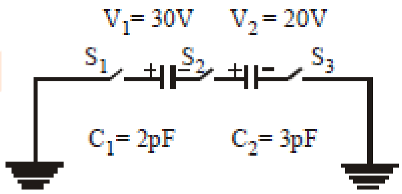
(a) $\frac{C_2}{C_1}$ (b) $\frac{C_1}{C_2}$ (c) $\frac{C_1^2}{C_2^2}$ (d) $\frac{C_2^2}{C_1^2}$

56. In the given figure, the charge on 3 μF capacitor is



(a) 10 μC (b) 15 μC (c) 30 μC (d) 5 μC

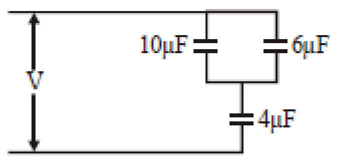
57. For the circuit shown in figure, which of the following statements is true?



(a) With S_1 closed $V_1 = 15V$, $V_2 = 20V$ (b) With S_3 closed $V_1 = V_2 = 25$ V

(c) With S_1 and S_2 closed $V_1 = V_2 = 0$ (d) With S_1 and S_3 closed, $V_1 = 30$ V, $V_2 = 20$ V

58. The equivalent capacitance of the combination of the capacitors is



(a) 3.20μF (b) 7.80μF (c) 3.90μF (d) 2.16μF

59. A capacitor has two circular plates whose radius are 8cm and distance between them is 1mm. When mica (dielectric constant = 6) is placed between the plates, the capacitance of this capacitor and the energy stored when it is given potential of 150 volt respectively are

(a) 1.06×10^{-5}F, 1.2×10^{-9} J (b) 1.068×10^{-9}F, 1.2×10^{-5} J

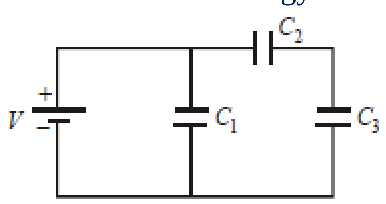
(c) 1.2×10^{-9}F, 1.068×10^{-5} J (d) 1.6×10^{-9}F, 1.208×10^{-5} J

60. In a charged capacitor, the energy is stored in

(a) the negative charges (b) the positive charges

(c) the field between the plates (d) both 'a' and 'b'

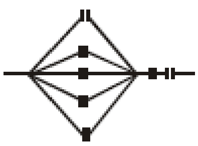
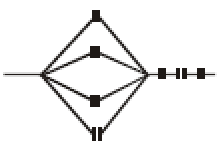
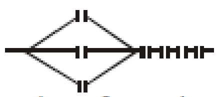
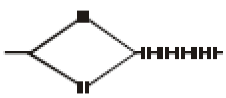
61. Three capacitors C_1, C_2 and C_3 are connected to a battery as shown in the figure. The three capacitors have equal capacitances. Which capacitor stores the most energy?



(a) C_2 or C_3 as they store the same amount of energy (b) C_2

(c) C_1 (d) All three capacitors store the same amount of energy

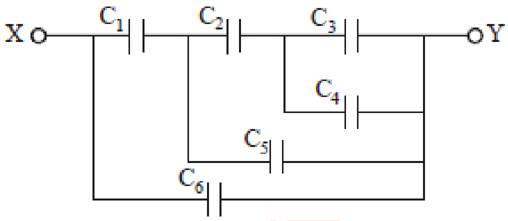
62. Seven capacitors each of capacitance $2\,\mu F$ are to be connected in a configuration to obtain an effective capacitance of $\left(\frac{10}{11}\right)\mu$F. Which of the combination (s) shown in figure will achieve the desired result?

(a)  (b)  (c)  (d) 

63. A capacitor of capacitance $C_1 = 1\,\mu F$ can withstand maximum voltage $V_1 = 6kV$ (kilo-volt) and another capacitor of capacitance $C_2 = 3\,\mu F$ can withstand maximum voltage $V_2 = 4kV$. When the two capacitors are connected in series, the combined system can withstand a maximum voltage of

(a) 4kV (b) 6kV (c) 8kV (d) 10kV

64. In the given network of capacitors as shown in Fig. given that $C_1 = C_2 = C_3 = 400$ pF and $C_4 = C_5 = C_6 = 200$ pF. The effective capacitance of the circuit between X and Y is



(a) 810 pF (b) 205 pF (c) 600 pF (d) 410 pF

65. Three capacitors connected in series have an effective capacitance of 4μF. If one of the capacitance is removed, the net capacitance of the capacitor increases to 6 μF. The removed capacitor has a capacitance of :

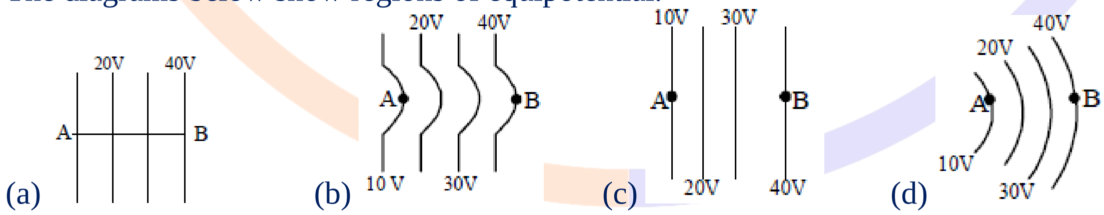
(a) 2 μF (b) 4 μF (c) 10 μF (d) 12 μF

NEET PREVIOUS YEARS QUESTIONS

1. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is **[2018]**

(a) independent of the distance between the plates
(b) linearly proportional to the distance between the plates
(c) inversely proportional to the distance between the plates
(d) proportional to the square root of the distance between the plates

2. The diagrams below show regions of equipotential. **[2017]**



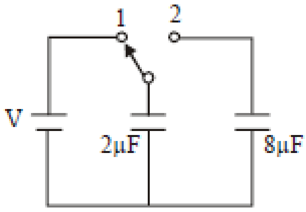
A positive charge is moved from A to B in each diagram.

(a) In all the four cases the work done is the same
(b) Minimum work is required to move q in figure (a)
(c) Maximum work is required to move q in figure (b)
(d) Maximum work is required to move q in figure (c)

3. 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: **[2017]**

(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

4. A capacitor of $2\,\mu F$ is charged as shown in the diagram. When the switch S is turned to position 2, the percentage of its stored energy dissipated is : **[2016]**



(a) 0% (b) 20% (c) 75% (d) 80%

5. A parallel plate air capacitor has capacity 'C' distance of separation between plates is 'd' and potential difference 'V' is applied between the plates. Force of attraction between the plates of the parallel plate air capacitor is : **[2015]**

(a) $\frac{CV^2}{2d}$ (b) $\frac{CV^2}{d}$ (c) $\frac{C^2V^2}{2d^2}$ (d) $\frac{C^2V^2}{d^2}$

6. If potential (in volts) in a region is expressed as V(x, y, z) = 6 xy – y + 2yz, the electric field (in N/C) at point (1, 1, 0) is: **[2015]**

(a) $-\left(6\hat{i}+5\hat{j}+2\hat{k}\right)$ (b) $-\left(2\hat{i}+3\hat{j}+\hat{k}\right)$ (c) $-\left(6\hat{i}+9\hat{j}+\hat{k}\right)$ (d) $-\left(3\hat{i}+5\hat{j}+3\hat{k}\right)$

7. A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect ? **[2015]**

(a) The energy stored in the capacitor decreases K times.

(b) The chance in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$

(c) The charge on the capacitor is not conserved.

(d) The potential difference between the plates decreases K times.

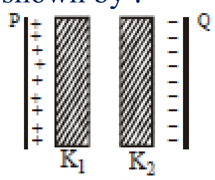
8. In a region, the potential is represented by V(x, y, z) = 6x – 8xy – 8y + 6yz, where V is in volts and x, y, z are in metres. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is: **[2014]**

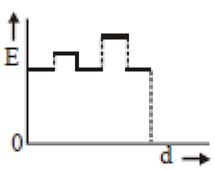
(a) $6\sqrt{5}$ N (b) 30 N (c) 24 N (d) $4\sqrt{35}$ N

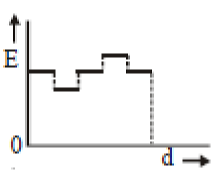
9. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are: **[2014]**

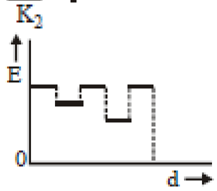
(a) Zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (b) $\frac{Q}{4\pi\varepsilon_0 R}$ and Zero (c) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (d) Both are zero

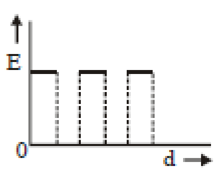
10. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between plates of a parallel plate capacitor, as shown in the figure. The variation of electric field 'E' between the plates with distance 'd' as measured from plate P is correctly shown by : **[2014]**



(a)


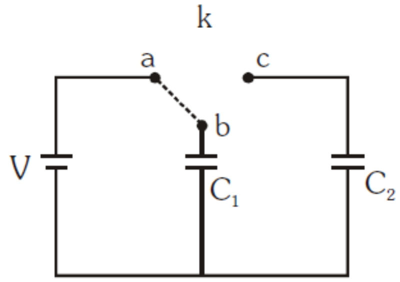
(b)


(c)


(d)


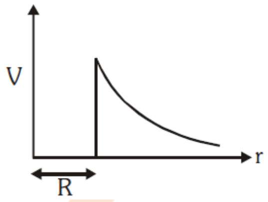
11. Two identical capacitors C_1 and C_2 of equal capacitance are connected as shown in the circuit. Terminals a and b of the key k are connected to charge capacitor C_1 using battery of emf V volt. Now disconnecting a and b the terminals b and c are connected. Due to this, what will be the percentage loss of energy ?

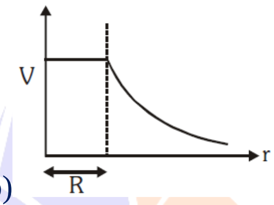
[NEET – 2019 (ODISSA)]

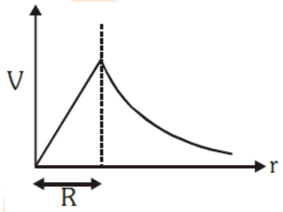


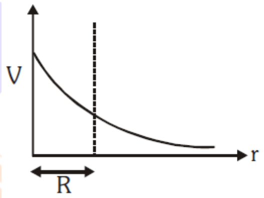
(1) 75% (2) 0% 3) 50% (4) 25%

12. The variation of electrostatic potential with radial distance r from the centre of a positively charged metallic thin shell of radius R is given by the graph **[NEET – 2020 (Covid-19)]**

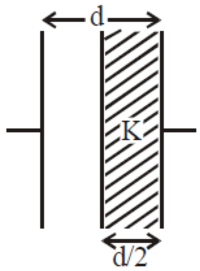
(a)


(b)


(c)


(d)


13. A parallel plate capacitor having cross-sectional area A and separation d has air in between the plates. Now an insulating slab of same area but thickness d/2 is inserted between the plates as shown in figure having dielectric constant K(= 4). The ratio of new capacitance to its original capacitance will be, **[NEET – 2020 (Covid-19)]**



(1) 2 : 1 (2) 8 : 5 (3) 6 : 5 (4) 4 : 1

14. A short electric dipole has a dipole moment of $16\times10^{-9}\,Cm$. The electric potential due to the dipole at a point at a distance of 0.6m from the centre of the dipole situated on a line making an angle of 60^0 with the dipole axis is $\left(\frac{1}{4\pi\varepsilon_0}=9\times10^9\,Nm^2/c^2\right)$ **[NEET – 2020]**

1) zero 2) 50 V 3) 200 V 4) 400 V

15. In a certain region of space with volume 0.2 m^3 the electric potential is found to be 5V throughout. The magnitude of electric field in this region is **[NEET – 2020]**

1) 5 N/C 2) zero 3) 0.5 N/C 4) 1 N/C

16. The capacitance of a parallel plate capacitor with air as medium is $6\mu F$. With the introduction of a dielectric medium, the capacitance becomes $30\mu F$. The permittivity of the medium is $\left(\epsilon_0=8.85\times10^{-12}C^2N^{-1}m^{-2}\right)$ **[NEET– 2020]**

1) $5.00\,C^2N^{-1}m^{-2}$ 2) $0.44\times10^{-13}\,C^2N^{-1}m^{-2}$ 3) $1.77\times10^{-12}\,C^2N^{-1}m^{-2}$ 4) $0.44\times10^{-10}\,C^2N^{-1}m^{-2}$

17. Polar molecules are the molecules: **[NEET-2021]**

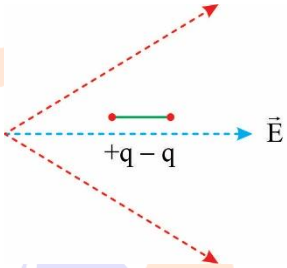
1) acquire a dipole moment only in the presence of electric field due to displacement of charges.
2) acquire a dipole moment only when magnetic field is absent.

3) having a permanent electric dipole moment 4) having zero dipole moment.

18. Two charged spherical conductors of radius R_1 and R_2 are connected by a wire. Then the ratio of surface charge densities of the spheres (σ_1/σ_2) is **[NEET-2021]**

1) $\frac{R_2}{R_1}$ 2) $\sqrt{\left(\frac{R_2}{R_1}\right)}$ 3) $\frac{R_1^2}{R_2^2}$ 4) $\frac{R_1}{R_2}$

19. A dipole is placed in an electric field as shown. In which direction will it move? **[NEET-2021]**

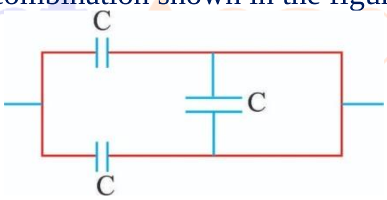


1)towards the right as its potential energy will decreases
2)towards the left as its potential energy will decrease
3)towards the right as its potential energy will increase
4) towards the left as its potential energy will increase

20. A parallel plate capacitor has a uniform electric field '$\vec{E}$' in the space between the plates. If the distance between the plates is 'd' and the area of each plate is 'A' the energy stored in the capacitor is: (ε_0 = permittivity of free space) **[NEET-2021]**

1) $\varepsilon_0 EAd$ 2) $\frac{1}{2}\varepsilon_0 E^2 Ad$ 3) $\frac{E^2 Ad}{\varepsilon_0}$ 4) $\frac{1}{2}\varepsilon_0 E^2$

21. The equivalent capacitance of the combination shown in the figure is : **[NEET-2021]**



1. $2C$ 2. $C/2$ 3. $3C/2$ 4. $3C$

22. Twenty seven drops of same size are charged at 220 V each. They combine to form a bigger drop. Calculate the potential of the bigger drop **[NEET-2021]**

1) 1320 V 2) 1520 V 3) 1980 V 4) 660 V

23. Two hollow conducting spheres of radii R_1 and R_2 $(R_1 >> R_2)$ have equal charges. The potential would be **[NEET-2022]**

1) more on bigger sphere 2) more on smaller sphere
3) equal on both the spheres 4) dependent on the material property of the sphere

$\therefore$ V is more for smaller sphere

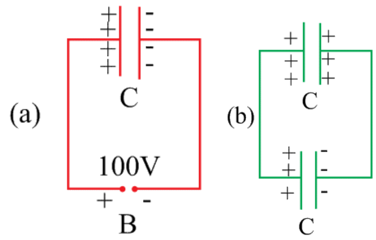
24. The peak voltage of the ac source is equal to: **[NEET-2022]**

1) The value of voltage supplied to the circuit 2) The rms value of the ac source
3) $\sqrt{2}$ time the rms value of the ac source 4) $1/\sqrt{2}$ times the rms value of the ac source

25. The angle between the electric lines of force and the equipotential surface is: **[NEET-2022]**

1) 0^0 2) 45^0 3) 90^0 4) 180^0

26. A capacitor of capacitance C = 900 pF is charged fully by 100 V battery B as shown in figure (a). Then it is disconnected from the battery and connected to another uncharged capacitor of capacitance C = 900 pF as shown in figure (b). The electrostatic energy stored by the system (b) is : **[NEET-2022]**



1) $4.5\times10^{-6}J$ 2) $3.25\times10^{-6}J$ 3) $2.25\times10^{-6}J$ 4) $1.5\times10^{-6}J$

NCERT LINE BY LINE QUESTIONS – ANSWERS

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

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	3	**2)**	2	**3)**	1	**4)**	3	**5)**	1	**6)**	2	**7)**	1	**8)**	4	**9)**	4	**10)**	3
11)	3	**12)**	1	**13)**	2	**14)**	3	**15)**	4	**16)**	3	**17)**	3	**18)**	4	**19)**	2	**20)**	1
21)	1	**22)**	2	**23)**	3	**24)**	2	**25)**	4	**26)**	3	**27)**	2	**28)**	1	**29)**	1	**30)**	4
31)	3	**32)**	2	**33)**	4	**34)**	2	**35)**	4	**36)**	1	**37)**	4	**38)**	3	**39)**	4	**40)**	4
41)	3	**42)**	3	**43)**	2	**44)**	3	**45)**	3	**46)**	4	**47)**	1	**48)**	3	**49)**	1	**50)**	1
51)	4	**52)**	2	**53)**	2	**54)**	4	**55)**	2	**56)**	1	**57)**	4	**58)**	1	**59)**	2	**60)**	3
61)	3	**62)**	1	**63)**	3	**64)**	4	**65)**	4										

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	1	2)	1	3)	1	4)	4	5)	1	6)	1	7)	3	8)	4	9)	2	10)	3
11)	3	12)	4	13)	2	14)	3	15)	2	16)	4	17)	3	18)	1	19)	1	20)	2
21)	1	22)	3	23)	2	24)	3	25)	3	26)	3								

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(c)** Electric potential inside a conductor is constant and it is equal to that on the surface of conductor.

2. **(b)** At. equipotential surface, the potential is same at any point i.e., $V_A = V_B$ as shown in figure. Hence no work is required to move unit charge from one point to another i.e.,

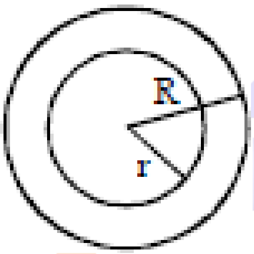
$$V_A - V_B = \frac{W}{\text{unit charge}} = 0 \Rightarrow W = 0$$

3. **(a)** The potential of uncharged body is less than that of the charged conductor and more than at infinity.

4. **(c)** Charge on the outer sphere $= q_1 = 4\pi R^2\sigma$

Charge on the inner sphere $= q_2 = 4\pi r^2\sigma$

$$v = \frac{1}{4\pi\in_0}\frac{q_1}{R} + \frac{1}{4\pi\in_0}\frac{q_2}{r}$$



$$= \frac{1}{4\pi\in_0}\left[\frac{4\pi R^2\sigma}{R} + \frac{4\pi r^2\sigma}{r}\right] = \frac{4\pi\sigma}{4\pi\in_0}(R+r) = \frac{\sigma}{\in_0}(R+r)$$

5. **(a)** E = 500 V/m V = 3000 V.

We know that electric field (E) $= 500 = \frac{V}{d}$ or $d = \frac{3000}{500} = 6\text{m}$

6. (b) Here distance between a and +q= distance between C and −q=y_1 (say);
distance between a and −q= distance between C and +q=y_2
similarly , d(+q)=d(−q)=b(−q)=b(+q)=r (say)

$$\text{Thus}, V_a = \frac{kq}{y_1} + \frac{-kq}{y_2}$$

$$V_b = \frac{kq}{r} + \frac{-kq}{r} = 0$$

$$V_c = \frac{kq}{y_2} + \frac{-kq}{y_1}$$

$$V_d = \frac{kq}{r} + \frac{-kq}{r} = 0$$

Since $y_2 > y_1$, Va is positive Vc is negative.
Thus Va>Vb=Vd>Vc

7. **(a)** Let d- distance between any vertex and the center.
The potential at center before and after the charges are interchanged =

$$\frac{1}{4\pi\varepsilon}\frac{q}{d} + \frac{1}{4\pi\varepsilon}\frac{q}{d} + \frac{1}{4\pi\varepsilon}\frac{-q}{d}$$

Field initially at center $= 4\frac{1}{4\pi\varepsilon}\frac{q}{d^2}\cos\left(\frac{\pi}{4}\right)$ from A to C

Field at center after interchanging the charges $= 4\frac{1}{4\pi\varepsilon}\frac{q}{d^2}\cos\left(\frac{\pi}{4}\right)$ from C to A

The direction of field has changed

8. **(d)** In equilibrium, $F = qE = (ne)\frac{V}{d} = mg$

$n = \frac{mgd}{eV} = \frac{1.96\times10^{-15}\times9.8\times0.02}{1.6\times10^{-19}\times800} = 3$

9. **(d)** $V = 5+4x^2$ $\qquad \therefore \frac{dV}{dx} = 8x$ **--------(1)**

Force on a charge is

$F = qE = q\left(-\frac{dV}{dx}\right) = q(-8x)$

$= -2\times10^{-6}\times(-8\times0.5) = 8\times10^{-6}\,N$

10. **(c)** $V_{small} = k\frac{q}{r}$

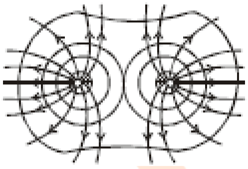
If the radius of big drop is R,

$\frac{4}{3}\pi R^3 = 1000\frac{4}{3}\pi r^3 \Rightarrow R = 10r$

and charge of big drop, Q = 1000 q

Now $V_{big} = k\frac{Q}{R} = k\frac{1000q}{10r} = 100k\frac{q}{r} = 100V_{small}$

11. **(c)** Equipotential surfaces are normal to the electric field lines. The following figure shows the equipotential surfaces along with electric field lines for a system of two positive charges.



12. **(a) Conceptual**

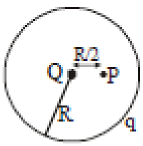
13. **(b)** When the charge is released to move freely, the work done by electric field is equal to change in kinetic energy

$\therefore W_{EF} = \Delta KE \qquad -q\Delta V = \Delta KE$

KE = – 3 × 10^{-6} (1 – 5) = 12 × 10^{-6} J

14. **(c)** Electric potential due to charge Q placed at the centre of the spherical shell at point P is

$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R/2} = \frac{1}{4\pi\varepsilon_0}\frac{2Q}{R}$



Electric potential due to charge q on the surface of the spherical shell at any point inside the shell is

$V_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$

$\therefore$ The net electric potential at point P is

$V = V_1 + V_2 = \frac{1}{4\pi\varepsilon_0}\frac{2Q}{R} + \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$

15. **(d)** Let the charge on the smaller sphere be q. As the potential of both will be the same finally,

$$\frac{q}{r^{|}} = \frac{Q-q}{r} \text{ or } q = \frac{Qr^{|}}{r+r^{|}}$$

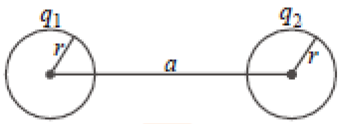
16. **(c)**

$$V_{0\ 0\ 0} - V_{2\ 1\ 9} = \int_{0\ 0\ 0}^{2\ 1\ 9} y^2dx + 2xydy = \int_{0\ 0\ 0}^{2\ 1\ 9} d(xy^2)$$

$$= xy^2\Big|_{(0,0,0)}^{(2,1,9)} = 2$$

17. **(c)** Due to small dipole $V \propto \frac{1}{r^2}$

18. (d) $V_1 = \frac{1}{4\pi \in_0}\left[\frac{q_1}{r} + \frac{q_2}{a}\right]$ and $V_2 = \frac{1}{4\pi \in_0}\left[\frac{q_2}{r} + \frac{q_1}{a}\right]$



After solving above equations, and neglecting r^2 in comparison to a, we get

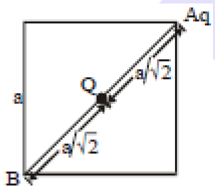
$$q_1 = -\frac{r}{a}(rV_2 - aV_1) \text{ and } q_2 = -\frac{r}{a}(rV_1 - aV_2)$$

19. **(b)** Electric lines of force are always perpendicular to an equipotential surface.

20. (a) Because work is to be done by an external agent in moving a positive charge from low potential to high potential and this work gets stored in the form of potential energy of the system. Hence, it increases.

21. **(a)** Here,

Hence, $V_A - V_B = 0$



Work done, $W = q(V_A - V_B) = 0$

22. **(b)** Charge on a particle, q = 2 e.

K.E. = work done = $q \times V = 2e \times 10^6$ V = 2 MeV.

23. **(c)** Since $W_{A\rightarrow B} = q(V_B - V_A) \Rightarrow V_B - V_A = \frac{16}{4} = 4V$

24. **(b)** Energy will be lost during transfer of charge (heating effect).

25. (d) Since the potential at each point of an equipotential surface is the same, the potential does not change while we move a unit positive charge from one point to another. Therefore work done in the process is zero.

26. **(c)** As work is done by the field, K.E. of the body increases by

K.E. = W = $q(V_A - V_B) = 10^{-8}(600 - 0) = 6\times10^{-6}$ J

27. **(b)** $W_{BA} = q(V_A - V_B)$

$$= q\left[\frac{Q}{4\pi\varepsilon_0 a} - \frac{Q}{4\pi\varepsilon_0 b}\right] = \frac{qQ}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{b}\right]$$

28. **(a)** Potential energy of the system

$$U = q_1V_1 + q_2V_2 + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_2}$$

Now, V_1 [electric potential at origin] = 0

V_2 [electric potential at (3m, 0)] = $4 \times 10^5 \times 3 = 12 \times 10^5$

$\Rightarrow U = (+200) \times 10^{-6} \times 12 \times 10^5 + 9 \times 10^9$

$$\times\frac{(200\times10^{-6})\times(-200\times10^{-6})}{3} = 240 - 120 = 120J$$

29. **(a)** $eV = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times20}{9.1\times10^{-31}}} = 2.65\times10^6\,m/s$

30. **(d)** $U_i = \frac{2kqQ}{a} + \frac{2k(-q)Q}{\sqrt{5}a} = \frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left[1-\frac{1}{\sqrt{5}}\right]$, $U_f = 0$

By conservation of energy
Gain in KE= loss in PE

$$K = \frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left[1-\frac{1}{\sqrt{5}}\right]$$

31. (c) potential difference=V=−4−10=−14V
Charge=q=100e =−1.6×10−17C

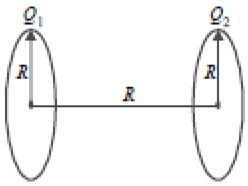
Now, potential difference, $V = \frac{W}{q}$
$\Rightarrow W=qV=-1.6\times10^{-17}\times(-14)$
$\Rightarrow W=2.24\times10^{-16}J$

32. **(b)** Work done $W_{21} = (V_1 - V_2)q$

$$V = \frac{1}{4\pi\in_0}\left[\frac{Q_1}{R}+\frac{Q_2}{\sqrt{2}R}\right] \text{and } V_2 = \frac{1}{4\pi\in_0}\left[\frac{Q_2}{R}+\frac{Q_1}{\sqrt{2}R}\right]$$

Thus, $W_{21} = \frac{q(Q_1-Q_2)(\sqrt{2}-1)}{\sqrt{2}.4\pi\in_0 R}$

33. **(d)**



34. **(b)** $\because q\propto V$ for $q = CV$
$\Rightarrow$ as charge on capacitor increases means P.D. between plates increases.

35. **(d)** Since battery remains connected so P.D. between the plates is constant. But as we introduce the dielectric, the capacitance increases and hence charge increases.

36. **(a)** Due to insertion of a dielectric slab capacitance increase by K times. The potential difference, the electric field and the stored energy decreases by 1/K times.

37. **(d)** increases four times

38. **(c)** **As** $C = \frac{Q}{V} = \frac{It}{V} \Rightarrow \frac{V}{t} = \frac{I}{C} = \frac{2}{1\times10^{-6}} = 2\times10^6\,V/s$

39. **(d)** The potential difference between the two identical metal plates is given as

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

Let the surface charge density is given as

$$\sigma_1 = \sigma_2 = \frac{Q}{A}$$

The net electric field is

$$E_{net} = \frac{\sigma_1 - \sigma_2}{2\varepsilon_0}$$

We know the potential difference is given as
V=E.d

By substituting the above values we get $V = \frac{Q_1 - Q_2}{2C}$

40. **(d)** Capacity of parallel plate capacitor

$$C=\frac{\varepsilon_r\varepsilon_0 A}{d} \qquad (\text{For air } \varepsilon_r = i)$$

So, $\frac{\varepsilon_0 A}{d} = 8\times10^{-12}$

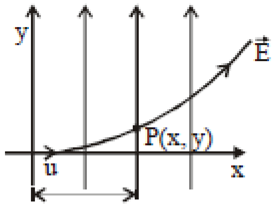
If $d \to \frac{d}{2}$ and $\varepsilon_r \to 6$ then new capacitance

$$C^{|} = 6\times\frac{\varepsilon_0 A}{d/2} = 12\frac{\varepsilon_0 A}{d} = 12\times 8pF = 96pF$$

41. **(c)** Capacitance will increase but not 5 times (because dielectric is not filled completely). Hence, new capacitance may be 200 mF.

42. **(c)** When charged particle enters perpendicularly in an electric field, it describes a parabolic path

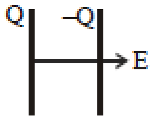
$$y=\frac{1}{2}\left(\frac{QE}{m}\right)\left(\frac{x}{4}\right)^2$$



This is the equation of parabola.

43. **(b)** The magnitude of electric field by any one plate is

$\frac{\sigma}{2\varepsilon_0}$ or $\frac{Q}{2A\varepsilon_0}$



Now force magnitude is $|Q||E|$ i.e. $|F| = \frac{Q^2}{2A\varepsilon_0}$

44. **(c)** $q_1 = C_1V = 10\times12 = 120mC$

$q_2 = C_2V = KC_1\times V = 5\times10\times12 = 600\,\mu C$

Additional charge that flows = $q_2 - q_1 = 600 - 120 = 480\,\mu C$.

45. **(c)** $V_0 = \frac{q}{C_0} \quad V = \frac{q}{C} \Rightarrow \frac{V}{V_0} = \frac{C_0}{C} \Rightarrow \frac{C_0}{C} = \frac{500}{75} = \frac{20}{3}$

$C = kC_0 \Rightarrow k = \frac{20}{3}$ By definition,

46. **(d)** As the permittivity of dielectric varies linearly from ε_1 at one plate to ε_2 at the other, it is governed by equation, $k=\left(\frac{\varepsilon_2-\varepsilon_1}{d}\right)x+\varepsilon_1$ consider a small element of thickness dx at a distance x from plate. Then

$$dV=\frac{E_0}{k}dx$$

$$\int_0^V dV = \int_0^d \frac{\sigma}{\varepsilon_0} = \frac{1}{\left(\frac{\varepsilon_2-\varepsilon_1}{d}\right)x+\varepsilon_1}dx$$

$$V=\frac{d\sigma}{\varepsilon_0(\varepsilon_2-\varepsilon_1)}\ln\left(\frac{\varepsilon_2}{\varepsilon_1}\right)$$

$$Q = CV \Rightarrow C = \frac{Q}{V} = \frac{\sigma A}{\frac{d\sigma}{\varepsilon_0(\varepsilon_2 - \varepsilon_1)}\ln\left(\frac{\varepsilon_2}{\varepsilon_1}\right)} = \frac{\varepsilon_0(\varepsilon_2 - \varepsilon_1)A}{d\ln\left(\frac{\varepsilon_2}{\varepsilon_1}\right)}$$

47. (a)

$$C_a = \frac{\in_0 A}{d} \textbf{ and } C_b = \frac{\in_0 A}{\frac{d}{2} + \frac{d}{2K}} = \frac{2\in_0 A(1+K)}{d}$$

$$C_c = \frac{\in_0 \frac{A}{2}}{d} + \frac{\in_0 \frac{A}{2}K}{d} = \frac{\in_0 A}{2d}(1+K) \textbf{ or } C_b = \frac{\in_0 A}{d}2(1+K) > C_a \textbf{ or } C_c = \frac{\in_0 A}{d}\frac{1+K}{2} > C_a$$

$\therefore C_b$ and $C_c > C_a$

48. **(c)** If we increase the distance between the plates its capacity decreases resulting in higher potential as we know $Q = CV$. Since Q is constant (battery has been disconnected), on decreasing C, V will increase.

49. (a) Volume of big drop $=n\times$ volume of small drop

$$\frac{4}{3}\pi R^3 - n \times \frac{4}{3}\pi r^3$$

$R=n^{1/3}r$

Capacitance of small drop, $C=4\pi\varepsilon_0 r$

Capacitance of big drop, $C=4\pi\varepsilon_0 R=4\pi\varepsilon_0 n^{1/3}r$; $C=n^{1/3}C$

The potential of small drop $V=q/C=\frac{q}{4\pi\varepsilon_0 r}$

The potential of big drop $V=\frac{q}{(4\pi\varepsilon_0 r)n^{1/3}r}$; $V=n^{2/3}V$

$\therefore$ Energy of small drop $=\frac{1}{2}CV^2$

Energy of big drop $=\frac{1}{2}CV^2=\frac{1}{2}n^{1/3}C(n^{2/3}V)^2=n^{5/3}\frac{1}{2}CV^2$

$$\therefore \frac{Energy_{(big\ drop)}}{Energy_{(small\ drop)}} = \frac{n^{5/3}}{1}$$

50. **(a)** Increase, because $C = \frac{K\varepsilon_0 A}{d}$

51. **(d)** As we know,

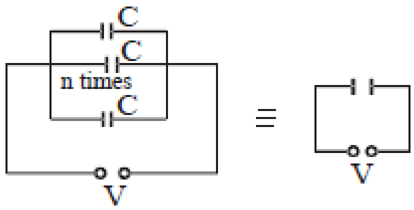
$$\text{Common potential} = \frac{\text{Total charge}}{\text{Total capacity}}$$

$Q_1 = C_0V_1, Q_2 = 0$, therefore $V_2 = \frac{C_0V_1 + 0}{C_0 + kC_0} = \frac{V_1}{1+k}$

$$1+k = \frac{V_1}{V_2} \text{ or } k = \frac{V_1}{V_2} - 1 = \frac{V_1 - V_2}{V_2}$$

52. **(b)** The equivalent capacitance of n identical capacitors of capacitance C is equal to nC. Energy stored in this capacitor

$$E = \frac{1}{2}(nC)V^2 = \frac{1}{2}nCV^2$$



53. **(b)** The capacitance of a parallel plate capacitor in which a metal plate of thickness t is inserted is given by $C = \frac{\varepsilon_0 A}{d-t}$. Here $t \to 0 \therefore C = \frac{\varepsilon_0 A}{d}$

54. **(d)** The work done is stored as the potential energy. The potential energy stored in a capacitor is given by

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\times\frac{\left(8\times10^{-18}\right)^2}{100\times10^{-6}} = 32\times10^{-32}\,J$$

55. **(b)** In parallel, potential is same, say V

$$\frac{Q_1}{Q_2} = \frac{C_1 V}{C_2 V} = \frac{C_1}{C_2}$$

56. **(a)** C = equivalent capacitance

$$\therefore \frac{1}{C} = \frac{1}{2}+\frac{1}{3}+\frac{1}{6} \Rightarrow \therefore C = 1\mu F$$

Charge in series circuit will be same.

$\therefore q = CV = (1\times10^{-6})\times10 = 10\,\mu C$

$\therefore$ Charge across '3μF' capacitor will be 10μC.

57. **(d)** Initial charge on capacitors C_1 and C_2 is given by,

$q_1 = C_1V_1 = 60$ pC $q_2 = C_2V_2 = 60$pC

When S_1 and S_3 are closed, capacitors C_1 and C_2 get connected in series. As a result charge on them should be same and so the charge do not redistribute on them. So potential on them remains same.

58. (a) Equivalent capacitance of two parallel capacitors $10\mu F$ and $6\mu F = (10+6)\mu F = 16\mu F$ This $16\mu F$ capacitor is in series combination with $4\mu F$ capacitor,

$\therefore$ Equivalent capacitance of the entire combination = $= \frac{16\times4}{16+4} = \frac{64}{20} = 3.2\mu F$

59. **(b)** Energy stored $= \frac{1}{2}CV^2 = \frac{1}{2}\times1.068\times10^{-9}\times150^2 = 1.2\times10^{-5}\,J$

$$C = \frac{KA\varepsilon}{\rho} = \frac{6\times\left(\pi\left(\frac{8}{100}\right)^2\right)\varepsilon_0}{1\times10^{-3}}$$

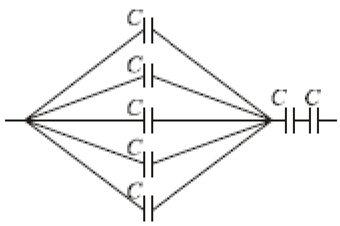
$$C = 6\pi\times\frac{64}{101}\times\frac{8.85\times10^{-12}}{10^{-3}} = \left(6\times\pi\times64\times8.85\right)\times10^{-12-4+3}$$

$$= 10676.38\times10^{-13} = 1.0676\times10^{-9}$$

60. **(c)** Electrostatic energy of a condenser lies in the field in between the plates of the condenser.

61. **(c)** Potential drop across C_1 is maximum. Hence, energy stored in C_1 is maximum as energy $\propto$ (potential drop)^2.

62. **(a)** The equivalent capacitance



$$\frac{1}{C_{eq}} = \frac{1}{2}+\frac{1}{2}+\frac{1}{2\times5} = \frac{11}{10} \Rightarrow C_{eq} = \frac{10}{11}\mu F$$

63. **(c)** As $Q = CV$, $(Q_1)_{max} = 10^{-6} \times 6 \times 10^3 = 6mC$
While $(Q_2)_{max} = 3 \times 10^{-6} \times 4 \times 10^3 = 12mC$
However in series charge is same so maximum charge on C_2 will also be 6 mC (and not 12 mC) and potential difference across it $V_2 = 6mC/3\,\mu F = 2kV$ and as in series $V = V_1 + V_2$ so $V_{max} = 6kV + 2kV = 8kV$

64. **(d)** Start with C_2 and C_4 in parallel, then C_2 in series, then C_5 in parallel, then C_1 in series and finally C_6 in parallel.

65. (d) Let there are three capacitors with capacitances C_1, C_2, C_3 respectively and C_1 is removed.

In first case, $\frac{1}{C_{eq1}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ -----------(1)

In second case, $\frac{1}{C_{eq2}} = \frac{1}{C_2} + \frac{1}{C_3}$ ------(2)

From (1) and (2), $\frac{1}{C_{eq1}} = \frac{1}{C_1} + \frac{1}{C_{eq2}}$

or $\frac{1}{4} = \frac{1}{C_1} + \frac{1}{6}$ or $C_1 = 12\mu F$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(a)** Electrostatic force between the metal plates

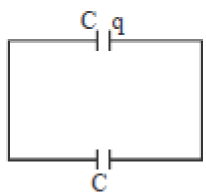
$$F_{plate} = \frac{Q^2}{2A_{\varepsilon_0}}$$

For isolated capacitor Q = constant
Clearly, F is independent of the distance between plates.

2. **(a)** As the regions are of equipotential, so Work done $W = q\Delta V$
ΔV is same in all the cases hence work - done will also be same in all the cases.

3. **(a)** When battery is replaced by another uncharged capacitor
As uncharged capacitor is connected parallel

So, $C^{|} = 2C$ and $V_c = \frac{q_1 + q_2}{C_1 + C_2}$; $V_c = \frac{q+0}{C+C} \Rightarrow V_c = \frac{V}{2}$



Initial Energy of system, $U_i = \frac{1}{2}CV^2$ ---------(i)

Final energy of system, $U_f = \frac{1}{2}(2C)\left(\frac{V}{2}\right)^2$ -------(i)

$= \frac{1}{2}CV^2\left(\frac{1}{2}\right)$; From equation (i) and (ii), $U_f = \frac{1}{2}U_i$

i.e., Total electrostatic energy of resulting system decreases by a factor of 2

4. **(d) When S and 1 are connected**
The $2\,\mu F$ capacitor gets charged. The potential difference across its plates will be V.
The potential energy stored in $2\,\mu F$ capacitor

$$U_i = \frac{1}{2}CV^2 = \frac{1}{2}\times 2\times V^2 = V^2$$

When S and 2 are connected

The 8 μF capacitor also gets charged. During this charging process current flows in the wire and some amount of energy is dissipated as heat. The energy loss is

$$\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}(V_1-V_2)^2$$

Here, $C_1 = 2\mu F, C_2 = 8\mu F, V_1 = V, V_2 = 0$

$$\therefore \Delta U = \frac{1}{2}\times\frac{2\times 8}{2+8}(V-0)^2 = \frac{4}{5}V^2$$

The percentage of the energy dissipated $= \frac{\Delta U}{U_i}\times 100 = \frac{\frac{4}{5}V^2}{V^2}\times 100 = 80\%$

5. **(a)** Force of attraction between the plates, F = qE

$$= q\times\frac{\sigma}{2\epsilon_0} = q\frac{q}{2A\epsilon_0} = \frac{q^2}{2\left(\frac{\epsilon_0 A}{d}\right)\times d} = \frac{c^2v^2}{2cd} = \frac{cv^2}{2d}$$

Here, $c = \frac{\epsilon_0 A}{d}, q = cv, A = \text{area}$

6. **(a)** Potential in a region

V = 6xy – y + 2yz

As we know the relation between electric potential and electric field is $\vec{E} = \frac{-dV}{dx}$

$$\vec{E} = \left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$$

$$\vec{E} = \left[\left(6y\hat{i} + (6x-1+2z)\hat{j} + (2y)\hat{k}\right)\right]$$

$$\vec{E}(1,1,0) = -\left(6\hat{i} + 5\hat{j} + 2\hat{k}\right)$$

7. **(c)** Capacitance of the capacitor, $C = \frac{Q}{V}$

After inserting the dielectric, new capacitance $C^{|} = \frac{V}{K}$

New potential difference

$$V^{|} = \frac{V}{K}$$

$$u_i = \frac{1}{2}cv^2 = \frac{Q^2}{2C}\ (\because Q = cV)$$

$$u_f = \frac{Q^2}{2f} = \frac{Q^2}{2kc} = \frac{C^2V^2}{2KC} = \left(\frac{u_i}{k}\right)$$

$$\Delta u = u_f - u_i = \frac{1}{2}cv^2\left\{\frac{1}{k}-1\right\}$$

As the capacitor is isolated, so change will remain conserved p.d. between two plates of the capacitor

$$L = \frac{Q}{KC} = \frac{V}{K}$$

8 **(d)** $\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{j}$

$$= -\left[(6-8y)\hat{i} + (-8x-8+6z)\hat{j} + (6y)\hat{k}\right]$$

At (1, 1, 1) $\vec{E} = 2\hat{i} + 10\hat{j} - 6\hat{k}$

$$\Rightarrow (\vec{E}) = \sqrt{2^2 + 10^2 + 6^2} = \sqrt{140} = 2\sqrt{35}$$

$$\therefore F = q\vec{E} = 2 \times 2\sqrt{35} = 4\sqrt{35}$$

9. **(b)** Due to conducting sphere

At centre, electric field E = 0

And electric potential $V = \dfrac{Q}{4\pi \in_0 R}$

10. **(c)** Electric field, $E \propto \dfrac{1}{K}$

As $K_1 < K_2$ so $E_1 > E_2$

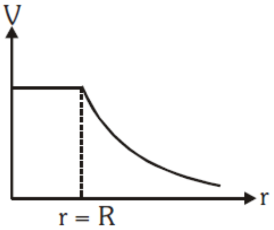
Hence graph (c) correctly dipicts the variation of electric field E with distance d.

11. $U_{initial} = \dfrac{1}{2}CV^2$

$$Loss = \frac{C.C}{2(C+C)}(V-0)^2 = \frac{1}{4}CV^2$$

$$\%Loss = \frac{\frac{1}{4}CV^2}{\frac{1}{2}CV^2} \times 100 = 50\%$$

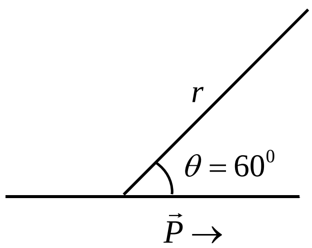
12. $V_{in} = V_S = \dfrac{KQ}{R}$ and $V_{out} = \dfrac{KQ}{r}(r > R)$



13. $C_O = \dfrac{\varepsilon_0 A}{d}$

$$C_K = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}} = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{8}} = \frac{8}{5}\frac{\varepsilon_0 A}{d} = \frac{8}{5}C_O$$

14. $V = \dfrac{KP\cos\theta}{r^2}$; $V = \dfrac{9\times10^9 \times 16\times10^9 \times \cos 60^0}{(0.6)^2}$



$$V = \frac{9 \times 16 \times \frac{1}{2}}{0.36} \;;\; V = \frac{72}{0.36} \;;\; V = 200V$$

15. Through out the volume electric potential is constant

V = constant $\Rightarrow dV = 0$

$\therefore E = \frac{-dV}{dr} = 0$

16. $\frac{\in_0 A}{d} = 6\mu F$ …. (1)

$\frac{\in A}{d} = 30\mu F$ ….. (2)

$\frac{(2)}{(1)} = \frac{\in}{\in_0} = 5 \Rightarrow \in = 5\in_0$

$= 5\times 8.85\times 10^{-12} = 44.25\times 10^{12} \approx 0.44\times 10^{-10} C^2 N^{-1} m^{-2}$

17. having a permanent electric dipole moment

18. For same potential $\frac{q_1}{q_2} = \frac{R_1}{R_2}$

$\frac{\sigma_1}{\sigma_2} = \frac{q_1}{q_2}\cdot\frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$

19. $u = -PE\cos\theta =$ PE

20. $\frac{1}{2}\rho V^2$; $\Rightarrow \frac{1}{2}\frac{\in_0 A}{d}.\mathrm{E}^2 d^2 = \frac{1}{2}\in_0 E^2 Ad$

21. 3rd capacitor is short circuited ; Ceq=2C

22. Electric potential due to a charged sphere $= \frac{kQ}{R}$

k = 9 × 10^9 N–m^2/C^2
Q : charge on sphere
R : Radius of sphere
Let charge and radius of smaller drop is q and r respectively

For smaller drop, $V = \frac{kq}{r} = 220V$

Let R be radius of bigger drop,

As volume remains the same $\left(\frac{4}{3}\pi r^3\right)\times 27 = \frac{4}{3}\pi R^3 \Rightarrow R = \sqrt[3]{27}r = 3r$

Now, using charge conservation,
$\Rightarrow Q = 27q$

$V_{big\,drop} = \frac{kQ}{R} = \frac{k(27q)}{3r} = 9\left(\frac{kq}{r}\right) = 9\times 200 = 1980V$

23. $V \propto \frac{1}{R}$

24. $V_{rms} = \frac{V_0}{\sqrt{2}}$

$V_0 = \sqrt{2}V_{rms}$

25. Electric lines of force are perpendicular to equipotential surface
$\therefore \theta = 90^0$

26. Common potential (V')

$$V' = \frac{CV+0}{2C} = \frac{V}{2} = \frac{100}{2} = 50V$$

Energy stored in the system

$$\frac{1}{2}CV_1^2 \times 2 = \left(\frac{1}{2}CV_1^2\right)\times 2 = \frac{CV^2}{4} = \frac{900\times10^{-12}\times(100)^2}{4} = 2.25\times10^{-6}\,J$$