UNIT-I ELECTROSTATICS

CH:2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

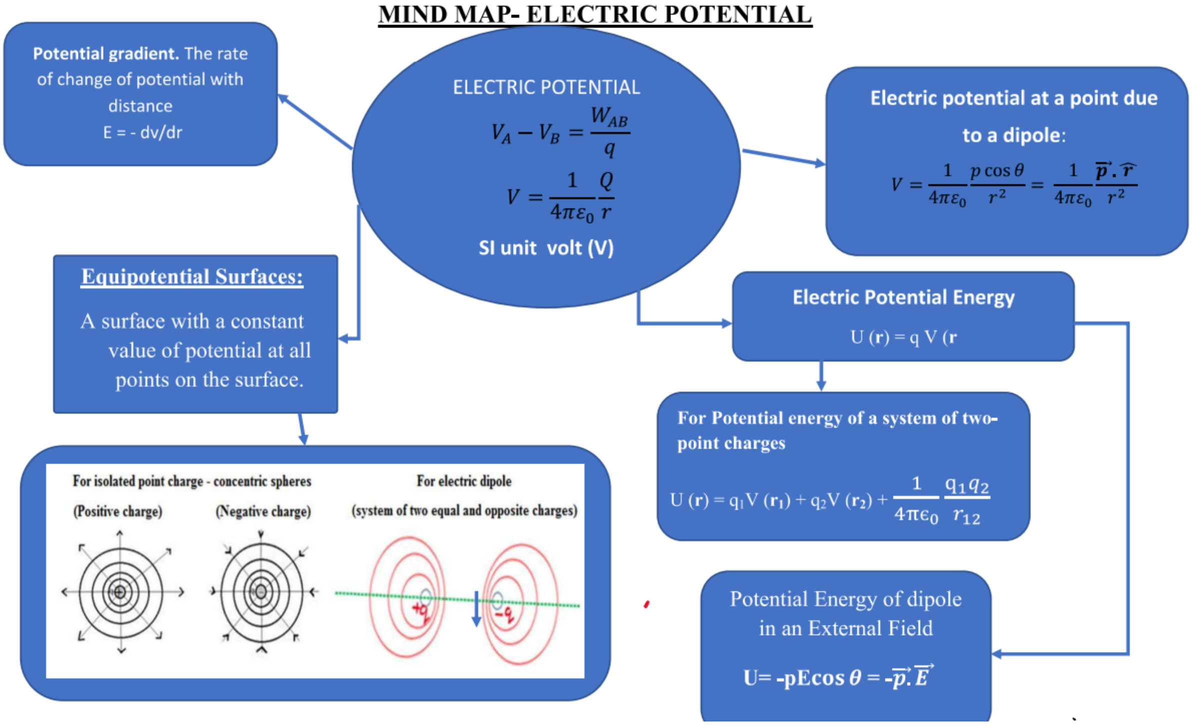
GIST

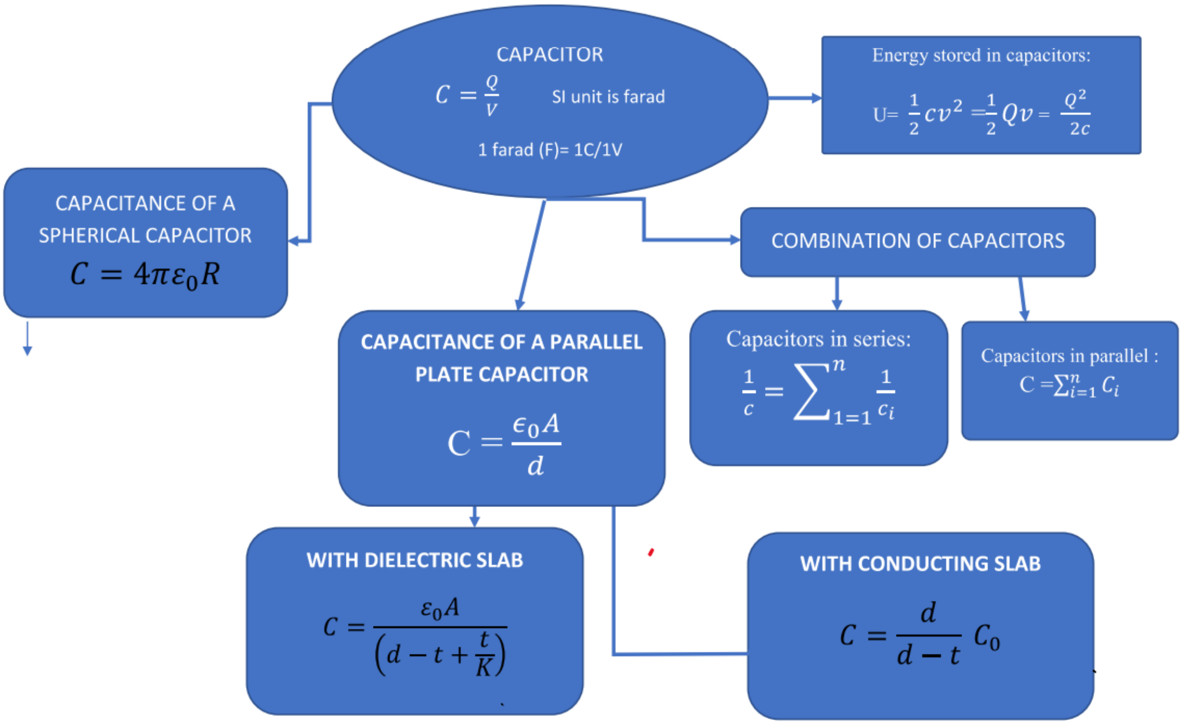
Electric potential, Potential difference, electric potential due to a point charge, a dipole and system of charges, equipotential surfaces, electric potential energy of a system of two point in charges and of electric dipole in an electrostatic field.

Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates; energy stored in a capacitor (no derivation formulae only.

MIND MAPS

MIND MAP- ELECTRIC POTENTIAL





IMPORTANT POINTS

➢ Work done by an electrostatic force in moving a charge from one point to another depends only on the initial & final position and not on the path followed by the charged particle.

➢ Work done by the electrostatic force in moving a charge in closed path is zero

➢ The potential due to a dipole depends not just on r but also in the angle between the position vector (r) and dipole moment vector ($\vec{P}$).

➢ The electric dipole potential falls off as 1/ r^2 not as 1/r characteristic of the potential due to a single charge .

➢ No work is done in moving a test charge over an equipotential surface.

➢ electric field is always normal to the equipotential surface at every point .

➢ No two equipotential surface can intersect each other.

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

Its magnitude is given by the change in the magnitude of potential per unit displacement normal to the equipotential surfaces at the point.

➢ On equatorial points of dipole , V=0 but E ≠ 0

➢ Inside a charged spherical shell , E=0 but V ≠ 0

. ➢ Net electric charge in the interior of a conductor is zero.

➢ Insertion of a dielectric reduces the electric field between the plates of a capacitor

➢ In a series combination of capacitor, the charges on each capacitor are same but the potential difference across any capacitor is inversely proportional to its capacitance.

➢ In a parallel combination of capacitors, the potential difference across each capacitor is same but the charged stored in any capacitor is proportional to its capacitance.

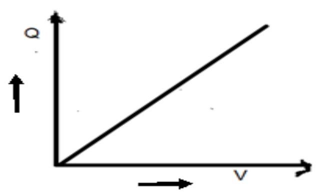
➢ When charges are shared between any two bodies, their potential become equal. The charges acquired are in the ratio of their capacities. No charges is lost, but some loss of energy does occur.

➢ The capacitance of a capacitor depends neither on Q nor on V. It depends upon the shape and size of the conductor.

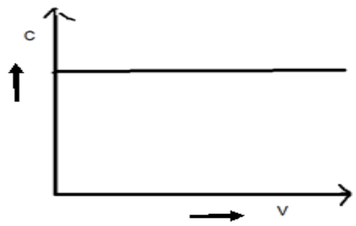
➢ The maximum electric field that a dielectric medium can withstand without break-down (of its insulating property) is called its dielectric strength; for air it is about $3 \times 10^{6}\ \mathrm{Vm^{-1}}$. For a separation between conductors of the order of 1 cm or so, this field corresponds to a potential difference of 3×10^{4} V between the conductors. Thus, for a capacitor to store a large amount of charge without leaking, its capacitance should be high enough so that the potential difference and hence the electric field do not exceed the break-down limits. Put differently, there is a limit to the amount of charge that can be stored on a given capacitor without significant leaking. In practice, a farad is a very big unit.

GRAPHS

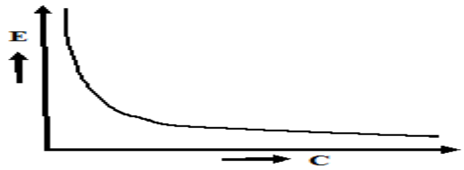
1.Graph between Q &V



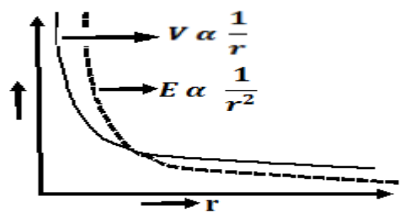
2.Graph between C& V



3.Graph between E & C



4.Graph of E & V verses distance r for a point charge



FORMULAE WITH NOTATIONS AND SYMBOLS

***Potential difference** : work done / charge =W/q

***Electric potential due to point charge q** at a distance r from it : V =Kq /r(1 /4π∈0 = K)

* **Electric potential at a point due to N point charges**:

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1}+\frac{q_2}{r_2}+\frac{q_3}{r_3}+-------+\frac{q_n}{r_n}\right)$$

***Electric potential at a point due to a dipole**:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r2}$$

***Potential Energy of a system of two-point charges**: U = $\frac{q_1 q_2}{4\pi\epsilon_0 r}$

***Potential Energy of a system of three-point charges**: U = $\frac{1}{4\pi\epsilon_0}\left[\frac{q_1 q_2}{r_{12}}+\frac{q_1 q_3}{r_{13}}+\frac{q_2 q_3}{r_{23}}\right]$

***Potential energy of a single charge in an external Field**: U (**r**) = q V (**r**)

* **Potential energy of two charges in an external Field**

U (**r**) = q_1V (**r₁**) +q_1V (**r₁**) + $\frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}}$

***Electric Potential Energy of an electric dipole**

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

If $\theta_1 = 90^o$ *and* $\theta_2 = \theta$ then U= -pE$\cos\theta$= -$\vec{p}.\vec{E}$

Units: Charge- coulomb, Electric dipole moment- coulomb metre (Cm)

Distance- metre ,

Energy- joule or electron volt (eV) (1eV = 1.6 × 10^{-19} J)

Capacitance: Ratio of charge & potential difference. (It is Scalar) $C = \frac{Q}{V}$.

SI.unit :**farad (F)**

Capacitance of a parallel plate capacitor with no medium between plates :C_0= C =$\frac{\epsilon_0 A}{d}$

Capacitance of a parallel plate capacitor with a dielectric medium of dielectric constant K thickness t in between :

$C_m = \frac{\epsilon_0 A}{\left(d-t+\frac{t}{K}\right)}$

If t = 0 then $C_0 = \frac{\varepsilon_0 A}{d}$ If t = d then $C_m = K\frac{\epsilon_0 A}{d}$ $C_m = KC_0$

***Combination of capacitors**: (i) Capacitors in series: $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$

(ii) Capacitors in parallel :**C** =$\sum_{i=1}^{n} C_i$

*__Energy stored in capacitors__: **U=** $\frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$

*__Energy density__ :**U$_d$ =** $\frac{1}{2}\epsilon_0 E^2 = \frac{\sigma^2}{2\epsilon_0}$

Capacitance of a parallel plate capacitor with a dielectric medium of dielectric constant K thickness t in between :

$$C_m = \frac{\epsilon_0 A}{\left(d - t + \frac{t}{K}\right)}$$

If t = 0 then $C_0 = \frac{\varepsilon_0 A}{d}$ If t = d then $C_m = K\frac{\epsilon_0 A}{d}$

⇒ $C_m = KC_0$

*__Combination of capacitors__: (i) Capacitors in series: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

(ii) Capacitors in parallel :**C =**$\sum_{i=1}^{n} C_i$

*__Energy stored in capacitors__: **U=** $\frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$

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*__Introducing dielectric slab between the plates of the charged conductor with:__

PROPERTY	**BATTERY CONNECTED**	**BATTERY DISCONNECTED**
Charge	KQ_0	Q_0
Potential difference	V_0	V_0/K
Electric Field	E_0	E_0/K
Capacitance	KC_0	KC_0
Energy	$K\,\frac{1}{2}\epsilon_0 E^2$ (Energy is supplied by battery)	$\frac{1}{K}\frac{1}{2}\epsilon_0 E^2$ (Energy used for polarization)

*__On connecting two charged capacitors:__

(a) Common Potential : $V = \frac{C_1V_1 + C_2V_2}{V_1 + V_2}$

(b)Loss of energy : $\Delta U = \frac{1}{2}\frac{C_1 \times C}{(C_1 + C_2)}(V_1 - V_2)^2$

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QUESTION BANK

MULTIPLE CHOICE QUESTIONS (LEVEL 1)

Q1. If voltage applied on a capacitor is increased from V to 2V, choose the correct conclusion.

(a) Q remains the same, C is doubled

(b) Q is doubled, C doubled

(c) C remains same, Q doubled

(d) Both Q and C remain same

Q2. A parallel plate capacitor is charged. If the plates are pulled apart

(a) The capacitance increases

(b) The potential differences increase

(c) The total charge increases

(d) The charge & potential difference remain the same

Q3. Which of the following is an example of a molecule whose centre of mass of positive and negative charges coincide each other?

(a)CO_2 (b) CO (c) CH_3OH (d) NH_3

Q4.What is the angle between electric field and equipotential surface?

(a) 90^o always (b)0^o always (c)0^o to 90 (d)0^o to 180^o

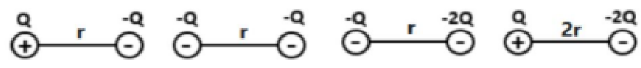
Q5. If we carry a charge once around an equipotential path, then work done by the charge is:

(a) Infinity (b) Positive (c) Negative (d) Zero

Q6. Capacitor of a spherical capacitor may depend upon

(a) radius of capacitor (b)dielectric medium (c)applied potential difference (d)both (a) and (b)

Q7. The decreasing order of the electrostatic potential energies for the given system of charges will be-



(a) c > b > a > d (b) d > a > c = b (c) a > c > d = b (d) c > b > a = d

Q8. An electron is accelerated from rest through a potential difference V. Its final speed is proportional to:

a) V b) V/2 c) √V d) 1/V

Q9.Capacitors A and B are identical. Capacitor A is charged so it stores 4 J of energy and capacitor B is uncharged. The capacitors are then connected in parallel. The total stored energy in the capacitors is now:

a) 16 J b) 8 J c) 4 J d) 2 J

Q10.If both the plate area and the plate separation of a parallel-plate capacitor are doubled, the capacitance is:

a) doubled b) halved c) unchanged d) tripled

Q11. An electric dipole of dipole moment p is placed in a uniform electric field of strength E in a direction perpendicular to the field. The work done in rotating the dipole by an angle 900 without acceleration in a plane perpendicular to the field is:

a) pE b) –pE c). Zero d). -2pE

Q12.A small metallic ball having charge q is placed inside an insulated box. The insulated box is then placed inside a metallic box. The net charge enclosed inside the metallic box is:

a)Zero b) q c)–q d) 2q

Q13. In a parallel plate capacitor, the capacity increases if

(a) area of the plate is decreased.

(b) distance between the plates increases.

(c) area of the plate is increased.

(d) dielectric constantly decreases.

Q14 An electron moves from point i to point f, in the direction of a uniform electric field. During this displacement:

a) The work done by the field is positive and the potential energy of the electron-field system increases.

b) The work done by the field is negative and the potential energy of the electron-field system increases.

c) The work done by the field is positive and the potential energy of the electron-field system decreases.

d) The work done by the field is negative and the potential energy of the electron-field system decreases.

ASSERTION – REASON QUESTIONS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) Assertion is correct, Reason is incorrect

(d) Both Assertion and Reason are correct.

Q15. Assertion : If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.

Reason : Capacity of the capacitor does not depend upon the nature of the material.

Q16. Assertion : A parallel plate capacitor is connected across battery through a key. A dielectric slab of dielectric constant K is introduced between the plates. The energy which is stored becomes K times.

Reason : The surface density of charge on the plate remains constant or unchanged.

Q17.Assertion: A spherical equipotential surface is not possible for a point charge.

Reason: A spherical equipotential surface is not possible inside a spherical capacitor.

Q18.Assertion: The equatorial plane of a dipole is an equipotential surface.

Reason: The electric potential at any point on equatorial plane is zero.

Q19.Assertion: Electric potential and electric potential energy are different quantities.

Reason: For a system of positive test charge and point charge electric potential energy = electric potential.

Q20.Assertion: Two equipotential surfaces cannot intersect each other.

Reason: Two equipotential surfaces are parallel to each other.

MULTIPLE CHOICE QUESTIONS (LEVEL 2)

Q1. A point P lies at a distance x from the mid point of an electric dipole on its axis. The electric potential at point P is proportional to

(a)$1/x^2$ (b)$1/x^3$ (c)$1/x$ (d) $1/x^{1/2}$

Q2. If the electric potential on the axis of an electric dipole at a distance r from its centre is V, then its potential at a point at the same distance on its equatorial linewill be
(a)2V (b) -V (c)V/2 (d) Zero

Q3.A +3.0 nC charge Q is initially at a distance of r_1 = 10 cm from a + 5.0 nC charge q fixed at the origin. The charge Q is moved away from q to a new position at r_2 = 15 cm. in this process work done by the field is
(a) 1.29×10^{-5} J (b) 3.6×10^{5} J (c) -4.5×10^{-7} J (d) 4.5×10^{-7} J

Q4.A variable capacitor is connected to a 200 V battery. If its capacitance is changed from 2 µF to X µF, then the decrease in energy of the capacitor is 0.02 J. the value of X is
(a) 1µF (b) 2 µF (c) 3 µF (d)4 µF

Q5.The capacitors each of 4µF are to be connected in such a way that the effective capacitance of the combination is 6 µF. this can be achieved by connecting

(a)All three in parallel
(b)All three in series
(c)Two of them connected in series and the combination in parallel to the third
(d)Two of them connected in parallel and the combination in series to the third

Q6. Three capacitors 2 µF, 3 µF and 6 µF are joined in series with each other. The equivalent capacitance is

(a) ½ µF (b)1 µF (c)2 µF (d)11 µF

Q7. The work done in moving a unit positive test charge over a closed path in an electric field is _____________.

(a) Always 1 (b)Infinite (c) Zero (d) Negative

Q8. Consider a uniform electric field in the z-direction. The potential is a constant
(a) for any x for a given z
(b) for any y for a given z
(c) on the x-y plane for a given z
(d) all of these

Q9. An electric dipole of moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. Then
(i) the torque on the dipole is $\vec{p} \times \vec{E}$

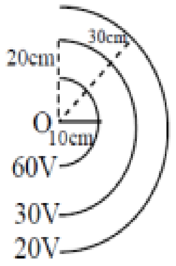
(ii) the potential energy of the system is $\vec{p} \cdot \vec{E}$

(iii) the resultant force on the dipole is zero.

Choose the correct option.

(a) (i), (ii) and (iii) are correct
(b) (i) and (iii) are correct and (ii) is wrong
(c) only (i) is correct
(d) (i) and (ii) are correct and (iii) is wrong

Q10. The figure shows some concentric equipotential surfaces. The correct choice related to the electric field and its direction is-



(a) $E \propto 1/r$ and radially inward (b) $E \propto 1/r^2$ and radially outward
(c) $E \propto 1/r$ and radially outward (d) $E \propto 1/r^2$ and radially inward

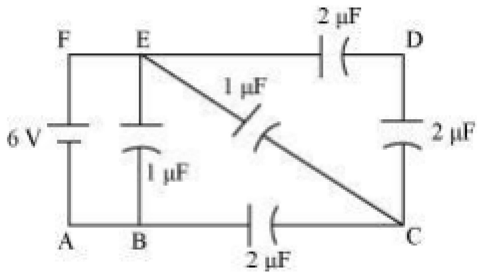
MULTIPLE CHOICE QUESTIONS (LEVEL 3)

Q1. Two charges 14 µC and -4 µC are placed at (-12 cm, 0,0) and (12 cm, 0,0) in an external electric field $E = (B/r^2)$, where $B = 1.2 \times 10^6$ N/cm^2 and r is in metres. The electrostatic potential energy of the configuration is
(a) 97.9 J (b) 102.1 J (c) 2.1 J (d) -97.9 J

Q2. The equivalent capacitance of the combination between A and B in the given figure is 4uf.Calculate capacitance of the capacitor C and charge on each capacitor if a 12V battery is connected across terminals A and B.

(a) 10uf and 48uC (b) 05uf and 48uC (c) 10uf and 24uC (d) 2.5uf and 48uC

Q3. Find the total energy stored in the capacitors in the given network.

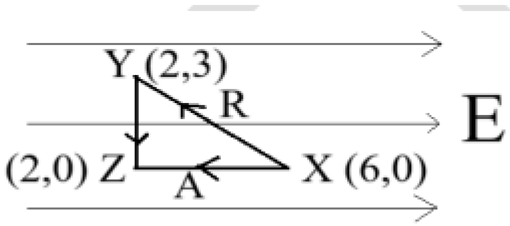


(a) 3.6×10^{-5} J (b) 3.6×10^{-6} J (c) 7.2×10^{-6} J (d) 7.2×10^{-5} J

Q4. Two point charges 10×10^{-8} μC and -2×10^{-8} μC are separated by distance of 60 cm in air. Find at what distance from the 1st charge, would the electric potential will be zero.

(a) 5m (b) 5cm (c) 50cm (d) 1m

Q5. Two charges of same nature and magnitude +q are kept fixed at points X inside a uniform electric field. Now to shift the charges, Rahul used a path X → Y → Z (shown as 'R' in the diagram) and Amol used a different path of direct X → Z (shown as 'A' in the diagram). Find the ratio of their work done to move the charge from X to Y.



(a) 2:1 (b) 1:2 (c) 1:3 (d) 1:1

Q6. An uniform electric field exists in the negative-Y direction. Which of the following statement(s) is/are correct:

i. The potential decreases as one moves along positive Y axis

ii. The potential remains constant as one moves along negative Y axis

iii. The potential remains constant as one moves along negative Z axis

iv. The potential remains constant as one moves along positive X axis

a. i, ii, iii and iv b. i and ii c. iii and iv d. i, iii and iv

Q7. Samir founds that a conductor has a potential V ≠ 0 and there are no charges anywhere else outside. Then he concludes-

(1) There must be charges on the surface or inside itself.

(2) There can't be any charge in the body of the conductor.

(3) There must be charges only on the surface.

(4) There must be charges inside the surface. The correct conclusions are-

(a) 1 and 4 (b) 1, 2 and 3 (c) 1 and 2 (d) all

Q8.In a certain region of 0.1 cubic metre of space ,electric potential is found to be 5V throughout .What is the electric field in this region ?
(a)0.5 v/m (b)2 V/m (c)0v/m (d)0.02 V/m

Q9.A thin metal sheet is placed in the middle of a parallel plate capacitor. What will be the effect on its capacitance ?
(gets doubled (b)no effect (c)halved (d)becomes three times

Q10. Three capacitors of 3 ,3 and 6 micro farad are connected in series to a 10V source. The charge on the 3icro farad capacitor is
(a)5 µC (b)12 µC (c)15µC (d)10 µC

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2 MARKS QUESTIONS (Level 1)

Q1.Sketch equi potential surfaces for
(a) A negative point charge (CBSE 2001)
(b) Two equal and positive charges separated by a small distance. (CBSE 2015)

Q2.Deduce the expression for the potential energy of an electric dipole placed with its axis at an angle θ to the external field $\vec{E}$.Hence discuss the conditions of its stable and unstable equilibrium. (CBSE 2008,2019,2021 Compt.)

Q3.A metal plate is introduced between the plates of a charged parallel plate capacitor. What is its effect on the capacitance of the capacitor.

Q4.Two capacitors have a capacitance of 5μF when connected in parallel and 1.2μF when connected in series. Calculate their capacitances.

Q5.An isolated capacitor of unknown capacitance C is charged to a potential difference V. It is then connected in parallel to an uncharged capacitor of cap acitance Co such that the potential difference across the combination become s V/3. Determine the unknown capacitance C.

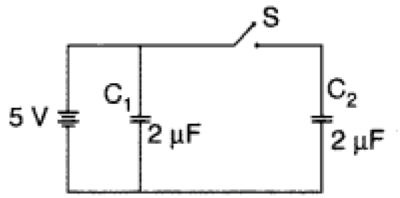
Q6.A parallel plate capacitor C with a dielectric in between the plates is charged to a potential V by connecting it to a battery. The capacitor is then isolated. If the dielectri c is withdrawn from the capacitor,
(a) Will the energy stored in the capacitor increase or decrease?
(b)Will the potential difference across the capacitor plates increase or decrease ? Give an explanation.

Q7.A capacitor is connected across a battery .(i)Why does each plate receive a charge of exactly the same magnitude ?(ii)Is this true even if the plates are of different sizes?

Q8. Establish the equation for electric potential at any point in the electric field due to a point change by using fundamental relation.

2 MARKS QUESTIONS(LEVEL 2)

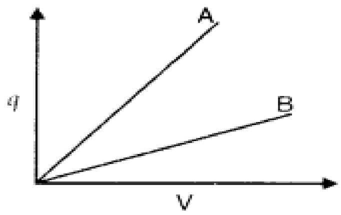
Q1.If two charged conductors are touched mutually and then separated, prove that the charges on them will be divided in the ratio of their capacitances.



Q2. Figure shows two identical capacitors C_1 and C_2, each of 2 μF capacitance, connected to a battery of 5 V. Initially switch 'S' is left open and dielectric slabs of dielectric constant K = 5 are inserted to fill completely the space between the plates of the two capacitors.

(i) How will the charge and

(ii) potential difference between the plates of the capacitors be affected after the slabs are inserted?



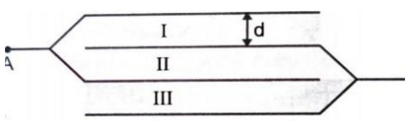
Q3. The given graph shows variation of charge 'q' versus potential difference 'V' for two capacitors C_1 and C_2. Both the capacitors have same plate separation but plate area of C_2 is greater than that of C_1. Which line (A or B) corresponds to C_1 and why?

Q4. Why does current in a steady state not flow in a capacitor connected across a battery? However momentary current does flow during charging or discharging of the capacitor. Explain.

Q5. Three capacitors of equal capacitance, when connected in series, have a net capacitance of C_s and when connected in parallel, have a capacitance of C_p. Calculate the value of C_s / C_p.

2 MARKS QUESTIONS (LEVEL 3)

Q1. A capacitor has some dielectric between its plates and the capacitor is connected to a DC source. The battery is now disconnected and then the dielectric is removed. State whether the capacitance, electric field, charge stored and the voltage will increase, decrease or remain constant.



Q2.What is the capacitance of arrangement of 4 plates of area A at distance d in air in fig.

Q3.A parallel plate capacitor has square plates of side 5 cm and separated by a distance of 1 mm. (a) Calculate the capacitance of this capacitor. (b) If a 10 V battery is connected to the capacitor, what is the charge stored in any one of the plates? (The value of $\varepsilon_0 = 8.85 \times 10^{-12}\ Nm^2\ C^{-2}$)

3MARKS QUESTIONS (LEVEL 1)

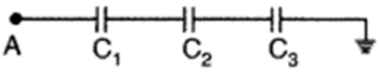
Q1. Obtain the expression for the resultant capacitance when three capacitors C_1 , C_2 and C_3 are connected (i) in series (ii) in parallel.

Q2. Define the capacitance of a capacitor. Obtain the expression for the capacitance of a parallel plate capacitor in vacuum in terms of plate area A and separation d between the plates.

Q3. Find the expression for the capacitance of a parallel plate capacitor of area A and plate separation d if a dielectric slab of thickness t (t<d) is introduced between the plates of capacitor.
Q4. (a) Define the SI unit of capacitance.
(b) Obtain the expression for the capacitance of a parallel plate capacitor.
Q5. A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

3 MARKS QUESTIONS (LEVEL 2)

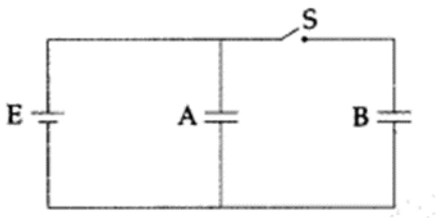
Q1. Calculate the potential difference and the energy stored in the capacitor C_2 in the circuit shown i the figure. Given potential at A is 90 V, C_1 = 20 µF, C_2 = 30 µF and C_3 = 15 µF.



Q2. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 300 µC. When potential across the capacitor is reduced by 100 V, the charge stored in it becomes 100 V. Calculate the potential V and the unknown capacitance. What will be the charge stored in the capacitor if the voltage applied had increased by 100 V?
Q3. A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from battery and then connected to another uncharged capacitor of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor.

3 MARKS QUESTIONS (LEVEL 3)

Q1. A 200 µF parallel plate capacitor having plate separation of 5 mm is charged by a 100 V dc source. It remains connected to the source. Using an insulated handle, the distance between the plates is doubled and a dielectric slab of thickness 5 mm and dielectric constant 10 is introduced between the plates. Explain with reason, how the (i) capacitance, (ii) electric field between the plates, (iii) energy density of the capacitor will change ?
Q2.Two identical parallel plate capacitors A and B are connected to a battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric.



Q3.The area of each of the plates of a parallel plate air capacitor is 7 cm^2 .
(a) Determine the maximum charge this capacitor can store without breakdown.
(b)A material of dielectric constant 2 and dielectric strength 15 x 10^6 V/m is inserted into the capacitor. Find the percentage change in the maximum chargethat can be stored in the capacitor with the dielectric material. (Take Dielectric strength of air = 3 x 10^6 V/m, ϵ_o = 8.8 x10^{-12} C^2/Nm^2)

5 MARKS QUESTIONS (LEVEL 1)

Q1.A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored on the capacitor. Without disconnecting the battery, the plates of the capacitor are pulled apart to a larger distance of separation. What changes will occur in each of the following quantities? Will they increase, decreas or remain the same? Give an explanation in each case.

(a) Capacitance (b) Charge (c) Potential difference (d) Electric field (e) Energy stored in the capacitor

5 MARKS QUESTIONS (LEVEL 2)

Q1. a) Explain, using suitable diagrams, the difference in the behaviour of a

(i) conductor and

(ii) dielectric in the presence of external electric field. Define the terms polarization of a dielectric and write its relation with susceptibility.

5 MARKS QUESTIONS (LEVEL 3)

Q1..(a) Define potential energy of a system of two charges.

(b)Two-point charges q_1 and q_2, separated by a distance r_{12} are kept in an external electric field. Derive an expression for the potential energy of the system of two charges in the field.

NUMERICALS (LEVEL 1)

Q1.Two +ve charges of 0.2 μC and 0.01 μC are placed 10 cm apart. Calculate the work done in reducing the distance to 5 cm.

Q2. A parallel plate capacitor has its plate of area 6.6 cm^2 separated by 0.7mm thick mica slab. Calculate the capacitance of the capacitor if dielectric constant of mica is 6.

Q3. A capacitor of unknown capacitance is connected across a battery of V volt. A charge of 120 μC is stored in it. When the potential across the capacitor is reduced by 40 V, the charge stored in the capacitor becomes 40 μC. Calculate V and the unknown capacitance. What would have been the charge in the capacitor if the voltage were increased by 40 V?

Q4. Two metal spheres, one of radius R and the other of radius 2R, both have same surface charge density σ. They are brought in contact and separated. What will be the new surface charge densities on them?

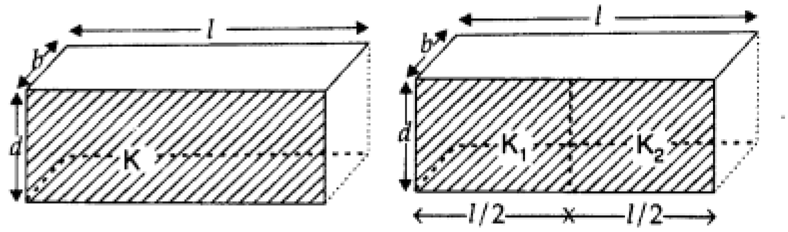
NUMERICALS (LEVEL 2)

Q1. A parallel plate capacitor, of capacitance 20pF, is conneted to a 100 V supply. After sometime the battery is disconnected, and the space, between the plates of the capacitor is filled with a dielectric, of dielectric constant 5. Calculate the energy stored in the capacitor

(i) before

(ii) after the dielectric has been put in between its plates.

Q2. Two identical capacitors of plate dimensions l × b and plate separation d have di-electric slabs filled in between the space of the plates as shown in the figure.



Obtain the relation between the dielectric constants K, K_1 and K_2.

Q3. A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Without disconnecting the battery, the distance between the plates is tripled and a dielectric medium of k = 10 is introduced between the plates is tripled and a dielectric medium of k = 10 is introduced between the plates of the capacitor. Explain giving reasons, how will the following be affected:

(i) capacitance of the capacitor

(ii) charge on the capacitor

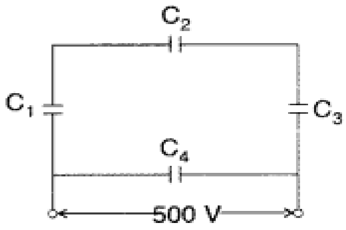
NUMERICALS (LEVEL 3)

Q1. A network of four capacitors each of 12μF capacitance is connected to a 500 V supply as shown in the figure.

Determine

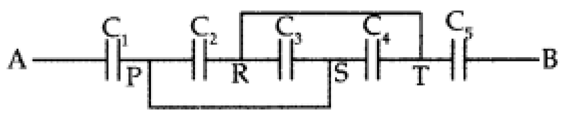
(a) equivalent capacitance of the network and

(b) charge on each capacitor.



Q2. A capacitor of unknown capacitance is connected across a battery of V volt. A charge of 240 pC is stored in it. When the potential across the capacitor is reduced by 80 V, the charge stored in the capacitor becomes 80 pC. Calculate V and the unknown capacitance. What would have been the charge in the capacitor if the voltage were increased by 80 V?

Q3. Find equivalent capacitance between A and B in the combination given below. Each capacitor is of 2 μF capacitance.



COMPETENCY BASED QUESTION

Q1.The capacitance of an infinite parallel capacitor without any dielectric betweenthe plates is C. It is then half-filled with a dielectric medium of K = 4 as in

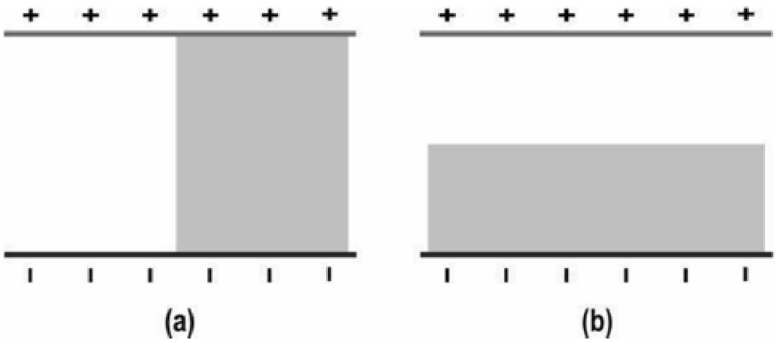
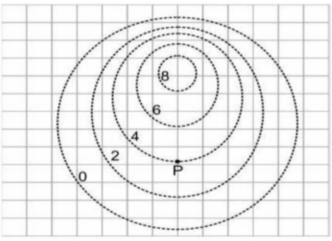


Fig (a) and then as in Fig (b). Show that capacitance in Fig (a) becomes 5C and in Fig (b) the capacitancebecomes (4/5)C due to the introduction of the dielectric medium.

Q2.The diagram below shows an arrangement of a set of equipotential lines in a given Region.Each line is marked with the potential it represents.
The background gridlines are squares of each side equal to 1 cm

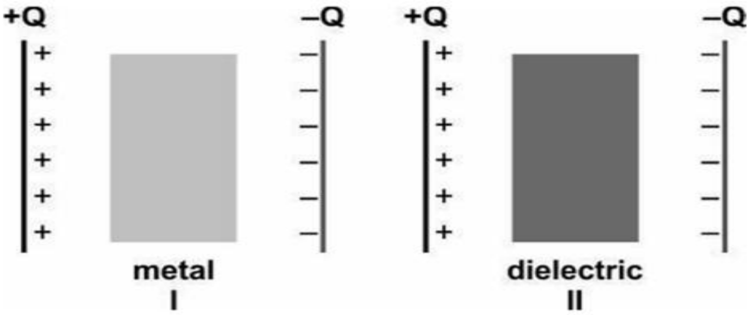


(a) Determine electric field at point P.

(b) Draw 6 field lines to represent the electric field in this region.

CCT BASED QUESTION

Q1.Given is a pair of parallel charged metal plates in the arrangement as shown.

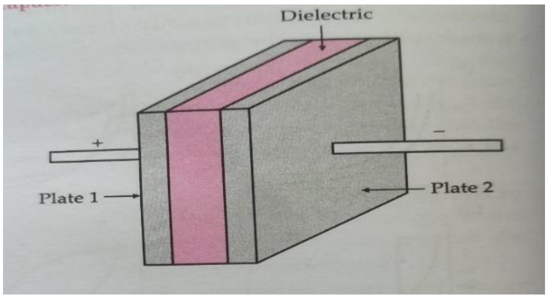


(a) Sketch the electric field lines between the plates in I and II.

(b) Mention whether net electric field intensity is zero or non-zero in each case.

CASE STUDY BASED QUESTION

An arrangement of two conductors separated by an insulating medium can be used to store electric charge and electric energy. Such a system is called a capacitor. The more charge a capacitor can store, the greater is its capacitance. Usually, a capacitor consists of two conductors having equal and opposite charge +Q and -Q. Hence, there is a potential difference V between them. By the capacitance of a



capacitor, we mean the ratio of the charge Q to the potential difference V. By the charge on a capacitor we mean only the charge Q on the positive plate. Total charge of the capacitor is zero. The capacitance of a capacitor is a constant and depends on geometric factors, such as the shapes, sizes and relative positions of the two conductors, and the nature of the medium between them. The unit of capacitance is farad (F), but the more convenient units are μF and pF. A commonly used capacitor consists of two long strips or metal foils, separated by two long strips of dielectrics, rolled up into a small cylinder. Common dielectric materials are plastics (such as polyestors and polycarbonates) and aluminium oxide. Capacitors are widely used in radio, television, computer, and other electric circuits.

1.A parallel plate capacitor C has a charge Q . The actual charge on its plates are

(a) Q,Q (b) Q/2, Q/2

(c) Q ,-Q (d) Q/2, -Q/2

2.A parallel plate capacitor is charged. If the plates are pulled apart .

(a) the capacitance increases (b) the potential difference increases

(c) the total charge increases (d) the charge & potential difference remains same

3.Three capacitors of 2 , 3 & 6 μF are connected in series to a 10 V source. The charge on the 3 μF capacitor is

(a) 5μC (b) 10μC (c) 12μC (d) 15μC

4.If n capacitors each of capacitance C are connected in series, then the equivalent capacitance of the combination is

(a) NC (b) n^2C (c) C/n (d) C/n^2

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SELF ASSESSMENT

MARKS 25 **DURATION 40 MINUTES**

MULTIPLE CHOICE QUESTIONS

Q1. A parallel plate capacitor is connected with the terminals of a battery. The distance between the plates is 6mm. If a glass plate (dielectric constant K = 9) of 4.5 mm is introduced between them, then the capacitance will become

(a) 2 times (b) the same (c) 3 times (d) 4 times.

Q2. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is then introduced between the plates, which results in

(a) reduction of charge on the plates and increase of potential difference across the plates.

(b) increase in the potential difference across the plate, reduction in stored energy, but no change in the charge on the plates.

(c) decrease in the potential difference across the plates, reduction in the stored energy, but no change in the charge on the plates.

(d) none of these

Q3. Which of the following statement is true?

(a) Electrostatic force is a conservative force.

(b) Potential at a point is the work done per unit charge in bringing a charge from any point to infinity.

(c) Electrostatic force is non-conservative

(d) Potential is the product of charge and work.

Q4. Which of the following statements is false for a perfect conductor?

(a) The surface of the conductor is an equipotential surface.

(b) The electric field just outside the surface of a conductor is perpendicular to the surface.

(c) The charge carried by a conductor is always uniformly distributed over the surface of the conductor.

(d) None of these

Q5. Assertion : Two equipotential surfaces cannot cut each other.

Reason : Two equipotential surfaces are parallel to each other.

Q6. Assertion : A dielectric is inserted between the plates of a battery connected capacitor. The energy of the capacitor increases.

Reason : Energy of the capacitor, $U=CV^2/2$

2 MARKS QUESTIONS

Q7. Consider a uniform electric field 3×10^3 i N/C. calculate the flux of this field through a square surface of area 10 cm^2 when

(i) Its plane is parallel to the y-z plane

(ii) The normal to its plane makes a 60^o angle with the x axis.

Q8. Define potential difference .How is it related to work. Calculate the work done in carrying an α-particle across a potential difference of one volt.

3MARKS QUESTIONS

Q9. A charge of 24μC is given to a hollow metallic sphere of radius 0.2 m. find the potential

a. At the surface of the sphere
b. At a distance 0.1cm from the centre of the sphere
c. At the centre of the sphere.

Q10. Derive the expression for electrostatic potential due to dipole .Hence ,find the value of potential on axial and equatorial line of dipole.

5 MARKS QUESTION

Q11. (a)Write any two properties of equipotential surfaces. What will be the equipotential surface for a dipole.
(b)Two charges –q and +q, are located at points (0, 0, –a) and (0, 0, a), respectively.
(i)What is the electrostatic potential at the points (0, 0, z) and (x, y, 0)?
(ii)Obtain the dependence of potential on the distance r of a point from the origin when r/a >> 1.
(iii) How much work is done in moving a small test charge from the point (5,0,0) to (–7,0,0) along the x-axis? Does the answer change if the path of the test charge between the same points is not along the x-axis?

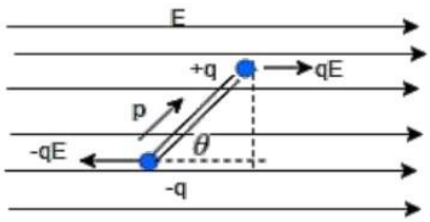
Q12.CASE STUDY BASED QUESTION

POTENTIAL ENERGY OF A DIPOLE

Consider a dipole with charge $q_1 = +q$ and $q_2 = -q$ placed in a uniform electric field E, as shown in figure. The dipole experiences no net force but experiences a torque τ given by $\tau = p \times E$, which will tend to rotate it (unless p is parallel or antiparallel to E). Suppose an external torque τ_{ext} is applied in such a manner that it just neutralizes this torque and rotates it in the plane of paper from angle θ_0 to θ_1 at an infinitesimal angular speed and without angular acceleration. The amount of work done by the external torque will be given by

$pE(\cos\theta_0 - \cos\theta_1)$

This work is stored as the potential energy of the system.



Q1.When a dipole is placed in uniform electric field ,then
(a)It experiences torque but not force
(b)It experiences force but not torque.
(c) It experiences both force and torque.
(d) It experiences neither force not torque.

Q2.The dipole experiences maximum torque when the angle between dipole and field is

(a)0degree (b)60 degree (c)90 degree (d)180 degree

Q3.If the work done required from 0 degree to 60 degree in uniform electric field is W,What is the work done in rotating the dipole in the same field from 0 to 180 degrees?

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

Q4.A dipole placed in uniform electric field experiences no torque when

(a)If the dipole is parallel to the field .

(b)If the dipole is antiparallel to the field.

(c)both (a) and (b)

(d)None of these

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