[Current Electricity]

Conceptual Questions :

1. If a copper wire is stretched to make it 0·1% longer, what is the percentage change in its resistance? (I.I.T. 1978)

2. Three equal resistors connected in series across a source of e.m.f. together dissipate 10 watts of power. What would be power dissipated if the same resistors are connected in parallel across the same source of emf?

3. A primary and a secondary cell have the same e.m.f. Which of these will provide higher value of the maximum current that can be drawn? Explain briefly. (I.I.T. 1977)

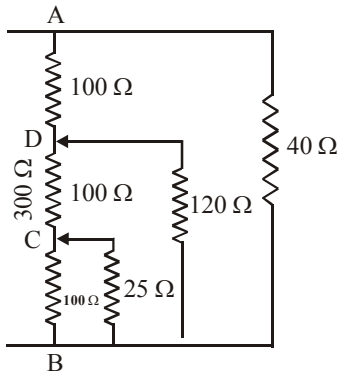
4. A steady current is flowing in a cylindrical conductor. Is there any electric field with in the conductor? (I.I.T. 1982)

5. Is a current – carrying conductor electrically charged?

6. The drift velocity of electrons is quite small. How then does a bulb light up as soon as the switch is turned on, although the bulb may be quite far from the switch?

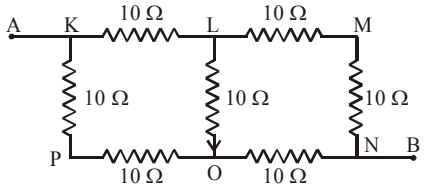
PART – A

1. A long resistor between A and B (in given fig.) have resistance of 300 ohm and are tapped at one-third points.

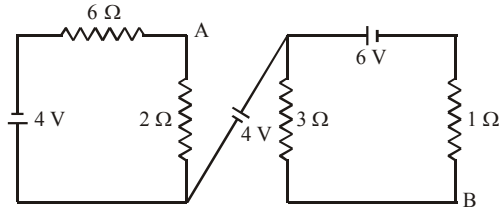


   (a) What is equivalent resistance between A and B.
   (b) If the potential difference between A and B is 320 V, what will be the potential difference between B and C?
   (c) Will this change, if the 40-ohm resistor is disconnected?

2. What is the equivalent resistance between the terminal point A and B in the network shown in figure. Assume that the resistance of each resistor is 10 ohm.



3. In the network shown in the figure below, calculate the potential difference between A and B.



4. In the network of resistors each of value R shown in the figure, calculate the equivalent resistance between the junction A and E first without using Kirchhoff's rules and then check the result by applying Kirchhoff's rules.

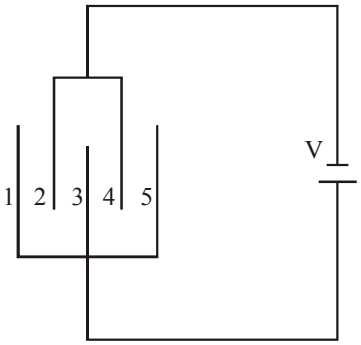
Capacitor

Conceptual

1. Why metals cannot be used as a dielectric in a capacitor.

2. A capacitor of capacitance C is charged upto a potential difference V. After removing the charging battery, the capacitor is connected
   (i) in parallel,
   (ii) in series with an uncharged capacitor of the same capacitance. What will be the effect on the potential difference of the first capacitor in each case?

3. Five identical capacitor plates, each of area A, are arranged such that adjacent plates are at distance d apart. The plates are connected to a source of emf V as shown in figure. The charge on plate 1 …… and that on plate 4 is ……



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

5. A point charge is placed at the center of a spherical Gauss Ian surface. Does φ_e change
   (i) if the sphere is replaced by a cube of the same volume,
   (ii) if a second charge is placed near, and outside, the original sphere, and
   (iii) if a second charge is placed inside the Gauss Ian Surface?

6. Why do electrolytic have large capacitances?

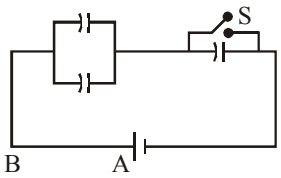
7. A dielectric slab is inserted at one end of a charged parallel-plate capacitor (the plates being horizontal and the charging battery having been disconnected) and then released. Describe what happens. Neglect friction.

8. Suppose a charge $+Q_1$ is given to the positive plate and a charge $-Q_2$ to the negative plate of a capacitor. What is the "charge on the capacitor"?

PART – A

1. It is required to construct a 10 μF capacitor, which can connect across a 200 V battery. Capacitors of capacitance 10 μF are available but they can withstand only 50V. Design a combination, which can yield the desired result.

2. Each capacitor shown in figure has a capacitance of 5·0 μF. the emf of the battery is 50V. How much charge will flow through AB if the switch S is closed?

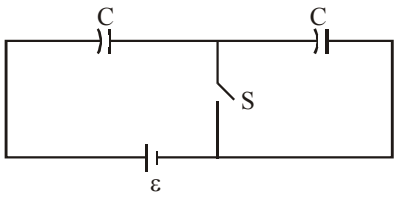


3. A charge of $+ 2{\cdot}0 \times 10^{-8}$ C is placed on the positive plate and a charge of $- 1{\cdot}0 \times 10^{-8}$ C on the negative plate pf a parallel-plate capacitor of capacitance $1{\cdot}2 \times 10^{-3}$ μF. Calculate the potential difference developed between the plates.

4. A capacitor having a capacitance of 100 μF is charged to a potential difference of 24V. The charging battery is disconnected and the capacitor is connected to another battery of emf 12V with the positive terminal to the battery.
   (a) Find the charges on the capacitor before and after the reconnection.
   (b) Find the charge flown through the 12V battery.
   (c) Does the battery does work or is it done on the battery? Find its magnitude.
   (d) Find the decrease in electrostatic field energy.
   (e) Find the heat developed during the flow of charge after reconnection.

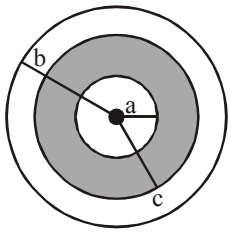
5. Consider the situation shown in figure. The switch S is open for a long time and then closed.

(a) Find the charge flown through the battery when the switch S is closed.
(b) Find the work done by the battery
(c) Find the change in energy stored in the capacitors.
(d) Find the heat developed in the system.

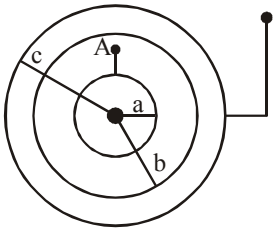


6. A parallel-plate capacitor of capacitance 5 μF is connected to a battery of emf 6V. The separation between the plates is 2mm.
(a) Find the charge on the positive plate.
(b) Find the electric field between the plates.
(c) A dielectric slab of thickness 1mm and dielectric constant 5 is inserted into the gap to occupy the lower half of its. Find the capacitance of the new combination.
(d) How much charges has flown through the battery after the slab is inserted?

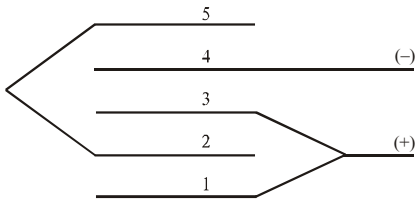
7. A spherical capacitor is made of two conducting spherical shells of radii *a* and *b*. The space between the shells is filled with a dielectric of dielectric constant K upto a radius *c* as shown in figure. Calculate the capacitance.



8. Consider an assembly of three conducting concentric spherical shells of radii *a*, *b* and *c* as shown in fig. Find the capacitance of the assembly between the points A and B.



9. Five identical conducting plates 1, 2, 3, 4 and 5 are fixed parallel to and equidistant from each other as shown in figure. A conductor connects plates 2 and 5 while another conductor joins 1 and 3. The junction of 1 and 3 and the plate 4 are connected to a source of constant e.m.f. V_0. Find



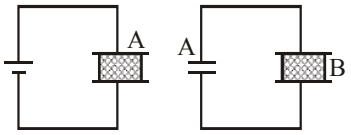
(i) The effective capacity of the system between the terminals of the source.
(ii) The charge on plates 3 and 5.

PART – B

1. A parallel plate capacitor of plate area 0·2 m^2 and spacing 10^{-2} m is charged to 10^3 volts and is then disconnected from the battery. How much work is required if the plates are pulled apart to double the plate spacing? Calculate the final voltage on the capacitor.
(Roorkee 1995)

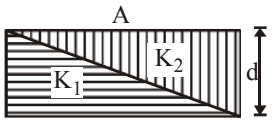
2. A battery of 10V is connected to a capacitor of capacity 0·1 F. The battery is now removed and this capacitor is connected to a second uncharged capacitor. If the charge distributes equally on these two capacitors, find the total energy stored in the first capacitor.
(Roorkee 1996)

3. Two parallel plate capacitors A and B have the same separation $d = 8{\cdot}85 \times 10^{-4}$ m between the plates. The plate area of A and B are 0·02 m^2 respectively. A slab of dielectric constant (relative permittivity) K = 9 has dimensions such that it can exactly fill the space between the plates of capacitor B.
(i) The dielectric slab is placed inside A. A is then charged to a potential difference of 110V. Calculate the capacitance of A and the energy stored in it.
(ii) The battery is disconnected and then the dielectric slab is removed from A. find the work done by the external energy in removing the slab from A.
(iii) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected. Calculate the energy stored in the system.
(I.I.T. 1993)

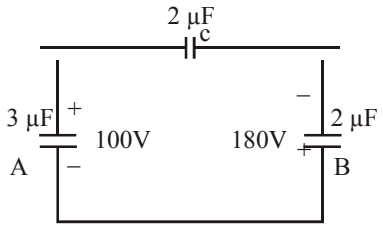


4. Two square metallic plates of 1m side are kept 0·01 m apart, like a parallel plate capacitor, in air in such a way that one of their edges is perpendicular to an oil surface in a tank filled with an insulating oil. The plates are connected to a battery of e.m.f. 500V. The plates are then lowered vertically into the oil at a speed of 0·001 m/s. Calculate the current drown from the battery during the process. (Dielectric constant of oil = 11, $\varepsilon_0 = 8{\cdot}85 \times 10^{-12}$ C^2 N^{-1} m^{-2}). **(I.I.T. 1994)**

5. The capacitance of a parallel plate capacitor with plate area A and separation *d* is C. The space between the plates is filled with two wedges of dielectric constants K_1 and K_2 respectively. Find the capacitance of resulting capacitor. **(I.I.T. 1996)**



6. Two capacitors A and B with capacities 3 F and 2 F are charged to a potential difference of 100V and 180V respectively. The plates of the capacitors are connected as shown in figure with one wire from each capacitor free.



The upper plate of A is positive and that of B is negative. An uncharged 2 F capacitor C with lead wires falls on the free ends to complete the circuit. Calculate

(i) the final charge on the three capacitors and

(ii) the amount if electrostatic energy stored in the system before and after the completion of the circuit. **(I.I.T. 1997)**

7. The circular plates A and B of a parallel plate air capacitor have a diameter of 0·1 m and are 2×10^{-3} m apart. The plates C and D, of a similar capacitor have a diameter of 0·12m and are 3×10^{-3} m apart. Plate A is earthed. Plates B and D are connected together. Plate C is connected to the positive pole of a 120V battery whose negative is earthed. Calculate

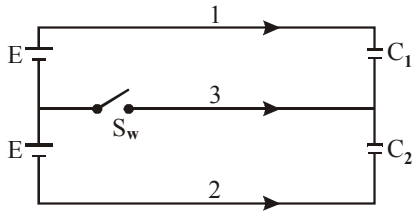
(i) the combined capacitance of the arrangement and

(ii) the energy stored in it. **(Roorkee 1998)**

8. A leaky parallel capacitor is filled completely with a material having dielectric constant k = 5 and electrical conductivity $\sigma = 7{\cdot}4 \times 10^{-12}$ Ω^{-1} m^{-1}. If the charge on the plate at the instant t = 0 is q = 8·85 μC, then calculate the leakage current at the instant t = 12 s. **(I.I.T. 1997)**

9. Two parallel plate condensers A and B having capacities of 1 μF and 5 μF are charged separately to the same potential of 100V. Now the positive plate of A is connected to the negative plate of A to the positive plate of B. Find the final charge on each condenser and total loss of electrical energy in the condensers. **(Roorkee 1993)**

11. In the circuit shown in figure, the e.m.f. of each battery is equal to E = 60V, and the capacitance are equal to C_1 = 2·0 μF and C_2 = 3·0 μF. find the charge which will flow after shorting of the switch Sw through sections 1, 2, 3 in the direction indicated.



12. A capacitor of capacitance C_1 = 1·0 μF charged upto a voltage V = 110V is connected in parallel to the terminals of a circuit consisting of two uncharged capacitors connected in series and processing the capacitances C_2 = 2·0 μF and C_3 = 3·0 μF. what charge will flow through the connecting wires?

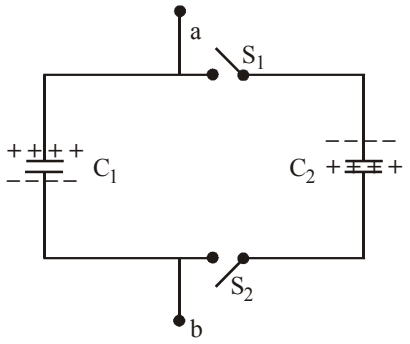
13. A cylindrical capacitor has radii *a* and *b*. Show that half the stored electric potential energy lies within a cylinder whose radius is $r = \sqrt{ab}$.

14. In fig. capacitor C_1 = 1·0 μF and C_2 = 3·0 μF are each charged to a potential V = 100V but with opposite polarity as shown. Switches S_1 and S_2 are now closed.

(a) What is the potential difference between points *a* and *b*?

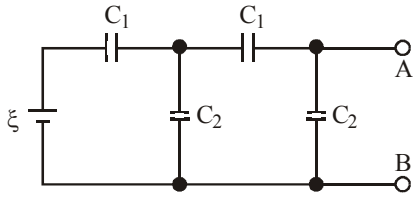
(b) What is the charge on C_1?

(c) What is the charge on C_2?

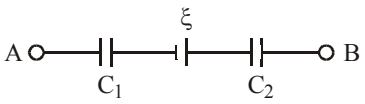


15. The gap between the plates of a parallel-plate capacitor is filled with isotropic dielectric whose permittivity ε varies linearly from ε_1 to ε_2 ($\varepsilon_2 > \varepsilon_1$) in the direction perpendicular to the plates. The area of each plate equals S, the separation between the plates is equal to *d*. Find the capacitance of the capacitor?

16. Find the potential difference between points A and B of the system shown in figure. If the emf is equal to ξ = 110V and the capacitance ratio $C_2 / C_1 = 2{\cdot}0$.

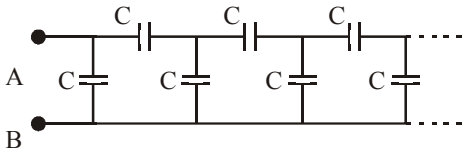


17. A circuit has a section AB shown in figure. The emf of the source equals ξ = 10V, the capacitor capacitance are equal to $C_1 = 1{\cdot}0$ μF and $C_2 = 2{\cdot}0$ μF, and the potential difference $\varphi_A - \varphi_B = 5{\cdot}0$V. Find the voltage across each capacitor.

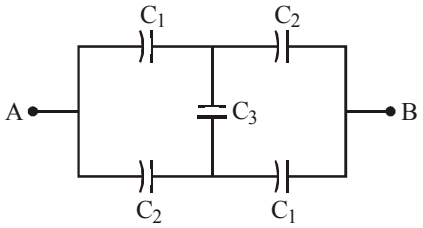


18. An uncharged capacitor is connected to a battery. Show that half the energy supplied by the battery is lost as heat while charging the capacitor.

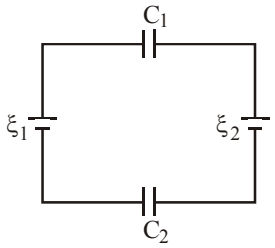
19. Find the capacitance of the infinite ladder shown in figure.



20. Find the equivalent capacitance between the point A and B in figure.

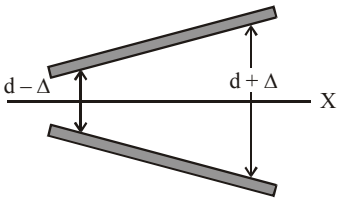


21. Find the charge on each capacitor in the circuit shown in figure.



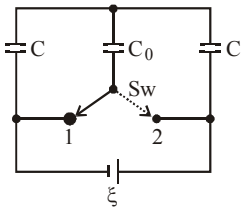
PART – C

1. The parallel-plate capacitor in fig. is slightly misaligned. The area of each plate is A, and the amount of misalignment Δ is much less than the mean distance *d* between the plates. Assume that the electric field lines are approximately vertical and the capacitor may be treated as a series of "strip" capacitors that have an infinitesimal width along the *x*-axis and that are connected in parallel. (a) What is the capacitance C of the capacitor? (b) Show that the answer to (a) reduces to $\frac{\in_0 A}{d}$ when Δ = 0.



2. Find the capacitance of an isolated ball-shaped conductor of radius R_1 surrounded by an adjacent concentric layer of dielectric with permittivity ε and outside radius R_2.

3. What amount of heat will be generated in the circuit shown in figure? After the switch S_w is shifted from position 1 to position 2?



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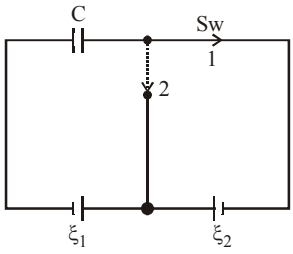
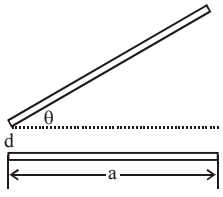


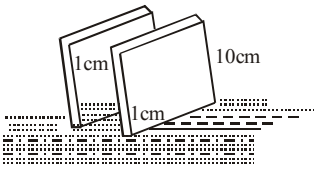
5. A capacitor consists of two stationary plates shaped as a semi-circle of radius R and a movable plate made of dielectric with permittivity ε and capable of rotating about an axis O between the stationary plates. The thickness of the movable plate is equal to *d*, which is practically the separation between the stationary plates. A potential difference V is applied to the capacitor. Find the magnitude of the moment of forces relative to the axis O acting on the movable plate in the position shown in figure.

6. A capacitor has square plates each of side a, making an angle θ between them as shown in figure. Show that for small θ the capacitance is

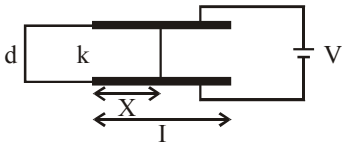
$$C = \frac{\varepsilon_0 a^2}{d}\left(1 - \frac{a\theta}{2d}\right)$$



7. A large vessel is filled with water (ε_r = 18). Two square plates each of length 10cm and separated by 1cm are held parallel to each other with their lower ends just touching the surface of the water. The plates are charged by applying a voltage V and then disconnected from the voltage source. If the liquid rises by 1 cm between the plates, what is the voltage V applied?



8. Figure shows a parallel-plate capacitor with plates of width *b* and length *l*. The separation between the plates is *d*. the plates are rigidly clamped and connected to a battery of emf V. A dielectric slab of thickness *d* and dielectric constant K is slowly inserted between the plates.
   (a) Calculate the energy of the system when a length *x* of the slab is introduced into the capacitor.
   (b) What force should be applied on the slab to ensure that it goes into the capacitor? Neglect any effect of friction or gravity.



9. A parallel-plate capacitor is placed in such a way that its plates are horizontal and the lower plate is dipped into a liquid of dielectric constant K and density ρ. Each plate has an area A. The plates are now connected to a battery, which supplies a positive charge of magnitude Q to the upper plate. Find the rise in the level of the liquid in the space between the plates.