LAKSHYA (JEE)

Electrostatic Potential & Capacitance

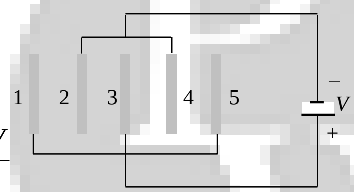
DPP-09

1. A parallel plate capacitor is connected to a battery. The plates are pulled apart with a uniform speed. If x is the separation between the plates, the time rate of change of electrostatic energy of capacitor is proportional to

(a) x^{-2} (b) x

(c) x^{-1} (d) x^2

2. Five identical plates each of area A are joined as shown in the figure. The distance between the plates is d. The plates are connected to a potential difference of $V\ volts$. The charge on plates 1 and 4 will be



(a) $\frac{\varepsilon_0 AV}{d}, \frac{2\varepsilon_0 AV}{d}$

(b) $\frac{\varepsilon_0 AV}{d}, \frac{2\varepsilon_0 AV}{d}$

(c) $\frac{\varepsilon_0 AV}{d}, \frac{-2\varepsilon_0 AV}{d}$

(d) $\frac{-\varepsilon_0 AV}{d}, \frac{-2\varepsilon_0 AV}{d}$

3. To form a composite $16\mu F, 1000V$ capacitor from a supply of identical capacitors marked $8\mu F, 250V$, we require a minimum number of capacitors

(a) 40 (b) 32

(c) 8 (d) 2

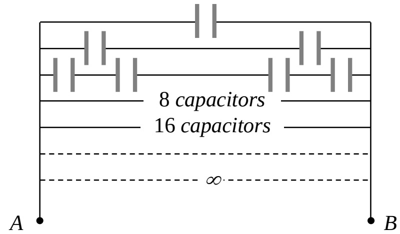
4. An infinite number of identical capacitors each of capacitance $1\mu F$ are connected as in adjoining figure. Then the equivalent capacitance between A and B is

(a) $1\mu F$

(b) $2\mu F$

(c) $\frac{1}{2}\mu F$

(d) ∞



5. Two condensers of capacities $2C$ and C are joined in parallel and charged upto potential V. The battery is removed and the condenser of capacity C is filled completely with a medium of dielectric constant K. The p.d. across the capacitors will now be

(a) $\frac{3V}{K+2}$ (b) $\frac{3V}{K}$

(c) $\frac{V}{K+2}$ (d) $\frac{V}{K}$

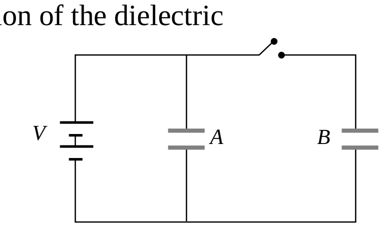
6. Figure given below shows two identical parallel plate capacitors connected to a battery with switch S closed. The switch is now opened and the free space between the plate of capacitors is filled with a dielectric of dielectric constant 3. What will be the ratio of total electrostatic energy stored in both capacitors before and after the introduction of the dielectric

(a) 3 : 1

(b) 5 : 1

(c) 3 : 5

(d) 5 : 3



7. A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance $2C$ is connected to another battery and is charged to potential difference $2V$. The charging batteries are now 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) $\frac{25CV^2}{6}$

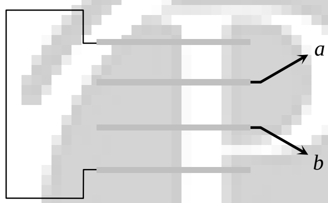
(c) $\frac{3CV^2}{2}$ (d) $\frac{9CV^2}{2}$

8. Condenser A has a capacity of 15 μF when it is filled with a medium of dielectric constant 15. Another condenser B has a capacity of $1\mu F$ with air between the plates. Both are charged separately by a battery of $100\,V$. After charging, both are connected in parallel without the battery and the dielectric medium being removed. The common potential now is

(a) $400\,V$ (b) $800\,V$

(c) $1200\,V$ (d) $1600\,V$

9. Four metallic plates each with a surface area of one side A are placed at a distance d from each other. The plates are connected as shown in the circuit diagram. Then the capacitance of the system between a and b is



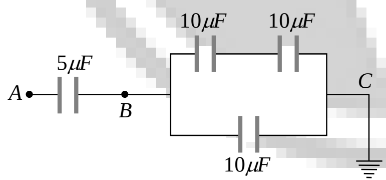
(a) $\frac{3\varepsilon_0 A}{d}$

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

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

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

10. In the given circuit if point C is connected to the earth and a potential of $+2000\ V$ is given to the point A, the potential at B is



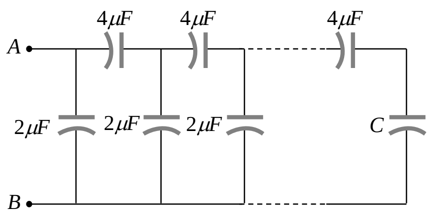
(a) $1500V$

(b) $1000\,V$

(c) $500\,V$

(d) $400\,V$

11. A finite ladder is constructed by connecting several sections of $2\mu F, 4\mu F$ capacitor combinations as shown in the figure. It is terminated by a capacitor of capacitance C. What value should be chosen for C such that the equivalent capacitance of the ladder between the points A and B becomes independent of the number of sections in between



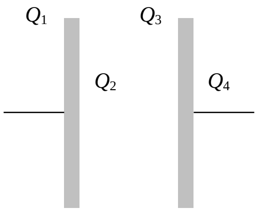
(a) $4\mu F$

(b) $2\mu F$

(c) $18\mu F$

(d) $6\mu F$

12. In an isolated parallel plate capacitor of capacitance C, the four surface have charges Q_1, Q_2, Q_3 and Q_4 as shown. The potential difference between the plates is



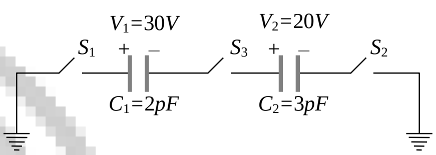
(a) $\frac{Q_1 + Q_2 + Q_3 + Q_4}{2C}$

(b) $\frac{Q_2 + Q_3}{2C}$

(c) $\frac{Q_2 - Q_3}{2C}$

(d) $\frac{Q_1 + Q_4}{2C}$

13. For the circuit shown, which of the following statements is true



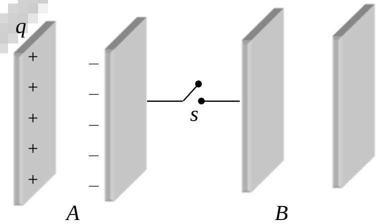
(a) With S_1 closed, $V_1 = 15V, V_2 = 20\,V$

(b) With S_3 closed $V_1 = V_2 = 25V$

(c) With S_1 and S_2 closed $V_1 = V_2 = 0$

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

14. Consider the situation shown in the figure. The capacitor A has a charge q on it whereas B is uncharged. The charge appearing on the capacitor B a long time after the switch is closed is



(a) Zero (b) $q/2$

(c) q (d) $2q$

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

(a) $4\,kV$ (b) $6\,kV$

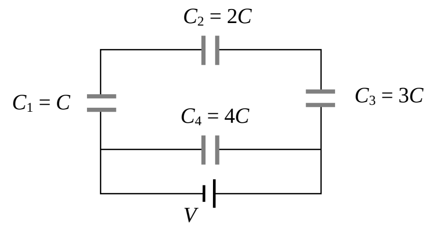
(c) $8\,kV$ (d) $10\,kV$

16. The plates of a parallel plate condenser are pulled apart with a velocity v. If at any instant their mutual distance of separation is d, then the magnitude of the time of rate of change of capacity depends on d as follows

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

(c) d^2 (d) d

17. A network of four capacitors of capacity equal to $C_1 = C, C_2 = 2C, C_3 = 3C$ and $C_4 = 4C$ are conducted in a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is



(a) $\frac{22}{3}$

(b) $\frac{3}{22}$

(c) $\frac{7}{4}$

(d) $\frac{4}{7}$

ANSWER KEY

1. (a)
2. (c)
3. (b)
4. (b)
5. (a)
6. (c)
7. (c)
8. (b)
9. (d)
10. (c)
11. (a)
12. (c)
13. (d)
14. (a)
15. (c)
16. (b)
17. (b)

Note - If you have any query/issue

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HINTS AND SOLUTIONS

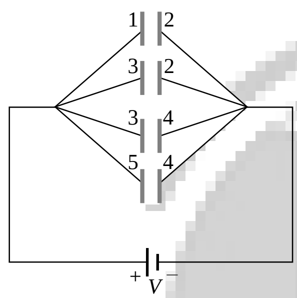
1. (a)

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{\varepsilon_0 A}{x}\right)V^2$$

$$\therefore \frac{dU}{dt} = \frac{1}{2}\varepsilon_0 AV^2\left(-\frac{1}{x^2}\frac{dx}{dt}\right) \Rightarrow \frac{dU}{dt} \propto x^{-2}$$

2. (c)

The given circuit can be redrawn as follows. All capacitors are identical and each having capacitance $C = \frac{\varepsilon_0 A}{d}$



|Charge on each capacitor| = |Charge on each plate|

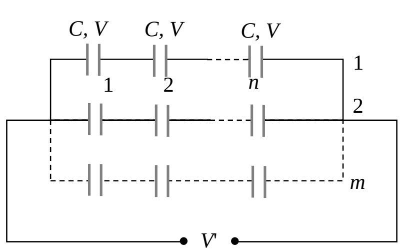
$$= \frac{\varepsilon_0 A}{d}V$$

Plate 1 is connected with positive terminal of battery so charge on it will be $+\frac{\varepsilon_0 A}{d}.V$

Plate 4 comes twice and it is connected with negative terminal of battery, so charge on plate 4 will be $-\frac{2\varepsilon_0 A}{d}V$

3. (b)

Suppose $C = 8\ \mu F$, $C' = 16\mu F$
and $V = 250\ V$, $V' = 1000V$



Suppose m rows of given capacitors are connected in parallel and each row contains n capacitors then potential difference across each capacitor $V = \frac{V'}{n}$ and equivalent capacitance of network $C' = \frac{mC}{n}$ on putting the values we get $n = 4$ and $m = 8$

$\therefore$ Total capacitors = $n \times m = 4 \times 8 = 32$

Short Trick : For such type of problems number of capacitors = $\frac{C'}{C} \times \left(\frac{V'}{V}\right)^2 = \frac{16}{8}\left(\frac{1000}{250}\right)^2 = 32$

4. (b)

This combination forms a G.P.

$$S = 1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} ......$$

Sum of infinite G.P. $S = \frac{a}{1-r}$

Here a = first term = 1 and r = common ratio $= \frac{1}{2}$

$$\Rightarrow S = \frac{1}{1-\frac{1}{2}} = 2 \Rightarrow C_{eq} = 2\mu F$$

5. (a)

$q_1 = 2CV,\ \ q_2 = CV$

Now condenser of capacity C is filled with dielectric K, therefore $C_2 = KC$

As charge is conserved

$$\therefore q_1 + q_2 = (C_2' + 2C)V'$$

$$\Rightarrow V' = \frac{3CV}{(K+2)C} = \frac{3V}{K+2}$$

6. (c)

Initially potential difference across both the capacitor is same hence energy of the system is

$$U_1 = \frac{1}{2}CV^2 + \frac{1}{2}CV^2 = CV^2 \qquad ......(i)$$

In the second case when key K is opened and dielectric medium is filled between the plates, capacitance of both the capacitors becomes $3C$, while potential difference across A is V and potential difference across B is $\frac{V}{3}$ hence energy of the system now is

$$U_2 = \frac{1}{2}(3C)V^2 + \frac{1}{2}(3C)\left(\frac{V}{3}\right)^2 = \frac{10}{6}CV^2 \ldots\text{(ii)}$$

So, $\frac{U_1}{U_2} = \frac{3}{5}$

7. (c)

Total charge $= (2C)(2V) + (C)(-V) = 3CV$

$\therefore$ Common potential $= \frac{3CV}{3C} = V$

$\therefore$ Energy $= \frac{1}{2}(3C)(V)^2 = \frac{3}{2}CV^2$

8. (b)

Charge on capacitor A is given by

$Q_1 = 15 \times 10^{-6} \times 100 = 15 \times 10^{-4}\,C$

Charge on capacitor B is given by

$Q_2 = 1 \times 10^{-6} \times 100 = 10^{-4}\,C$

Capacity of capacitor A after removing dielectric $= \frac{15 \times 10^{-6}}{15} = 1\mu F$

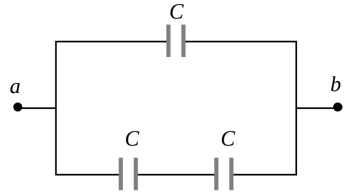
Now when both capacitors are connected in parallel their equivalent capacitance will be $C_{eq} = 1 + 1 = 2\mu F$

So common potential

$$= \frac{(15 \times 10^{-4}) + (1 \times 10^{-4})}{2 \times 10^{-6}} = 800\,V.$$

9. (d)

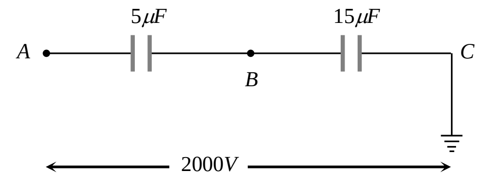
The given circuit can be redrawn as follows



$\Rightarrow C_{eq} = \frac{3C}{2} = \frac{3\varepsilon_0 A}{2d}$

10. (c)

The given circuit can be redrawn as follows



$$(V_A - V_B) = \left(\frac{15}{5+15}\right) \times 2000$$

$\Rightarrow \quad V_A - V_B = 1500\;V$

$\Rightarrow \quad 2000 - V_B = 1500\,V \Rightarrow V_B = 500\,V$

11. (a)

If the value of C is chosen as $4\mu F$, the equivalent capacity across every part of the section will be $4\mu F$.

12. (c)

Plane conducting surfaces facing each other must have equal and opposite charge densities. Here as the plate areas are equal, $Q_2 = -Q_3$.

The charge on a capacitor means the charge on the inner surface of the positive plate (here it is Q_2)

Potential difference between the plates

$$= \frac{\text{charge}}{\text{capacitance}} = \frac{Q_2}{C} = \frac{2Q_2}{2C}$$

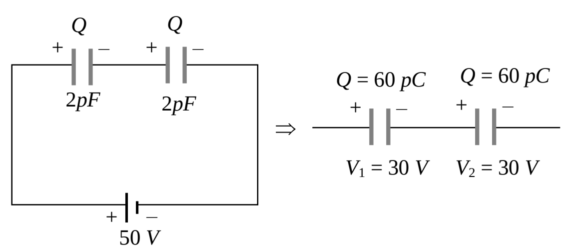
$$= \frac{Q_2 - (-Q_2)}{2C} = \frac{Q_2 - Q_3}{2C}.$$

13. (d)

Charges on capacitors are $Q_1 = 30 \times 2 = 6\,pC$

and $Q_2 = 20 \times 3 = 60\,pC$ or $Q_1 = Q_2 = Q$ (say)

The situation is situation is similar as the two capacitors in series are first charged with a battery of emf 50 V and then disconnected



$\therefore$ when S_3 is closed $V_1 = 30\,V$ and $V_2 = 20\,V$

14. (a)

The $\pm q$ charges appearing on the inner surfaces of *A*, are bound charges. As *B* is uncharged initially, as it is isolated, the charges on *A* will not be affected on closing the switch *S*. No charge will flow in to *B*.

15. (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 $V_{max} = 6KV + 2KV = 8KV$

16. (b)

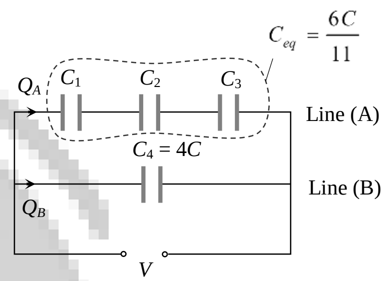
$$C = \frac{\varepsilon_0 A}{x}; \qquad \therefore \qquad \frac{dC}{dt} = \varepsilon_0 A \frac{d}{dt}\left(\frac{1}{x}\right)$$

$$= \frac{-\varepsilon_0 A}{x^2}\left(\frac{dx}{dt}\right) = \frac{-\varepsilon_0 A}{d^2}\left(\frac{dx}{dt}\right)$$

$$\Rightarrow \left|\frac{dC}{dt}\right| = \frac{\varepsilon_0 A}{d^2} v \ \ i.e.\ \left|\frac{dC}{dt}\right| \propto \frac{1}{d^2}$$

17. (b)

The given circuit can be redrawn as follows



$$C_{eq} = \frac{C_1 C_2 C_3}{C_1 C_2 + C_2 C_3 + C_3 C_1} = \frac{6C}{11}$$

$$\frac{Q_A}{Q_B} = \frac{C_A}{C_B} = \frac{6C/11}{4C} = \frac{3}{22}$$