ELECTRIC CAPACITY: -

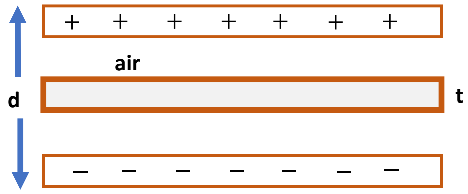
- The ratio of charge to potential of a conductor is called its capacity $C = \frac{Q}{V}$

Unit: farad (F)

Parallel Plate Capacitor: If two plates each of area A are separated by a distance 'd' then its capacity $C = \frac{\varepsilon_0 A}{d}$ (air as medium), $C = \frac{k\varepsilon_0 A}{d}$ (dielectric medium)

When a dielectric medium is introduced between the plates of a parallel plate capacitor, its capacity increases to 'k' times the original capacity.

- When a dielectric slab of thickness 't' is introduced between the plates of a parallel plate capacitor,



$$\text{newcapacity} = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{k}\right)} = \frac{\epsilon_0 A}{(d - t) + \frac{t}{k}}$$

- When a metal slab of thickness 't' is introduced betweessn the plates of a parallel plate capacitor,

$\text{new capacity} = \frac{\varepsilon_0 A}{d - t}$ (for metal k = ∞)

- The method for the calculation of capacitance requires integration of the electric field between two conductors or the plates which are separated with a potential difference V_{ab}

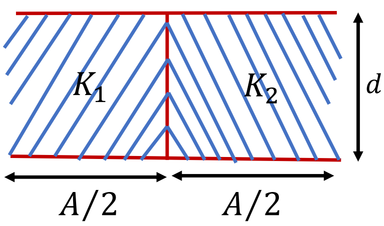
i.e. $V_{ab} = -\int_b^a \bar{E}.d\bar{r}$

or $V_+ - V_- = -\int \bar{E}.d\bar{r}$ from this $C = \frac{q}{V_{ab}}$

- When a thin metal sheet $(t \approx 0)$ is introduced between the plates of a parallel plate capacitor, then capacity remains unchanged.

- A dielectric slab of thickness 't' is introduced between the plates, to restore the original capacity, if the distance between the plates is increased by x, then $x = t\left(1 - \frac{1}{k}\right)$

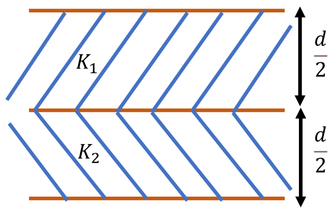
- Two dielectric slabs of equal thickness are introduced between the plates of a capacitor as shown in figure, then new capacity $= \frac{C}{2}(K_1 + K_2)$.



If the two dielectrics are of different face areas A_1 and A_2 but of same thickness, then capacity,

$$C=\frac{\epsilon_0}{d}(K_1A_1+K_2A_2)$$

- If two dielectric slabs of constants k_1 and k_2 are introduced as shown in figure, new capacity $=\frac{2k_1k_2}{(k_1+k_2)}.C$



- If number of dielectric slabs of same cross-sectional area 'A' and of thicknesses $t_1,t_2,t_3,.....t_n$ and constants $k_1,k_2.......k_n$ are introduced between the plates, effective capacity

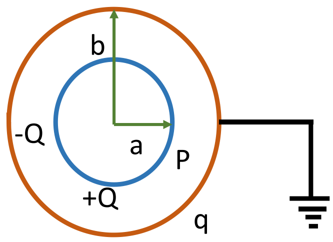
$$C=\frac{\varepsilon_0 A}{d-(t_1+t_2+.....t_n)+\left(\frac{t_1}{k_1}+.....+\frac{t_n}{k_n}\right)}$$

- In the above case if the dielectric media are completely filled between the plates, effective Capacity $C=\frac{\varepsilon_0 A}{\left(\frac{t_1}{k_1}+....+\frac{t_n}{k_n}\right)}$
- Capacity of a spherical conductor $4\pi\epsilon_0 r$, where r is the radius of the sphere.
- If we imagine earth to be a uniform solid sphere then capacity of earth is $4\pi\epsilon_0 R$

Where R = Radius of the earth = $6400\times10^3\,m$

$$C=4\pi\epsilon_0 R=\frac{1}{9\times10^9}\times6.4\times10^6=711\mu F$$

Spherical Capacitor



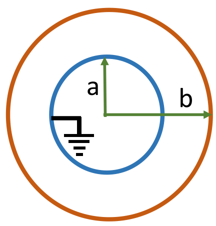
$$V=V_p-V_q=\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{a}+\frac{-q}{b}\right)-0$$

$$=\frac{1}{4\pi\varepsilon_0}q\left(\frac{b-a}{ab}\right)$$

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

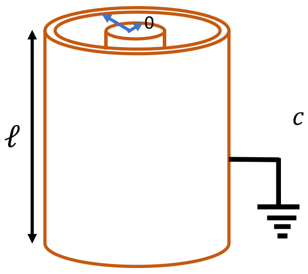
(a) $C=4\pi\epsilon_0\frac{ab}{b-a}$, if inner sphere is charged and outer sphere is earthed.

(b) $C=4\pi\epsilon_0\frac{b^2}{b-a}$,



If inner sphere is earthed and outer sphere is charged.

Cylindrical Capacitor: A cylindrical capacitor consists of two coaxial cylinders and its capacitance is given by

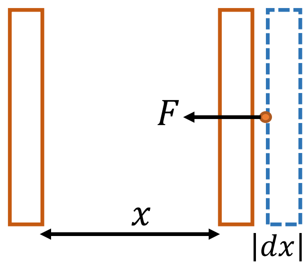


$$c = \frac{2\pi\varepsilon_0 l}{\log_e\left(\frac{b}{a}\right)}$$

Where l is the length of each cylinder and a and b are the radii of the inner and outer cylinders.

Force between the plates of a capacitor

Consider a parallel plate capacitor with plate area A. Let Q and −Q be the charges on the plates of capacitor. Let F be the force of attraction between the plates. Let E is the field between the capacitor plates. The expression for the force can be derived by energy method. Let the distance between the plates be x. So electric field energy between the plates is



$$U = \frac{1}{2}\in_0 E^2 (Ax)$$

$$\frac{dU}{dx} = \frac{1}{2}\in_0 E^2 A$$

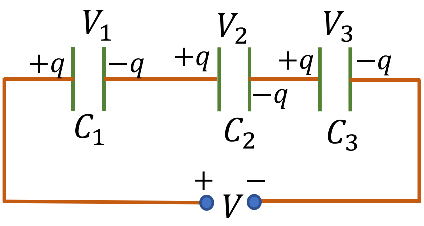
By definition $F = -\frac{dU}{dx} = \frac{-1}{2}\in_0 E^2 A$

(Conservative force)

So, the force of attraction between the plates is $F = \frac{1}{2}\in_0 E^2 A$

Note: For an isolated charged capacitor $F = \frac{Q^2}{2\in_0 A}$. This force does not depend on the separation between the plates, and so the constant amount of force is needed to change the separation.

Capacitors in series: -



$$q = C_1V_1 = C_2V_2 = C_3V_3$$

$$V_1 = \frac{q}{C_1}, V_2 = \frac{q}{C_2}, V_3 = \frac{q}{C_3}$$

But $V = V_1 + V_2 + V_3$

$$V = q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right] \ldots\ldots(1)$$

If a single capacitor when connected across the same source draws the same charge, that capacitance is said to be the equivalent capacitance of the three capacitors. If C_S is the equivalent capacitance.

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

$$V = \frac{q}{C_S} \qquad \text{.... (2)}$$

Substituting (2) in (1)

$$\frac{q}{C_S} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

In general $\frac{1}{C_S} = \sum \frac{1}{C_1}$

- The ratio of potential differences across three capacitors is

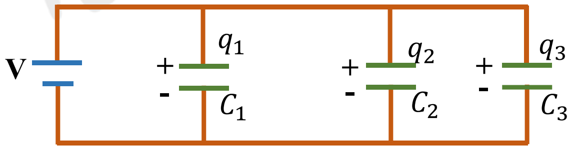
$$V_1 : V_2 : V_3 = \frac{Q}{C_1} : \frac{Q}{C_2} : \frac{Q}{C_3} = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}$$

- P.D across first capacitor is

$$V_1 = \frac{\frac{1}{C_1}}{\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)} V$$

Similarly we can find V_2 and V_3.

Capacitors in parallel: -



$$V = \frac{q_1}{C_1} = \frac{q_2}{C_2} = \frac{q_3}{C_3}$$

$$\therefore q_1 + q_2 + q_3 = C_1V + C_2V + C_3V$$

$$q = V(C_1 + C_2 + C_3)$$

$$\frac{q}{V} = C_1 + C_2 + C_3 \qquad \text{.... (1)}$$

If a single capacitor when connected to the same source draws a charge q then that capacitor is said to be the effective or equivalent capacitor for the three parallel capacitors. If the effective capacitance is $C_{p'}$

$C_P = \frac{q}{V}$ ... (2)

from (1) and (2)

$$C_P = C_1 + C_2 + C_3$$

In general $C_P = \sum C_n s$

The ratio of charges on three capacitors is

$$Q_1 : Q_2 : Q_3 = C_1V : C_2V : C_3V = C_1 : C_2 : C_3$$

The charge on first capacitor is

$$Q_1 = \frac{C_1}{C_1 + C_2 + C_3} Q$$

similarly we can find Q_2 and Q_3

- When n identical capacitors each of capacity **C** are first connected in series and next connected in parallel then the ratio of their effective capacities

$$C_S = \frac{C}{n}; C_P = nC \qquad \frac{C_S}{C_P} = n^2 : 1$$

Types of dielectrics :-

If a dielectric is charged by induction, then induced charge q' is less than inducing charge q. induced charge.

$$q^1 = -q\left[1 - \frac{1}{K}\right]$$

- Electric field due to induced charges on the dielectric is

$$E_{ind} \text{ or } E_p = E_0 - \frac{E_0}{K} = E_0\left(1 - \frac{1}{k}\right)$$

- If a condenser is connected across a battery and U is the energy stored in the condenser then the work done by the battery in charging the condenser is $2U(W = qV = 2U)$.

  For a parallel plate capacitor

$$U = \frac{1}{2}(Ad)\frac{\sigma^2}{\epsilon_0}\left(\text{as } E = \frac{\sigma}{\epsilon_0}\right)$$

  Energy density

  $\frac{U}{V} = \frac{\sigma^2}{2\epsilon_0} = \frac{1}{2}\epsilon_0 E^2$ (here V is volume i.e. Ad)

- a) When three capacitors are in **series**, the ratio of energies is

$$U_1 : U_2 : U_3 = \frac{Q^2}{2C_1} : \frac{Q^2}{2C_2} : \frac{Q^2}{2C_3} = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}$$

b) When three capacitors are in **parallel**, the ratio of energies is

$$U_1 : U_2 : U_3 = \frac{1}{2}C_1V^2 : \frac{1}{2}C_2V^2 : \frac{1}{2}C_3V^2 = C_1 : C_2 : C_3$$

c) Energy density (μ) = energy/ volume

$$\mu = \frac{1}{2}\varepsilon E^2 = \frac{1}{2}k\varepsilon_0 E^2$$

(Where k in the dielectric constant of medium between the plates)

Effect of Dielectric:

- A parallel plate capacitor is fully charged to a potential V.

  Without disconnecting the battery if the gap between the plates is completely filled by a dielectric medium, capacity increases to k times the original capacity.
- P.D. between the plates remains same.
- Charge on the plates increases to k times the original charge.
- Energy stored in the capacitor increases to k times the original energy.
- **After disconnecting the battery** if the gap between the plates of the capacitor is filled by a dielectric medium, capacity increases to k times the original capacity.
- P.D. between the plates decreases to $\frac{1}{k}$ times the original potential.
- Charge on the plates remains same.
- Energy stored in the capacitor decreases to $\frac{1}{k}$ times the original energy.
- A capacitor is fully charged to a potential 'V'. After disconnecting the battery, the distance between the plates of capacitors is increased by means of insulating handles. Potential difference between the plates increases. ($V = \frac{Q}{C}$, Q remains same, and C decreases)
- A capacitor with a dielectric is fully charged. Without disconnecting the battery if the dielectric slab is removed, then some charge flows back to the battery.

  Mixed Grouping of Capacitors:
- Number of capacitors in a row $n = \frac{\text{desired potential}}{\text{given potential}}$
- Number of such rows $m = \frac{\text{desired capacity}}{\text{original capacity}}$
- Total number of capacitors = $m \times n$

- **Coalescence of a Charged Oil Drops:**

There are ‘n’ charged drops of radius ‘r’ and charge ‘q’. The drops merge to form a bigger drop. If capicity of small drop is ‘C’ then

1) capacity of bigger drop is $C^1 = n^{\frac{1}{3}} \times C$

2) Potential of bigger drop is $V^1 = \frac{Q}{C^1} = \frac{nq}{n^{1/3}.C} = \frac{n^{2/3}q}{C} = n^{2/3}V$

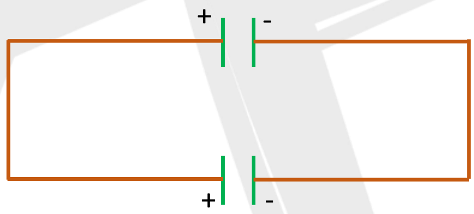
3) Energy of bigger drop is $U^1 = \frac{Q^2}{2C^1} = \frac{n^2q^2}{2n^{1/3}.C} = \frac{n^{5/3}q^2}{2C} = n^{5/3}U.$

4) Surface charge density of bigger drop is $\sigma^1 = \frac{Q}{4\pi R^2} = \frac{nq}{4\pi n^{2/3}.r^2} = \frac{n^{1/3}q}{4\pi r^2} = n^{1/3}.\sigma$

REDISTRIBUTION OF CHARGE, COMMON POTENTIAL AND LOSS OF ENERGY

Two capacitors of capacities C_1 and C_2 are charged to potentials V_1 and V_2 separately and they are connect so that charge flows. Here charge flows from higher potential to lower potential till both capacitors get the same potential

a) Two capacitors are connected in parallel such that positive plate of one capacitor is connected to positive plate of other capacitor



Let V be the common potential

Then $Q = Q_1 + Q_2$ (charge conservation)

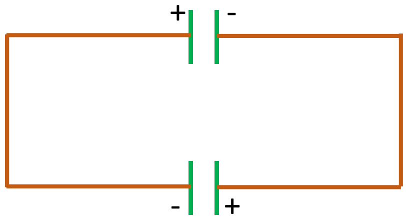
$$(C_1 + C_2)V = C_1V_1 + C_2V_2;\ V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

In this case there will be loss in energy of the system

$$\Delta U = U_f - U_i;\ \text{where } U_f = \frac{1}{2}C_1V^2 + \frac{1}{2}C_2V^2$$

$$U_i = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2;\ \ \Delta U = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)^2$$

b) If positive plate of one capacitor is connected to negative plate of other capacitor, common potential is given by



$$V = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$$

Here charge flow takes place if $V_1 \neq V_2$

In this case, the loss of energy

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

Charge transferred is $= q_1 - q_1^1 (\text{or}) \left(q_2 - q_2^1\right)$

$$= C_1V_1 - C_1V \ (\text{or}) C_2V_2 - C_2V$$
$$= C_1(V_1 - V)(\text{or}) C_2(V_2 - V)$$

a) Redistribution of charges when two conductors are connected by a conducting wire

In charging a conductor, work is required to be done. This work done is stored up as the potential

energy of the conductor.

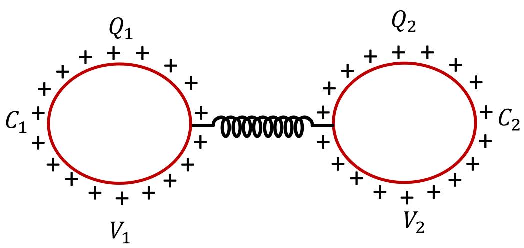
Energy of a charged conductor,

$$U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$$

When two charged bodies are connected by a conducting wire then charge flows from a conductor at higher potential to that at lower potential until their potentials are equal. Let the amounts of charge on two conductors A and B are Q_1 and Q_2 their capacities are C_1 and C_2 and their potentials are V_1 and V_2 respectively, then $Q_1 = C_1V_1$ and $Q_2 = C_2V_2$

Let the amount of charge after the conductors are connected, are Q_1' and Q_2' respectively, then

$$Q_1' = C_1V; Q_2' = C_2V$$



Charges are redistributed in the ratio of their capacities.

$\therefore Q'_1 : Q'_2 = C_1 : C_2$ (Since V is same)

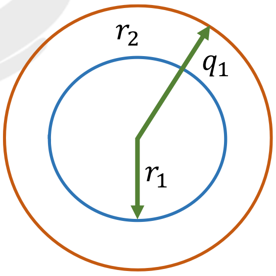
In case of spherical conductors, $C = 4\pi\varepsilon_0 r$

So, $Q'_1 : Q'_2 = r_1 : r_2$

Van De Graff Generator

Van De Graaff generator is used to develop very high voltages and resulting large electric fields and used to accelerate charged particles to high energies

Principle :- Whenever a charge is given to a metal body it will spread on the outer surface of it. If we put a charged metal body inside the hollow metal body and the two are connected by a wire, whole of the charge of inner body will flow to the outer surface of the hallow body. No matter how large the charge is on the inner body. Consider a spherical conductor 1 of radius r_1 holding charge q_1 uniformly distributed on it. It is kept inside a hollow conductor 2 of radius r_2 which is uncharged.



Electric potential of inner sphere is

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1}$$

Electric potential of outer sphere is

$$V_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_2}$$

potential difference between the two conductors

$$V_1 - V_2 = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

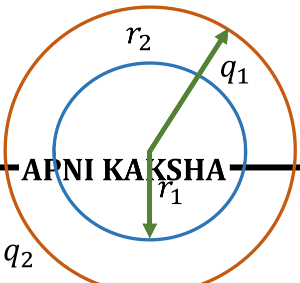
If 'q_2' charge is on the outer shell

$$V_1 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$V_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 + q_2}{r_2}\right)$$

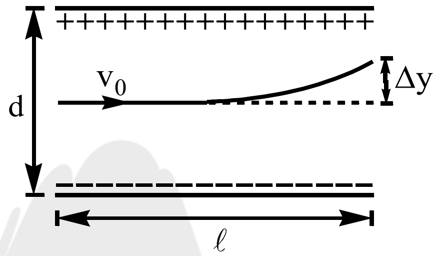
$$V_1 - V_2 = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

potential difference $(V_1 - V_2)$ **will remain the same for any value of** q_2



EXERCISE-1

1. In a parallel plate air capacitor, a cathode beam comprising $n = 10^6$ electrons is emitted with a velocity $v_0 = 10^8 \text{ m/s}$ into the space between the plates. The potential difference between the plate is $\phi = 400\text{ V}$, the separation between the plates is d = 2 cm and the area of each plate is $\ell^2 = 100 \text{ cm}^2$. The deflection of the electron beam, is $\frac{176\text{mm}}{n}$. Find n?



2. Two identical sheets of a metallic foil, separated by a distance d and having capacitance C, are charged to a potential difference E. Keeping the charge constant, the separation is increased by ℓ. Then,

(A) The new capacitance is $\frac{\varepsilon_0 A}{d}$

(B) The new capacitance is $\frac{\varepsilon_0 A}{d+\ell}$

(C) The potential difference is $\left(1-\frac{\ell}{d}\right)E$

(D) The potential difference is $\left(1+\frac{\ell}{d}\right)E$

3. A battery is connected to an uncharged capacitor. Now the distance between the plates of capacitor is decreased then :

(A) electric field between the plates will increase

(B) capacitance decreases

(C) work done by external agent is positive

(D) charge on capacitor decreases

4. A parallel plate capacitor of value 1.77 μF is to be designed using a dielectric material of dielectric constant = 200, break through strength $= 3\times10^6 \text{ Vm}^{-1}$. In order to make such a capacitor, which can withstand a potential difference of 20 V across the plates, the separation between the plates d and the area of the plates A (each) can be :

(A) $d = 10^{-6}\text{ m}, A = 10^{-3}\text{ m}^2$

(B) $d = 10^{-5}\text{ m}, A = 10^{-2}\text{ m}^2$

(C) $d = 10^{-4}\text{ m}, A = 10^{-4}\text{ m}^2$

(D) $d = 10^{-4}\text{ m}, A = 10^{-5}\text{ m}^2$

5. Two parallel plate capacitors of a capacitance C_0 and $2C_0$ are connected in parallel and charged to a potential difference V_0. The battery is disconnected and the region between the capacitor plates of capacitance C_0 is completely filled with a dielectric of dielectric constant K. The potential difference across the capacitors is $\frac{V_0\alpha}{k+\beta}$. Find $\alpha+\beta$?

6. A photographic flash unit consists of a Xenon-filled flash tube energised by the discharge of a capacitor, previously charged by a 1000 V source. The average power delivered to the tube is 2000 W in a time of 0.04 s. The capacitance of the capacitor can be estimated as $n\times10^{-6}$ F. Find F?

7. To measure the capacitance of a conductor, it is first charged to a potential $V_0 = 1350\,V$. It is then connected by a conducting wire to a distant metal sphere of radius r = 3 cm. As a result the conductor potential drops to $V_1 = 900\,V$. Choose the correct option(s) :

(A) Initial charge on the conductor is 9 nC

(B) Capacitance of the conductor is $\frac{1}{150}$nF

(C) Charge on the metal sphere after connection is 6 nC

(D) Electrostatic potential energy decreases after redistribution of charges

8. Two identical parallel plates capacitors of capacitance C = 0.01 F each are connected in parallel and charged to voltage 300 V and disconnected from the power source. The plates of one of the capacitors were spaced at a distance of twice the original. What is the charge passed (in C) during this time through the connecting wires?

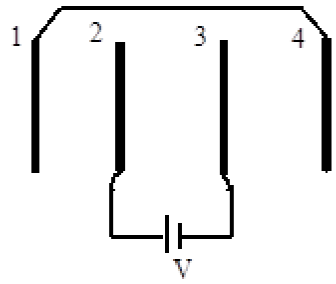
(A) 1C (B) 2C (C) 3C (D) 4C

9. A thermonuclear device consists of a torus of mean diameter 3 m with a tube of diameter 1m, containing deuterium gas at 10^{-2} mm mercury pressure and at room temperature $(20°C)$. A bank of capacitors of $1200\,\mu F$ is discharged through the tube at 50 kV. If only 20% of the electrical energy is transformed to plasma kinetic energy, then the maximum temperature attained is assuming that the energy equally shared between the deuterons and electrons in the plasma.

(A) 1.18×10^4 k (B) 1.18×10^5 k

(C) 1.18×10^6 k (D) 1.18×10^7 k

10. Four identical conducting plates of area 'A' each are connected as shown in circuit and the gap 'd' between adjacent plates is same. ε_0 is permittivity of vacuum. Select the correct statements: (Initially charge on each plate is zero)



(A) Equivalent capacitance between the terminals of battery is $\frac{3\varepsilon_0 A}{2d}$

(B) Sum of charges on plates 1 and 4 is zero

(C) The charge on right side of plate 2 is $\frac{\varepsilon_0 AV}{d}$

(D) The charge on left side of plate 2 is zero

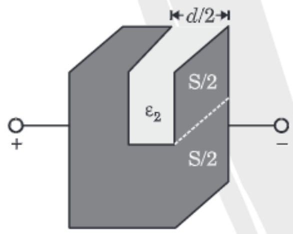
EXERCISE-2

1. An isolated parallel-plates capacitor has circular plates of radius 4.0 cm. Its gap is filled with a partially conducting material of dielectic constant K and conductivity $5.0\times10^{-4}\,\Omega^{-1}\,m^{-1}$. When the capacitor is charged to a surface charge density of $15\,\mu C/m^2$, the initial current between the plates is 1.0 A. Determine the value of dielectric constant K (approximately) $\frac{426}{n}$. Find n?

2. Capacity of an isolated sphere of radius R_1 is increased n times when it is enclosed by an earthed concentric sphere of radius $R_2 (R_2 > R_1)$. The ratio $\frac{R_2}{R_1}$ is :

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

3. A parallel plate capacitor having plates of area S and plates separation d, has capacitance C_1 in air. When two dielectrics of different relative permittivities ($\varepsilon_1 = 4$ and $\varepsilon_2 = 2$) are introduced between the two plates as shown in the figure, the capacitance becomes C_2. The ratio $\frac{C_2}{C_1}$ is $\frac{2n}{3}$. Find n?



4. We have a parallel plate capacitor made of two conducting, circular sheets of radius 2R each. They are kept at a small separation d between then. Suppose, we insert a circular shape dielectric of radius R and thickness d, between the gap with its centre coinciding with the plate centres the dielectric constant is k. The correct statement is/are :

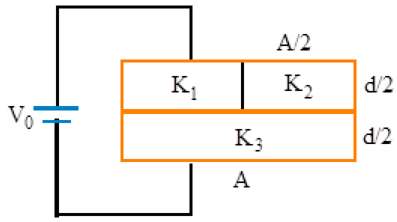
(A) Capacitance of the capacitor is $\frac{(k+3)\varepsilon_0\pi R^2}{d}$

(B) Capacitance of the capacitor is $\frac{k\varepsilon_0\pi(4R^2)}{d}$

(C) Ratio of electric field in the region with dielectric and without dielectric is 1

(D) Ratio of electric field in the region with dielectric and without dielectric is 1 : k

5. An ideal parallel plate capacitor of area A is filled with three dielectric slabs having dielectric constants $K_1 = 3.0, K_2 = 5.0$ and $K_3 = 2.0$ as shown in the figure. Choose the correct option(s) :



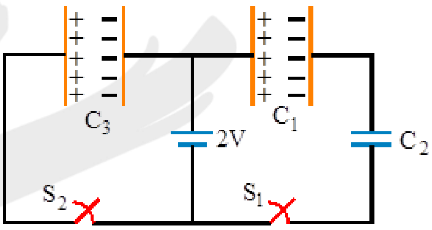
(A) the equivalent capacitance of the system is $\frac{8\varepsilon_0 A}{3d}$

(B) the electric field in K_1 is more than the electric field in K_2

(C) the electric field on the left half of K_3 is less than the electric field on the right half of K_3

(D) the electric field on the left half of K_3 is more than the electric field on the right half of K_3

6. Three capacitors $C_1 = 2\ \mu F, C_2 = 2\ \mu F$ and $C_3 = 3\ \mu F$ having initial charges $4\ \mu C$, zero and $1\ \mu C$ connected through a battery of emf 2 V as shown, on closing the switches S_1 and S_2.



(A) Charge on capacitor C_1 is $4\ \mu C$

(B) Charge on capacitor C_2 is 0

(C) Charge on capacitor C_3 is $6\ \mu C$

(D) Charge flown through S_2 is $5\ \mu C$

7. When two capacitors are charged to different potentials and then connected in parallel to each other, then :

(A) final charge is eual to sum of initial charges

(B) final potential difference is equal to average of the initial potential difference

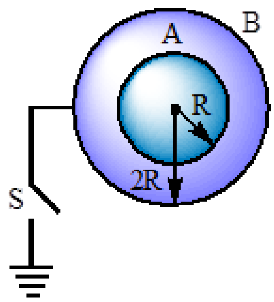
(C) final potential difference is difference from the sum of initial potential difference

(D) final energy stored is less than the sum of initial stored energy

8. Plate 1 of a capacitor having capacitance 1.5 μF is given a charge of 30 μc while the other plate is uncharged. The capacitor is now connected with a battery of potential 40 V with plate 1 connected to the positive terminal. Work done by battery is _____ μJ.

9. A parallel plate capacitor is charged to potential V and battery is removed. Separation between plates is d_0. Now the distance between plates is changed periodically $d = d_0 + d_1 \sin\omega t$. The value of d_1 if voltage of capacitor is given by $V = V_0\left(1+\frac{1}{2}\sin\omega t\right)$ is $\frac{\alpha d_0}{\beta}$. Find $\alpha+\beta$?

10. Two concentric conducting spherical shells of radii R and 2R having charges q_A and q_B and potential 2V and $\frac{3V}{2}$ respectively. Now shell B is earthen by closing switch S. Let charges on spherical shells A and B become q'_A and q'_B respectively, then :



(A) $\frac{q_A}{q_B} = \frac{1}{2}$ (magnitude)

(B) $\frac{q'_A}{q'_B} = 1$ (magnitude)

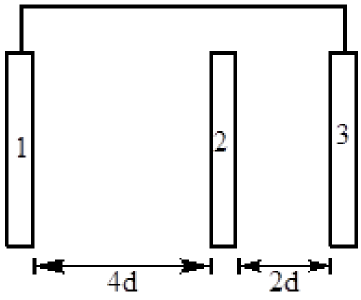
(C) potential of A after earthing becomes $\frac{3V}{2}$

(D) potential difference between A and B after earthing becomes $\frac{V}{2}$

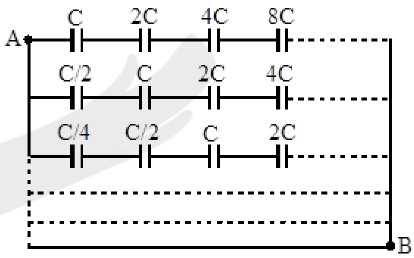
EXERCISE-3

1. A metal sphere of radius 10 cm is mounted to an insulating stand and is connected (with some conducting material) to an electro-meter of negligible capacitance. The meter reads 15 kV. Another uncharged metal sphere (also mounted to an insulating stand), which is far from the first one, is connected to the charged sphere with a thin piece of wire. Then the reading on the meter is 10 kV. What is the radius (in cm) of the initially uncharged sphere?

2. Three identical metal plates of large area A numbered 1, 2, 3 are arranged as shown in the diagram. The plates 1 and 3 are connected by a conducting wire. The charge given to plate 2 is 2q and no other plate is given any charge. The potential difference between the plates 2 and 3 is $\frac{\alpha q_0 d}{\beta \varepsilon_0 A}$. Find $\alpha+\beta$?



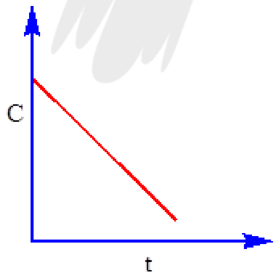
3. Consider an infinite matrix of capacitors as shown in the figure. The effective capacitance between points A and B will be :

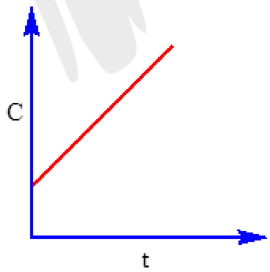


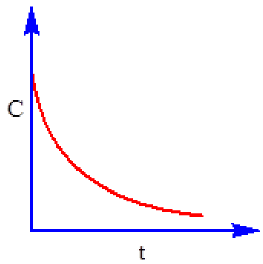
(A) C (B) 2C

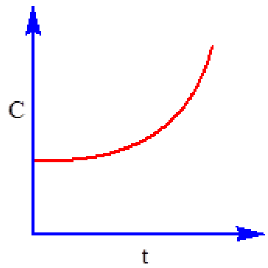
(C) 3C (D) $\frac{C}{2}$

4. A parallel plate capacitor with a dielectric slab completely occupying the space between the plates is charged by a battery and then disconnected. The slab is pulled out with a constant speed. Which of the following curves represent qualitatively the variation of the capacitance C of the system with time?

(A) 

(B) 

(C) 

(D) 

5. The potential across a $3\ \mu F$ capacitor is 12 V when it is not connected to anything. It is then connected in parallel with an uncharged $6\ \mu F$ capacitor. At equilibrium, the charge q on the $3\ \mu F$ capacitor and the potential difference V across it are :

(A) The charge q on the $3\ \mu F$ capacitor is $12\mu C$

(B) The charge q on the $3\ \mu F$ capacitor is $6\mu C$

(C) The potential difference V acros it is 4 volt

(D) The potential difference V acros it is 8 volt

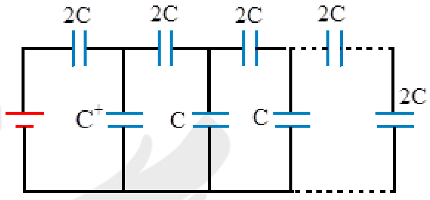
6. In the circuit shown, if the charge present in the first vertical branch capacitor is equal to Q then what is the charge in the N^{th} vertical branch capacitor of capacitance C ?

(A) $Q/2^N$

(B) $Q/2^{N-1}$

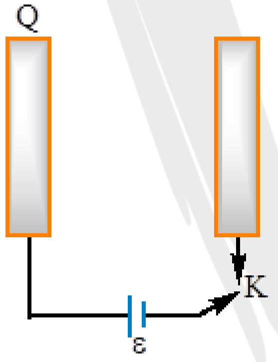
(C) Q

(D) $2^N Q$



Observe carefully that the last vertical capacitor is of 2C. All the remaining vertical capacitors are of C

7. In the given figure the capacitance of capacitor is C. The left plate of the capacitor is given charge Q and right plate is uncharged. Then choose the correct statement(s) :



(A) The amount of charge that will flow through the battery till the steady state is reached when the switch K is closed will be $C\varepsilon + \frac{Q}{2}$

(B) The charge appearing on the inner face of the left plate at steady state is $C\varepsilon$

(C) The charge appearing on the innerface of the right plate at steady state is $-C\varepsilon$

(D) If $\varepsilon = \frac{2Q}{C}$, then work done by cell after closing the switch is $\frac{3Q^2}{C}$

8. A particular spherical capacitor consists of two concentric conducting spherical shells of radii R and 2R. Neglect edge effects in each.

(A) A coaxial cylindrical capacitor, made of two concentric cylindrical conductors of radii R and 2R, has the same capacitance as the spherical capacitor. Its length should be 4R/ln 2

(B) A coaxial cylindrical capacitor, made of two conectric cylindrical conductors of radii R and 2R, has the same capacitance as the spherical capacitor. Its length should be 4R ln 2

(C) A parallel-plate capacitor, made of two circular plates of radius R, has the same capacitance as the spherical capacitor. The plates are at a distance of R/8

(D) A parallel-plate capacitor, made of two circular plates of radius R, has the same capacitance as the spherical capacitor. The plates are at a distance of R/4

9. To measure capacitance of a conductor it is first charged to a potential $V_0 = 1350\text{ V}$. It is then connected by a long conducting wire to a metal sphere of radius r = 3 cm. As a result the conductor potential drops to $V_1 = 900\text{ V}$. Choose the correct option(s) :

(A) Initial charge on the conductor is 9 nC

(B) Capacitance of the conductor is 1/150 nF

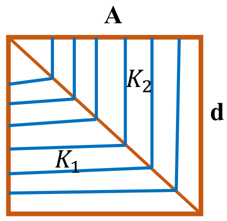
(C) Charge on the metal sphere after connection is 6 nC

(D) Electrostatic potential energy is conserved in the process of connection

10. The plates of a parallel plate capacitor are charged upto 100 volt. A 2 mm thick plate is inserted between the plates, then to maintain the same potential difference, the distance between the capacitor plates is increased by 1.6 mm. Find the dielectric constant of the plate.

(A) 2 (B) 4 (C) 5 (D) 3

11. The capacitance of a parallel plate capacitor with plate are 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 (figure). Find the capacitance of the resulting capacitor.



12. Three concentric, conducting spherical shells A, B, and C have radii a = 10 cm. b = 20 cm and c = 30 cm respectively. The innermost shell A is earthed and charged $q_2 = 4\mu C$ and $q_3 = 3\mu C$ are given to shells B and C respectively.

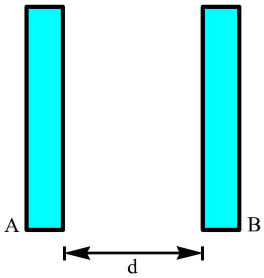
(A) The charge q_1 induced on shell A is $3\ \mu C$

(B) The charge q_1 induced on shell A is $-3\ \mu C$

(C) The energy stored in the system is 0.45 J

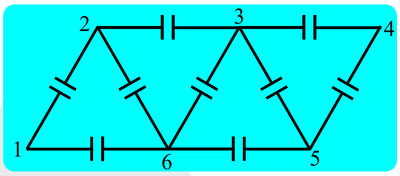
(D) The energy stored in the system is 0.90 J

13. Each plate of a parallel plate air capacitor has area $S = 5\times10^{-3}\ m^2$ and are d = 8.85 mm apart as shown in figure. Plate A has a positive charge $q_1 = 10^{-10}$ coulomb and plate B has charge $q_2 = +2\times10^{-10}$ coulomb. Calculate energy supplied by a battery of emf E = 10 volt when its positive terminal is connected with plate A and negative terminal with plate B.



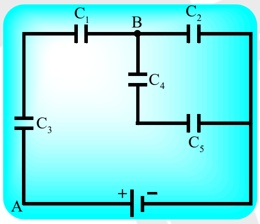
(A) 10^{-7} J (B) 10^{-8} J (C) 10^{-9} J (D) 10^{-10} J

14. Nine identical capacitors, each of capacitance $C = 15\mu F$ are connected as shown in figure. Calculate equivalent capacitance $(\text{in } \mu F)$ between terminals 1 and 4.



15. In the circuit shown in figure, $C_1 = 5\mu F,\ C_2 = 2.9\mu F,\ C_3 = 6\mu F,\ C_4 = 3\mu F$ and $C_5 = 7\mu F$.

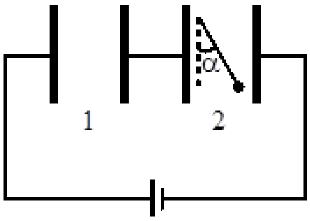
If in steady state potential difference between points A and B is 11 volt, calculate potential difference across C_5.



(A) 0.6 volt (B) 1.2 volt (C) 1.8 volt (D) 2.4 volt

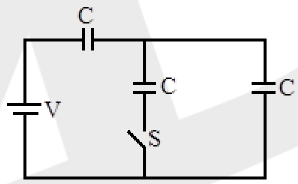
EXERCISE-4

1. Two identical parallel plate capacitors 1 and 2 are placed vertically and connected in series to a battery. In capacitor-2 there is a charged small particled attached by a thin wire to a fixed point, as shown. Ignore the effect of the charge particle on the cahrge distribution of the capacitor plates. At equilibrium, the angle between the wire and the vertical direction is α. Now slowly pull a plate of capacitor-1 until the distance between its two plates is doubled. After equilibrium, angle between the wire and the vertical direction is :



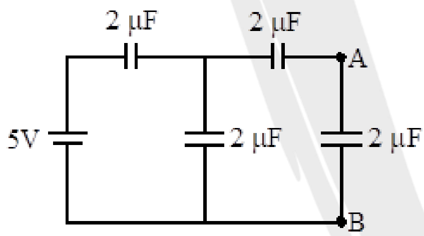
(A) $\tan^{-1}\left(\frac{2}{3}\tan\alpha\right)$ (B) $\tan^{-1}\left(\frac{1}{3}\tan\alpha\right)$ (C) $\tan^{-1}\left(\frac{1}{2}\tan\alpha\right)$ (D) $\tan^{-1}\left(\frac{3}{2}\tan\alpha\right)$

2. In the circuit shown, find heat dissipated in the circuit after switch is opened (Initially switch is closed) :

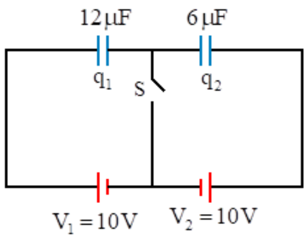


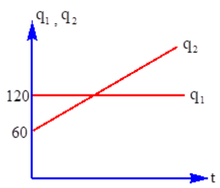
(A) $\frac{CV^2}{3}$ (B) $\frac{CV^2}{6}$ (C) $\frac{CV^2}{12}$ (D) 0

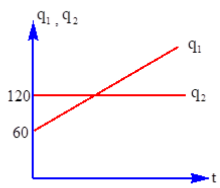
3. Find the potential difference (in volt) across AB. If voltage of ideal battery 5 volt is :

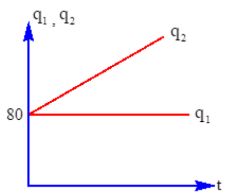


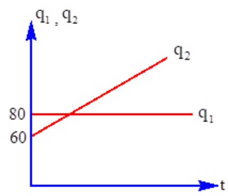
4. In the figure switch S is closed and steady state is reached. Now at t = 0 voltage V_2 is increased according to equation $V = t + 10$; upto the breakdown state. The correct plot of charges q_1 and q_2 with respect to t will be :



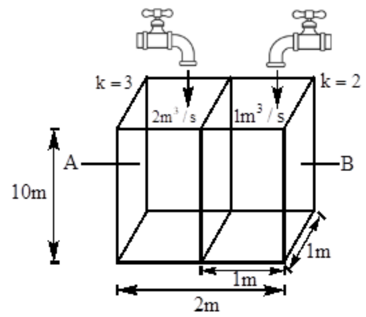
(A)


(B)


(C)


(D)


5. A thin metallic partition of negligible thickness is inserted between two shaded metallic plates as shown. The remaining ends are then packed with insulating plates to form a container like structure. 2 taps shown are opend at t = 0 and finally closed at t = 5s. Find capacitance of system between A and B after closing taps. (Assume liquid to be non-conduting) Volumetric flow rates and dielectric constants of liquid are given.



(A) 8.85×10^{-11} F (B) 8.85×10^{-10} F (C) 4.42×10^{-10} F (D) 4.42×10^{-11} F

6. A $3\,\mu F$ and a $5\,\mu F$ capacitor are connected in series across a 30 V battery. A $7\,\mu F$ capacitor is then connected in parallel across the $3\,\mu F$ capacitor. Choose the **incorrect** option.

(A) Voltage across $3\,\mu F$ capacitor before connecting $7\,\mu F$ capacitor is 18.75 V

(B) Charge flown through battery after connecting $7\,\mu F$ capacitor is $43.75\,\mu C$

(C) $5\,\mu F$ capacitor and $7\,\mu F$ capacitor can be said to be in series

(D) After connecting $7\,\mu F$ capacitor, it has charge of $70\,\mu C$

7. A dielectric slab fills the space between the plates of a parallel-plate capacitor. The magnitude of the bound charge on the slab is 75% of the magnitude of the free charge on the plates. The capacitance of the capacitor is $480\,\mu F$ with the slab inserted. The maximum charge that can be stored on the capacitor is $240\,\varepsilon_0 L^2 E_{max}$, where E_{max} is the breakdown field. Choose the correct statement(s) :

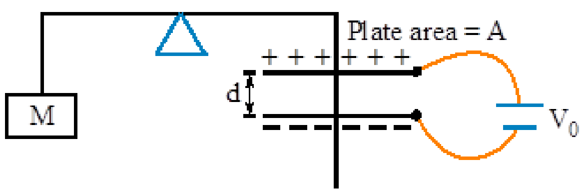
(A) The dielectric constant for the dielectric slab is 4

(B) Without the dielectric, the capacitance of the capacitor would be $360\,\mu F$

(C) The plate area is $60L^2$

(D) If the dielectric slab is having the same area as the capacitor plate but the width half that of the capacitor, the capacitance would be $192\,\mu F$

8. A capacitance balance is shown in figure. The balance has a weight attached on one side and a capacitor that has a variable gap width on other side. Assume the upper plate of the capacitor has negligible mass. When the capacitor potential difference between plates is V_0. The attractive force between the plates balances the weight of the hanging mass :



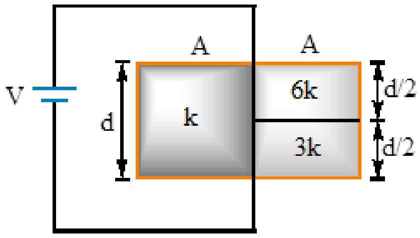
(A) Equilibrium of weight is stable

(B) Equilibrium of weight is unstable

(C) Value of V_0 required to balance weight is given by $V_0 = d\sqrt{\frac{2Mg}{\varepsilon_0 A}}$

(D) For a small displacement block of mass M executes simple harmonic motion

9. 3 dielectric slabs (each of area A) are filled between capacitor of plate are 2A. Capacitor is connected with battery of emf V. Electric field and electric field energy stored in dielectric k, 6k, 3k are E_1, E_2, E_3 and U_1, U_2, U_3 respectively :



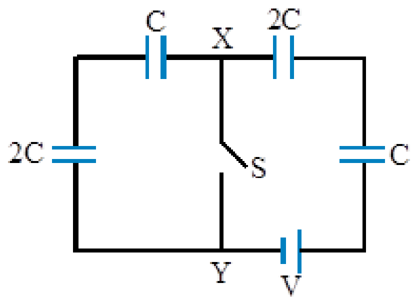
(A) Total energy stored in capacitors is $\frac{5Ak\varepsilon_0 V^2}{2d}$

(B) $E_1 : E_2 : E_3 :: 3 : 2 : 4$

(C) $U_1 : U_2 : U_3 :: 3 : 4 : 8$

(D) Capacitance of capacitor is $\frac{5Ak\varepsilon_0}{d}$

10. Consider the situation shown in the figure. The switch S is open for a long time and then closed and again steady state reached then :



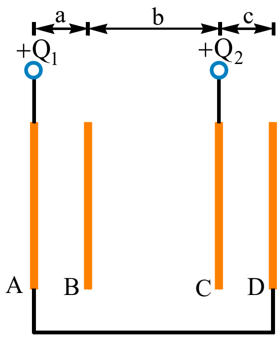
(A) charge flowing from X to Y is $\frac{2CV}{3}$

(B) charge flowing from Y to X is $-\frac{CV}{3}$

(C) work done by battery is $\frac{CV^2}{3}$

(D) work done by battery is $\frac{2CV^2}{3}$

11. Figure shows an arrangement of four identical rectangular plates A, B, C and D each of area S. Ignore the separation between the plates in comparison to the plate dimensions.



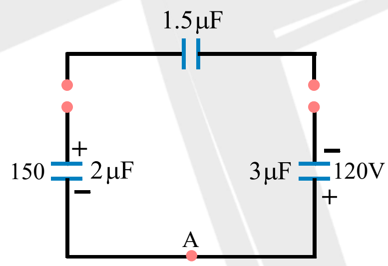
(A) Potential difference between plates A and B is independent of Q_1

(B) Potential difference between plates C and D is independent of Q_1

(C) Potential difference between plates A and B is independent of Q_2

(D) Potential difference between plates C and D is independent of Q_2

12. Negative plate of a $2\ \mu F$ capacitor charged to 150 volts is connected to the oppositely charged plates of $3\ \mu F$ capacitor charged to 120 volts. The other plates of each capacitor are connected to free wires. An uncharged capacitor of $1.5\ \mu F$ is dropped onto free ends as shown in diagram. After steady state select the correct statements :



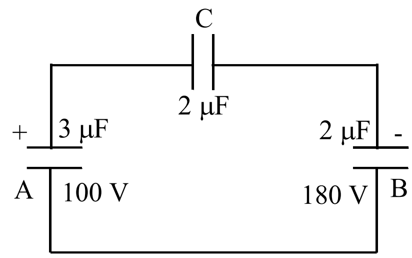
(A) Potential drop across $2\ \mu F$ capacitor is 60 V

(B) Potential drop across $1.5\ \mu F$ capacitor is 120 V

(C) Potential drop across each capacitor is same and it is 90 V

(D) Charge on $2\ \mu F$ capacitor is $120\ \mu C$

13. Two capacitors A and B with capacitances $3\ \mu F$ and $2\ \mu F$ are charged to a potential difference of 100 V and 180 V respectively. The plates of the capacitors are connected as shown in the figure with one wire of each capacitor free. The upper plate of A is positive and that of B is negative. An uncharged $2\ \mu F$ capacitor C with lead wires falls on the free ends to complete the circuit. Then



(A) The final charge on the three capacitors is $q_1 = 90\ \mu C$, $q_2 = 210\ \mu C$ and $q_3 = 150\ \mu C$ respectively.

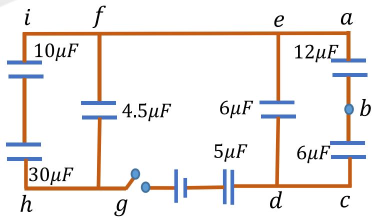
(B) The final charge on the three capacitors is $q_1 = 150\mu C$, $q_2 = 210\mu C$ and $q_3 = 90\mu C$ respectively.

(C) The amount of electrostatic energy stored in the system before and after completion of the circuit are $U_i = 47.4\,mJ$ and $U_f = 18\ mJ$ respectively.

(D) The amount of electrostatic energy stored in the system before and after completion of the circuit are $U_i = 18\ mJ$ and $U_f = 47.4\ mJ$ respectively.

PASSAGE – 1

In the circuit diagram shown here seven capacitors are connected to a source of emf E. Initially, the switch S is closed and steady state attained. Now, the potential difference between the points 'a' and 'b' is 4 volt. Now, answer the following questions:



14. The emf E of the battery is :

(A) 46V (B) 26V (C) 14V (D) 10 V

15. The charge on $4.5\mu F$ is:

(A) $90\mu C$ (B) $45\mu C$ (C) $54\mu C$ (D) zero

16. The charge on $10\mu C$ is :

(A) $70\mu C$ (B) $45\mu C$ (C) $75\mu C$ (D) $120\mu C$

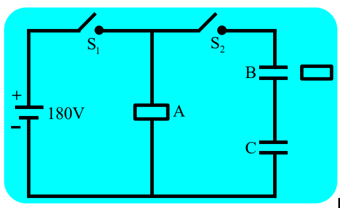
17. The charge on $5\mu F$ is :

(A) $70\mu c$ (B) $45\mu c$ (C) $75\mu c$ (D) $120\mu c$

18. The charge on $12\mu F$ is :

(A) $48\mu c$ (B) $90\mu c$ (C) $120\mu c$ (D) $60\mu c$

19. In the circuit shown in figure, capacitor A has capacitance $C_1 = 2\mu F$ when filled with a di-electric slab $(K = 2)$. Capacitors B and C are



air capacitors and have capacitances $C_2 = 3\mu F$ and $C_3 = 6\mu F$, respectively. A is charged by closing switch S_1 alone.

(A) The energy supplied by battery during process of charging. Switch (S_1 is now opened and S_2 is closed), is 0.0648 J

(B) The charge on B and energy stored in the system when electrical equilibrium is attained. (Now switch S_2 is also opened, slab of A is removed. Another di-electric slab of K = 2, which can just fill the space in B, is inserted into it and then switch S_2 alone is closed), are $180\ \mu C$ and $0.0162\,J$

(C) The electric field B is increased 0.75 times

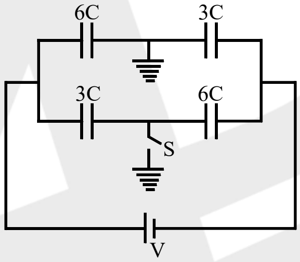
(D) The loss of energy during redistribution of charge is 0.0054 J

EXERCISE-5

1. Consider a huge charge reservoir at potential V. A spherical capacitor C_1 is brought in contact with the charge reservoir and then removed. Next another spherical capacitor C_2 is brought in contact with C_1 and removed. We repeat this process a large number of times. Assume that potential of reservoir does not charge during this exercise. Then the charge on C_2 after a very long time is :

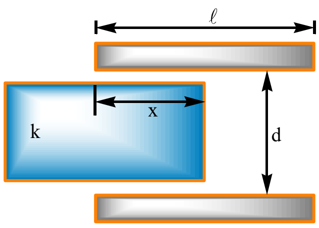
(A) C_2V (B) C_1V (C) $\frac{C_2C_1V}{(C_1+C_2)}$ (D) $(C_1+C_2)V$

2. Consider a network shown in figure. Initially the switch S is open. The amount of charge flow through earth wire after closing the switch S is :



(A) CV (B) 2CV (C) $\frac{1}{2}CV$ (D) $\frac{3CV}{2}$

3. Two square plates of sides ℓ are placed parallel to each other with separation d as suggested in figure. You may assume d is much less than ℓ. The plates carry uniformly distributed static charges $+Q_0$ and $-Q_0$. A block of metal has width ℓ, length ℓ, and thickness slightly less than d. It is inserted at distance x into the space between the plates. The charges on the plates remain uniformly distributed as the block slides in. In a static situation, a metal prevents an electric field from penetrating inside it. The metal can be thought of as a perfect dielectric, with $k \to \infty$.



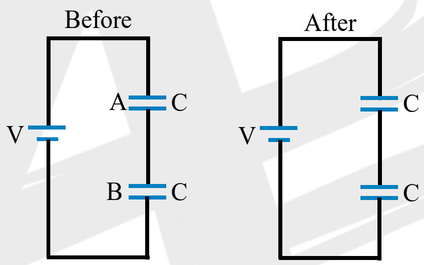
(A) The stored energy as a function of x is given by $\frac{Q_0^2 d(\ell - x)}{(2\ell^3 \varepsilon_0)}$

(B) The magnitude of the force that acts on the metallic block is given by $\frac{Q_0^2 d}{\left(\ell^3 \varepsilon_0\right)}$ to the right

(C) The area of the advancing front face of the block is essentially equal to ℓd, the stress (force per unit area) on it is $\frac{Q_0^2}{\left(2\ell^2 \varepsilon_0\right)}$

(D) The energy density in the electric field between the charged plates in terms of Q_0, ℓ, d, and ε_0 is $\frac{Q_0^2}{\left(2\ell^4 \varepsilon_0\right)}$

4. Two identical capacitors are connected in series as shown in the figure. A dielectric slab (k > 1) is placed between the plates of the capacitor B and the battery remains connected. Which of the following statement(s) is/are correct following the insertion of the dielectric?



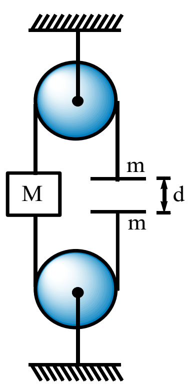
(A) The charge supplied by the battery increases

(B) The capacitance of the system increases

(C) The electric field in the capacitor B increases

(D) The electrostatic potential energy decreases

5. Two plates of mass m each are connected to mass M by two light inextensible strings. The pulleys are ideal. To hold system in equilibrium, we need to charge the plates by a battery of at least 8 volt. If distance between plates is $1\,\mu m$, capacitance formed is $1\,\mu F$, $\left(g = 10\ m/s^2\right)$



(A) $M = 12.8$ kg (B) $m = 3.2$ kg

(C) $M = 6.4$ kg (D) $m = 1.6$ kg

6. A dielectric slab fills the space between the plates of a parallel-plate capacitor. The magnitude of the bound charge on the slab is 75% of the magnitude of the free charge on the plates. The capacitance is 480 μF and the maximum charge that can be stored on the capacitor is $240\varepsilon_0 L^2 E_{max}$ (in μC), where E_{max} is the breakdown field (in V/m).

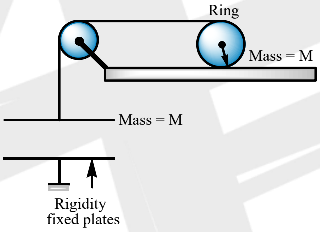
(A) the dielectric constant for the dielectric slab is 4

(B) without the dielectric, the capacitance of the capacitor would be 360 μF

(C) the plate area is 60 m^2

(D) if the dielectric slab is having the same area as the capacitor plate but the width half that of the capacitor, the capacitance would be 192 μF

7. If ring of radius 'R' is placed on smooth floor connected by a string at the top. Other end of string is connected to upper plate of capacitor of same mass 'M' and charge density σ and area A. Lower plate of capacitor is rigidly fixed. Then which of the following statements are correct if upper plate of capacitor is falling freely with acceleration 'g'.



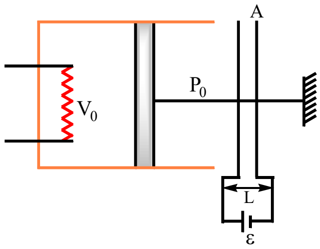
(A) Charge density of plates of capacitor must be $\sigma = \sqrt{2Mg\varepsilon_0}$

(B) The gain in kinetic energy of the ring and the plate of capacitor is equal to the loss in gravitational potential energy

(C) Charge of plates of capacitor must be $q = \sqrt{Mg\varepsilon_0 A}$

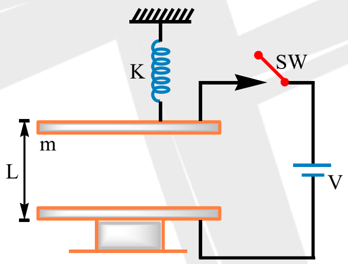
(D) The gain in kinetic energy of the ring and the plates of capacitor is 1.5 times the loss in gravitational potential energy

8. An ideal gas is enclosed in a cylinder fitted with a frictionless piston. The piston is connected with a light rod to one plate of capacitor whose other plate is fixed as shown. Initially the volume of the gas inside the cylinder is V_0, pressure is P_0, atmospheric pressure is also P_0, separation between the plates of capacitor is L, area of the piston as well as of the capacitor plates is A and emf of battery is ε. A heater supplies necessary heat to the gas such that equilibrium is achieved when pressure of the gas is given as $P = P_0 - \frac{n\varepsilon_0^2 \varepsilon^2}{L^2}$ and piston is displaced towards right by a distance $\frac{L}{2}$. Find the value on n.



(A) $\frac{2}{9}$A (B) $\frac{4}{9}$A (C) $\frac{5}{9}$A (D) $\frac{7}{9}$A

9. A parallel plate capacitor having its lower end fixed and upper end is attached with spring having spring constant K. Upper is in equilibrium before switch is closed. After switch is closed, then the condition on the potential of battery so that the system can acquire new equilibrium position is
[V is potential difference across the battery]

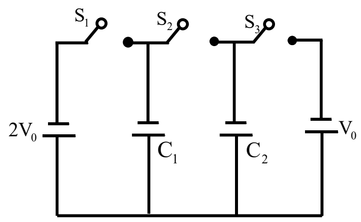


(A) $V \le \sqrt{\left(\frac{2}{3}\right)\frac{L^3k}{A\varepsilon_0}}$ (B) $V \le \sqrt{\left(\frac{2}{3}\right)^2\frac{L^3k}{A\varepsilon_0}}$ (C) $V \le \sqrt{\left(\frac{2}{3}\right)^3\frac{L^3k}{A\varepsilon_0}}$ (D) $V \le \sqrt{\left(\frac{2}{3}\right)^4\frac{L^3k}{A\varepsilon_0}}$

10. Between the plates of a parallel-plate capacitor having separation d, we put a metallic plate of thickness 0.6 d. When that plate is absent the capacitor has a capacity C = 20 Nf. The capacitor is connected to a dc voltage source of emf of 100 volt. The metallic plate is slowly extracted from the gap. Find the mechanical work performed in the process of plate extraction is

(A) $50\,\mu J$ (B) $100\,\mu J$ (C) $150\,\mu J$ (D) $200\,\mu J$

11. In the circuit shown in the figure, there are two parallel plate capacitors each of capacitance C. The switch S_1 is pressed first for fully charge the capacitor C_1 and then released. The switch S_2 is then pressed to charge the capacitor C_2. After some time, S_2 is released and then S_3 is pressed. After some time,

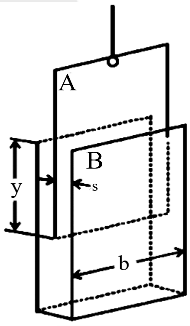


(A) The charge on the upper plate of C_1 is $2CV_0$ (B) The charge on the upper plate of C_1 is CV_0

(C) The charge on the upper plate of C_2 is 0 (D) The charge on the upper plate of C_2 is $-CV_0$

Paragraph For Questions 12 and 13:

A flat conducting sheet A is suspended by an insulating thread between the surfaces formed by the bent conducting sheet B as shown in the figure. The sheets are oppositely charged, the difference in potential is constant and equal to ΔV. This causes a force F pulling A downward. (Neglect gravity)



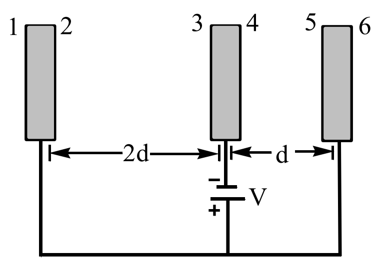
12. The modulus of work done by external agent needed to slowly increase the inserted distance by Δy is:

(A) $\frac{2(\Delta V)^2 b \in_0 \Delta y}{s}$ (B) $\frac{(\Delta V)^2 b \in_0 \Delta y}{s}$ (C) $\frac{(\Delta V)^2 b \in_0 \Delta y}{2s}$ (D) $\frac{4(\Delta V)^2 b \in_0 \Delta y}{s}$

13. An expression for the difference in potential ΔV in terms of F and relevant dimensions shown in the figure is:

(A) $\sqrt{\frac{sF}{\in_0 b}}$ (B) $\sqrt{\frac{2sF}{\in_0 b}}$ (C) $\sqrt{\frac{sF}{2\in_0 b}}$ (D) $2\sqrt{\frac{sF}{\in_0 b}}$

14. In the given arrangement all the plates are large and conducting. The area of each plate is A. All surfaces of plates are marked as shown in the figure.



Match the column I and column II

LIST - I		LIST - II	
A)	Charge on surface 3	P)	zero
B)	Charge on surface 5	Q)	V
C)	Potential difference between surfaces 2 and 3	R)	$\frac{\varepsilon_0 A}{2d}V$
D)	Potential difference between surfaces 2 and 5	S)	$\frac{\varepsilon_0 A}{d}V$

(A) A-R, B-S, C-Q, D-P (B) A-S, B-Q, C-P, D-R

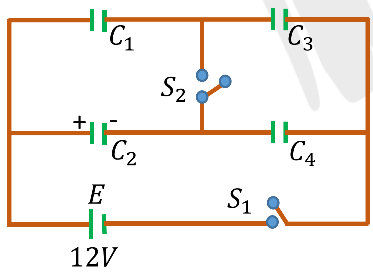
(C) A-Q, B-P, C-S, D-R (D) A-P, B-R, C-S, D-Q

15. Two square metal plates of side 1m 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 emf 500 V. the plates are then lowered vertically into the oil at a speed of $0.001\,ms^{-1}$. Calculate the current drawn from the battery during the process. (Dielectric constant of oil = 11, $\varepsilon_0 = 8.85\times10^{-12}C^2N^{-1}m^{-1}$).

(A) $1.11\times10^{-9}A$ (B) $2.31\times10^{-9}A$ (C) $3.11\times10^{-9}A$ (D) $4.43\times10^{-9}A$

Passage

Four capacitors $C_1 = (1\mu F), C_2 = (2\mu F), C_3 = (3\mu F)$ and $C_4 = (4\mu F)$ are connected in a network as shown in the diagram. The emf of the battery is E=12V and its internal resistance is negligible. The keys S_1 and S_2 can be independently put on or off. Indicate the charge on the capacitors by q_1, q_2, q_3 and q_4 respectively and the potential drops across them by V_1, V_2, V_3 and V_4 respectively.



16. Initially both the keys are open. Then the key S_1 is closed. Then the charges on the capacitors are

(A) $q_1 = q_2 = 16\mu C, q_3 = q_4 = 9\mu C$ (B) $q_1 = q_3 = 16\mu C, q_2 = q_4 = 9\mu C$

(C) $q_1 = q_4 = 9\mu C, q_2 = q_3 = 16\mu C$ (D) $q_1 = q_3 = 9\mu C, q_2 = q_4 = 16\mu C$

17. Initially key S_2 is closed. Then the key S_1 is now closed. Then the charges on the capacitors are

(A) $q_1 = q_2 = 24\mu C, q_3 = q_4 = 12\mu C$

(B) $q_1 = q_2 = 12\mu C, q_3 = q_4 = 24\mu C$

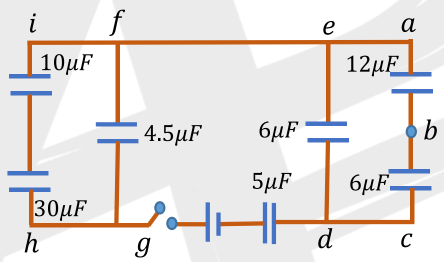
(C) $q_1 = 10.8\mu C, q_2 = 14.4\mu C$, $3q_3 = 2q_4, 2q_4 = 25.2\mu C$

(D) $2q_1 = q_2 = 16.8\mu C, 4q_3 = 3q_4 = 43.2\mu C$

18. Initially key S_2 is open. The key S_1 is closed and the capacitors are charged. If now the key S_2 be closed, the charge that will flow across this key is

(A) $2.4\mu C$ (B) $0.4\mu C$ (C) $0.2\mu C$ (D) $1.2\mu C$

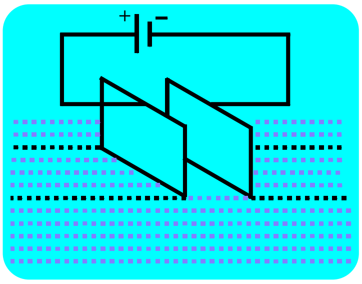
19. In the cirucuit diagram shown here, seven capacitors are connected to a source of emf E. Initialy, the switch S is closed and steady state attained. Now the potential difference between the points 'a' and 'b' is 4 volt. Now, match the following; for potential difference between different points.



	Column – I		Column – II
(A)	12 volt	p.	P.d Between g and b
(B)	10 volt	q.	P.d Between g and d
(C)	14 volt	r.	P.d Between g and i
(D)	22 volt	s.	P.d Between g and a
		t.	P.d Between a and d

20. Two square metallic plates of side a = 1 m are kept d = 8.85 mm apart, like a parallel plate capacitor, in air, in such a way that their surfaces are normal to oil surface in a tank filled with that insulating oil (K = 11). The plates are connected to a battery of emf V = 500 volt as shown in figure. The plates are then lowered vertically into the oil at a speed of $v = 10^{-3}\ ms^{-1}$. Neglecting resistance of connecting wires, calculate the current drawn from battery during the process.

$\left(\varepsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}\right)$



(A) 2.5×10^{9} A (B) 2.5×10^{-9} A (C) 5×10^{-9} A (D) 5×10^{9} A

EXERCISE – 6 (JEE MAINS)

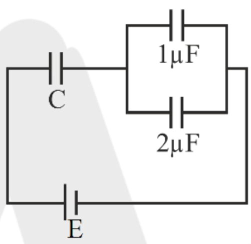
1. A parallel plate capacitor is made of two circular plates separated by a distance of 5 mm and with a dielectric of dielectric constant 2.2 between them. When the electric field in the dielectric is 3×10^4 V/ m, the charge density of the positive plate will be close to:

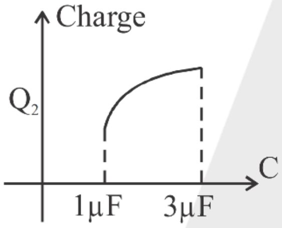
[JEE MAIN 2014]

(A) $6 \times 10^{-7} C/m^2$ (B) $3 \times 10^{-7} C/m^2$ (C) $3 \times 10^4 C/m^2$ (D) $6 \times 10^4 C/m^2$

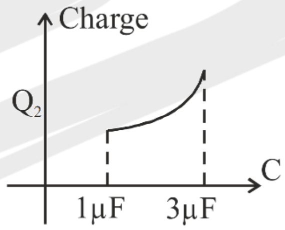
2. In the given circuit, charge Q_2 on the $2\mu F$ capacitor changes as C is varied from $1\mu F$ to $3\mu F$. Q_2 as a function ' C ' is given properly by : (figures are drawn schematically and are not to scale)

[JEE MAIN 2015]

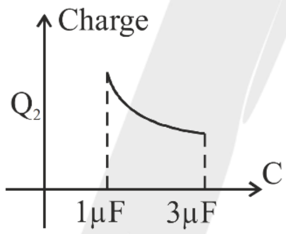




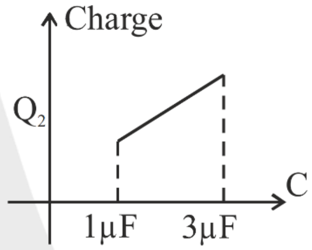
(A)



(B)

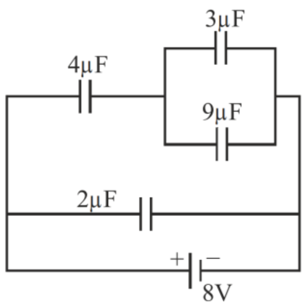


(C)



(D)

3. A combination of capacitors is set up as shown in the figure. The magnitude of electric field, due to a point charge Q (having a charge equal to the sum of the charges on the $4\mu F$ and $9\mu F$ capacitors), at a point distant 30 m from it, would equal: **[JEE MAIN 2016]**



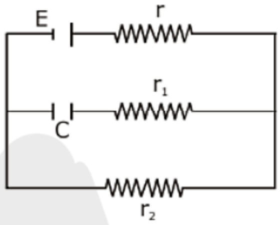
(A) 360 N/C (B) 420 N/C (C) 480 N/C (D) 240 N/C

4. A capacitance of $2\mu F$ is required in an electrical circuit across a potential difference of 1.0kV. A large number of $1\mu F$ capacitors are available which can withstand a potential difference of not more than 300 V. **[JEE MAIN 2017]**

The minimum number of capacitors required to achieve this is :

(A) 2 (B) 16 (C) 24 (D) 32

5. In the given circuit diagram when the current reaches steady state in the circuit, the change on the capacitor of capacitance C will be : **[JEE MAIN 2017]**



(A) CE (B) $CE\frac{r_1}{(r_2+r)}$ (C) $CE\frac{r_2}{(r+r_2)}$ (D) $CE\frac{r_1}{(r_1+r)}$

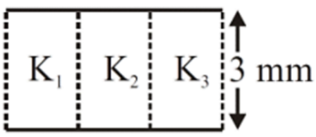
6. A parallel plate capacitor of capacitance 90pF is connected to a battery of emf 20 V. If a dieletric material of dielectric constant $K=\frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be : **[JEE Main-2018]**

(A) 0.9 nC (B) 1.2 n C (C) 0.3 n C (D) 2.4 n C

7. A parallel plate capacitor is made of two square plates of side ' a ', separated by a distance $d(d << a)$. The lower triangular portion is filled with a dielectric of dielectric constant K, as shown in the figure. Capacitance of this capacitor is : **[JEE Main-2019]**

(A) $\frac{1}{2}\frac{k\epsilon_0 a^2}{d}$ (B) $\frac{k\epsilon_0 a^2}{d}\ln K$ (C) $\frac{k\epsilon_0 a^2}{d(K-1)}\ln K$ (D) $\frac{k\epsilon_0 a^2}{2d(K+1)}$

8. A parallel plate capacitor is of area $6\ cm^2$ and a separation 3 mm. The gap is filled with three dielectric materials of equal thickness (see figure) with dielectric constants $K_1,=10,\ K_2=12$ and $K_3=14$. The dielectric constant of a material which when fully inserted in above capacitor, gives same capacitance would be : **[JEE Main-2019]**



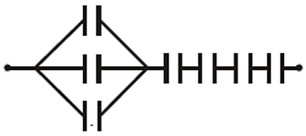
(A) 4 (B) 14 (C) 36 (D) 12

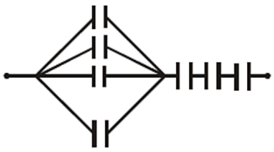
9. A parallel plate capacitor having capacitance 12pF is charged by a battery to a potential difference of 10 V between its plates. The charging battery is now disconnected and a porcelain slab of dielectric constant 6.5 is slipped between the plates the work done by the capacitor on the slab is : **[JEE Main-2019]**

(A) 692pJ (B) 560pJ (C) 508pJ (D) 600pJ

10. Seven capacitors, each of capacitance 2μF, are to be connected in a configuration to obtain an effective capacitance of $\left(\frac{6}{13}\right)$ μF. Which of the combinations, shown in figures below, will achieve the desired value ? **[JEE Main-2019]**

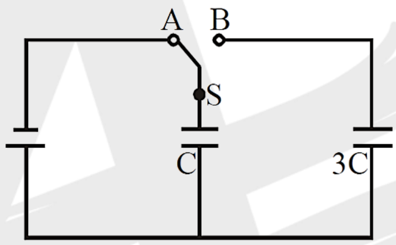
(A) 

(B) 

(C) 

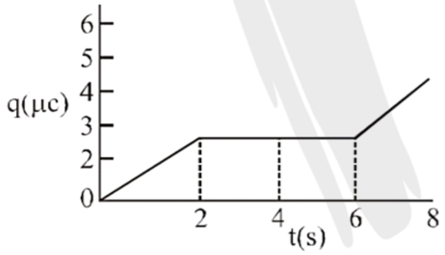
(D) 

11. In the figure shown, after the switch ' S ' is turned from position ' A ' to position ' B ', the energy dissipated in the circuit in terms of capacitance ' C ' and total charge ' Q ' is: **[JEE Main-2019]**



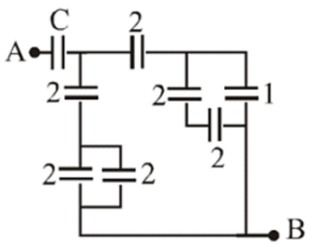
(A) $\frac{3}{8}\frac{Q^2}{C}$ (B) $\frac{5}{8}\frac{Q^2}{C}$ (C) $\frac{1}{8}\frac{Q^2}{C}$ (D) $\frac{3}{4}\frac{Q^2}{C}$

12. The charge on a capacitor plate in a circuit, as a function of time, is shown in the figure:
What is the value of current at t = 4 s ? **[JEE Main-2019]**



(A) 1.5μA (B) 2μA (C) zero (D) 3μA

13. In the circuit shown, find C if the effective capacitance of the whole circuit is to be 0.5μF. All values in the circuit are in μF. **[JEE Main-2019]**



(A) $\frac{7}{11}$ μF (B) 4μF (C) $\frac{7}{10}$ μF (D) $\frac{6}{5}$ μF

14. A parallel plate capacitor with plates of area $1\ m^2$ each, area t a separation of 0.1 m. If the electric field between the plates is 100 N/C, the magnitude of charge each plate is :-

(Take $\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N-m^2}$) **[JEE Main-2019]**

(A) $7.85 \times 10^{-10}C$ (B) $9.85 \times 10^{-10}C$

(C) $8.85 \times 10^{-10}C$ (D) $6.85 \times 10^{-10}C$

15. A parallel plate capacitor has plates of area A separated by distance ' d ' between them. It is filled with a dielectric which has a dielectric constant that variesask x) = K(1 + αx) where ' x is the distance measured from one of the plates. If (αd) << 1, the total capacitance of the system is best given by the expression: **[JEE Main-2020]**

(A) $\frac{Ak\varepsilon_0}{d}\left(1+\frac{\alpha d}{2}\right)$ (B) $\frac{A\epsilon_0 K}{d}\left(1+\frac{\alpha^2 d^2}{2}\right)$

(C) $\frac{A\epsilon_0 K}{d}\left(1+\left(\frac{\alpha d}{2}\right)^2\right)$ (D) $\frac{AK\epsilon_0}{d}(1+\alpha d)$

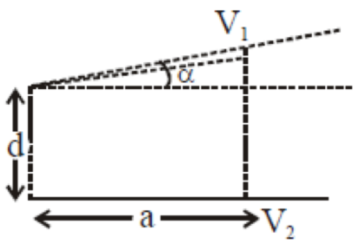
16. A 60pF capacitor is fully charged by a 20 V supply. It is then disconnected from the supply and is connected to another uncharged 60pF capacitor in parallel. The electrostatic energy that is lost in this process by the time the charge is redistributed between them is (in nJ)__________.

[JEE Main-2020]

17. Effective capacitance of parallel combination of two capacitors C_1 and C_2 is 10μF. When these capacitors are individually connected to a voltage source of 1 V, the energy stored in the capacitor C_2 is 4 times that of C_1. If these capacitors are connected in series, their effective capacitance will be: **[JEE Main-2020]**

(A) 1.6μF (B) 3.2μF (C) 8.4μF (D) 4.2μF

18. A capacitor Ls made of two square plates each of side ' a ' making a very small angle a between them, as shown in figure. The capacitance will be close to : **[JEE Main-2020]**



(A) $\frac{\epsilon_0 a^2}{d}\left(1-\frac{\alpha a}{4d}\right)$ (B) $\frac{\epsilon_0 a^2}{d}\left(1+\frac{\alpha a}{d}\right)$

(C) $\frac{\epsilon_0 a^2}{d}\left(1-\frac{\alpha a}{2d}\right)$ (D) $\frac{\epsilon_0 a^2}{d}\left(1-\frac{3\alpha a}{2d}\right)$

19. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities capacities in the two cases will be – **[JEE Main 2021]**

(1) 2: 1 (2) 1: 4 (3) 4: 1 (4) 1: 2

20. An electron with kinetic energy K_1 enters between parallel plates of a capacitor at an angle ' α ' with the plates. It leaves the plates at angle ' β' with kinetic energy K_2. Then the ratio of kinetic energies $K_1 : K_2$ will be: **[JEE Main 2021]**

(1) $\frac{\sin^2 \beta}{\cos^2 \alpha}$ (2) $\frac{\cos^2 \beta}{\cos^2 \alpha}$ (3) $\frac{\cos \beta}{\sin \alpha}$ (4) $\frac{\cos \beta}{\cos \alpha}$

21. Consider the combination of 2 capacitors C_1 and C_2, with $C_2 > C_1$, when connected in parallel, the equivalent capacitance is $\frac{15}{4}$ times the equivalent capacitance of the same connected in series. Calculate the ratio of capacitors, $\frac{C_2}{C_1}$ **[JEE Main 2021]**

Note: NTA has dropped this question in the final official answer key.

(1) $\frac{15}{11}$ (2) $\frac{29}{15}$ (3) $\frac{15}{4}$ (4) None of the above

22. 27 similar drops of mercury are maintained at 10 V each. All these spherical drops combine into a single big drop. The potential energy of the bigger drop is _____ times that of a smaller drop. **[JEE Main 2021]**

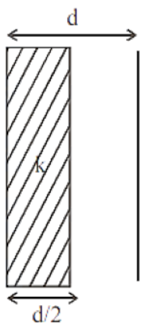
23. For changing the capacitance of a given parallel plate capacitor, a dielectric material of dielectric constant K is used, which has the same area as the plates of the capacitor. The thickness of the dielectric slab is $\frac{3}{4}$ d, where ' d ' is the separation between the plates of parallel plate capacitor. The new capacitance (C') in terms of original capacitance (C_0) is given by the following relation : **[JEE Main 2021]**

(1) $C' = \frac{3+K}{4K} C_0$ (2) $C' = \frac{4+K}{3} C_0$

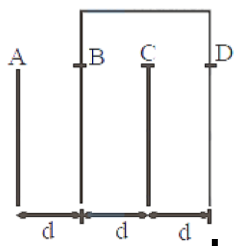
(3) $C' = \frac{4K}{K+3} C_0$ (4) $C' = \frac{4}{3+K} C_0$

24. In a parallel plate capacitor set up, the plate area of capacitor is 2 m^2 and the plates are separated by 1 m. If the space between the plates are filled with a dielectric material of thickness 0.5 m and area 2 m^2 (see fig.) the capacitance of the set-up will be ε_0. (Dielectric constant of the material = 3.2)

(Round off to the Nearest Integer) **[JEE Main 2021]**



25. Four identical rectangular plates with length, $l = 2$ cm and breadth, $b = \frac{3}{2}$ cm are arranged as shown in figure. The equivalent capacitance between A and C is $\frac{x\varepsilon_0}{d}$. The value of x is (Round off to the Nearest Integer) **[JEE Main 2021]**

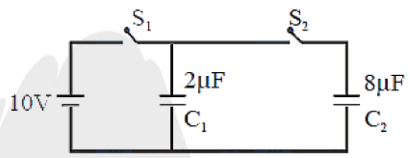


26. A parallel plate capacitor whose capacitance C is 14pF is charged by a battery to a potential difference $V = 12\text{ V}$ between its plates. The charging battery is now disconnected and a porcelin plate with $k = 7$ is inserted between the plates, then the plate would oscillate back and forth between the plates with a constant mechanical energy of pJ (Assume no friction)

[JEE Main 2022]

27. A 2μF capacitor C_1 is first charged to a potential difference of 10 V using a battery. Then the battery is removed and the capacitor is connected to an uncharged capacitor C_2 of 8μF. The charge in C_2 on equilibrium condition is $---$μC. (Round off to the Nearest inte)

[JEE Main 2022]

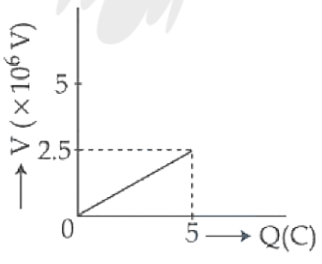


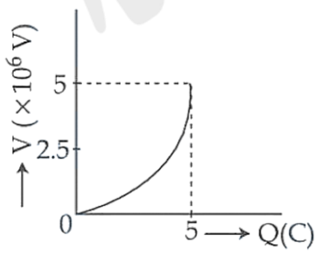
28. A parallel plate capacitor has plate area 100 m^2 and plate separation of 10 m. The space between the plates is filled up to a thickness 5 m with a material of dielectric constant of 10. The resultant capacitance of the system is 'x' pF. The value of $\varepsilon_0 = 8.85 \times 10^{-12}\text{ F} \cdot \text{m}^{-1}$ The value of ' x ' to the nearest integer is _____ . **[JEE Main 2022]**

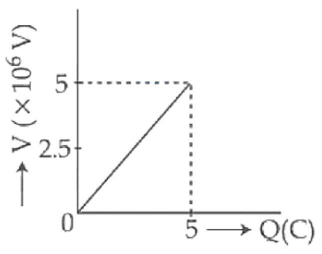
29. An infinite number of point charges, each carrying 1μC charge, are placed along the y-axis at $y = 1\text{ m}, 2\text{ m}, 4\text{ m}, 8\text{ m}$ .... The total force on a 1C point charge, placed at the origin, is $x \times 10^3$ N. The value of x, to the nearest integer, is ___. **[JEE Main 2022]**

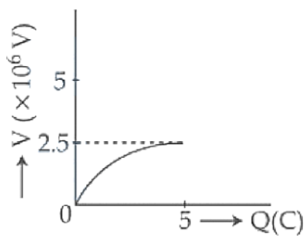
$$\left[\text{Take } \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{Nm}^2/\text{C}^2\right]$$

30. A condenser of 2μF capacitance is charged steadily from 0 to 5C. Which of the following graph represents correctly the variation of potential difference (V) across it's plates with respect to the charge (Q) on the condenser ? **[JEE Main 2022]**

(A)


(B)


(C)


(D)


31. Capacitance of an isolated conducting sphere of radius R_1 becomes n times when it is enclosed by a concentric conducting sphere of radius R_2 connected to earth. The ratio of their radii $\left(\frac{R_2}{R_1}\right)$ is: **[JEE Main 2022]**

(A) $\frac{n}{n-1}$ (B) $\frac{2n}{2n+1}$ (C) $\frac{n+1}{n}$ (D) $\frac{2n+1}{n}$

32. Two parallel plate capacitors of capacity C and 3C are connected in parallel combination and charged to a potential difference 18 V. The battery is then disconnected and the space between the plates of the capacitor of capacity C is completely filled with a material of dielectric constant 9. The final potential difference across the combination of capacitors will be V.

[JEE Main 2022]

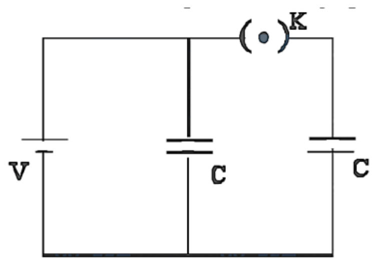
33. The total charge on the system of capacitance $C_1 = 1\mu F, C_2 = 2\mu F, C_3 = 4\mu F$ and $C_4 = 3\mu F$ connected in parallel is (Assume a battery of 20 V is connected to the combination)

[JEE Main 2022]

(A) 200μC (B) 200C (C) 10μC (D) 10C

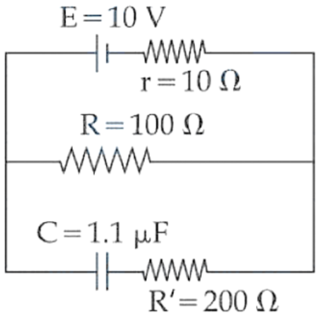
34. A composite parallel plate capacitor is made up of two different dielectric materials with different thickness (t_1 and t_2) as shown in figure. The two different dielectric material are separated by a conducting foil F. The voltage of the conducting foil is V. **[JEE Main 2022]**

35. A source of potential difference V is connected to the combination of two identical capacitors as shown in the figure. When key ' K ' is closed, the total energy stored across the combination is E_1. Now key ' K ' is opened and dielectric of dielectric constant 5 is introduced between the plates of the capacitors. The total energy stored across the combination is now E_2. The ratio E_1/E_2 will be : **[JEE Main 2022]**



(A) $\frac{1}{10}$ (B) $\frac{2}{5}$ (C) $\frac{5}{13}$ (D) $\frac{5}{26}$

36. As show in the figure, in steady state, the charge stored in the capacitor is ____ $\times 10^{-6}$C. **[JEE Main 2022]**



37. A parallel plate capacitor with width 4 cm, length 8 cm and separation between the plates of 4 mm is connected to a battery of 20 V. A dielectric slab of dielectric constant 5 having length 1 cm, width 4 cm and thickness 4 mm is inserted between the plates of parallel plate capacitor. The electrostatic energy of this system will be ____ ϵ_0 J. (Where ϵ_0 is the permittivity of free space) **[JEE Main 2022]**

38. Two capacitors, each having capacitance 40μF are connected in series. The space between one of the capacitors is filled with dielectric material of dielectric constant K such that the equivalence capacitance of the system became 24μF. The value of K will be : **[JEE Main 2022]**

(A) 1.5 (B) 2.5 (C) 1.2 (D) 3

39. sectional area as the plates of a parallel plate capacitor and thickness $\frac{3}{4}$ d, where d is the separation of the plates. The capacitance of the capacitor when the slab is inserted between the plates will be : (Given C_0 = capacitance of capacitor with air as medium between plates.)

(A) $\frac{4KC_0}{3+K}$ (B) $\frac{3KC_0}{3+K}$ (C) $\frac{3+K}{4KC_0}$ (D) $\frac{K}{4+K}$ **[JEE Main 2022]**

40. Two identical thin metal plates has charge q_1 and q_2 respectively such that $q_1 > q_2$. The plates were brought close to each other to form a parallel plate capacitor of capacitance C. The potential difference between them is : **[JEE Main 2022]**

(A) $\frac{(q_1+q_2)}{C}$ (B) $\frac{(q_1-q_2)}{C}$ (C) $\frac{(q_1-q_2)}{2C}$ (D) $\frac{2(q_1-q_2)}{C}$

41. A parallel plate capacitor with air between the plate has a capacitance of 15pF. The separation between the plate becomes twice and the space between them is filled with a medium of dielectric constant 3.5. Then the capacitance becomes $\frac{x}{4}$ pF. The value of x is **[JEE Main 2023]**

42. A parallel plate capacitor has plate area 40 cm^2 and plates separation 2 mm. The space between the plates is filled with a dielectric medium of a thickness 1 mm and dielectric constant 5. The capacitance of the system is : **[JEE Main 2023]**

(1) $24\varepsilon_0$ F (2) $\frac{3}{10}\varepsilon_0$ F (3) $\frac{10}{3}\varepsilon_0$ F (4) $10\varepsilon_0$ F

43. A capacitor has capacitance 5μF when it's parallel plates are separated by air medium of thickness d. A slab of material of dielectric constant 1.5 having area equal to that of plates but thickness $\frac{d}{2}$ is inserted between the plates. Capacitance of the capacitor in the presence of slab will be ____ μF. **[JEE Main 2023]**

44. A capacitor of capacitance 900μF is charged by a 100 V battery. The capacitor is disconnected from the battery and connected to another uncharged identical capacitor such that one plate of uncharged capacitor connected to positive plate and another plate of uncharged capacitor connected to negative plate of the charged capacitor. The loss of energy in this process is measured as $x \times 10^{-2}$ J. The value of x is **[JEE Main 2023]**

45. Two parallel plate capacitors C_1 and C_2 each having capacitance of 10μF are individually charged by a 100 V D.C. source. Capacitor C_1 is kept connected to the source and a dielectric slab is inserted between it plates. Capacitor C_2 is disconnected from the source and then a dielectric slab is inserted in it. Afterwards the capacitor C_1 is also disconnected from the source and the two capacitors are finally connected in parallel combination. The common potential of the combination will be V. (Assuming Dielectric constant = 10) **[JEE Main 2023]**

46. A charge particle of 2μC accelerated by a potential difference of 100 V enters a region of uniform magnetic field of magnitude 4mT at right angle to the direction of field. The charge particle completes semicircle of radius 3 cm inside magnetic field. The mass of the charge particle is ____ $\times 10^{-18}$ kg. **[JEE Main 2023]**

47. Given below are two statements : One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : Two metallic spheres are charged to the same potential. One of them is hollow and another is solid, and both have the same radii. Solid sphere will have lower charge than the hollow one.

Reason R : Capacitance of metallic spheres depend on the radii of spheres. In the light of the above statements, choose the correct answer from the options given below. **[JEE Main 2023]**

(1) A is false but R is true

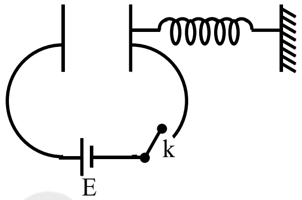
(2) Both A and R are true and R is the correct explanation of A

(3) A is true but R is false

(4) Both A and R are true but R is not the correct explanation of A

Proficiency Test-1

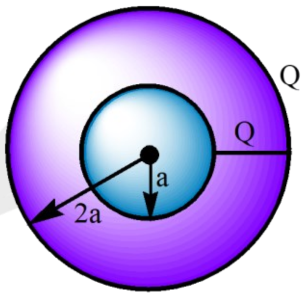
1. A plate A of a parallel plate capacitor is fixed, while the plate B is attached to the wall by a spring and can move, remaining parallel to the plate A (see figure). The capacitor is charged, plate B starts moving and comes to rest in an equilibrium position. The separation between the plates d, decreases by 10%. What will be the decrease in the plate separation if the charging is done in a very short time that the plate B could not shift noticeably.



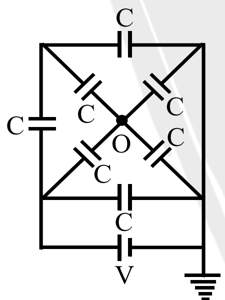
(A) 10% (B) 8.1% (C) 9% (D) 6.3%

2. Figure shows a solid metal sphere of radius a surrounded by a concentric thin metal shell of radius 2a. Initially both are having charges Q each. When the two are connected by a conducting wire as shown in figure, then amount of heat produced in this process is $\frac{kQ^{\alpha}}{\beta a}$.

Find $\alpha + \beta$?



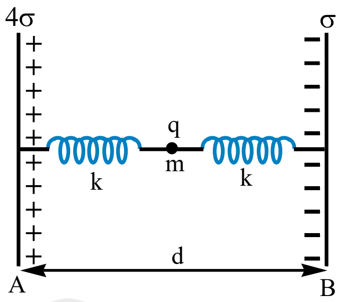
3. In the given circuit, the potential at point 'O' is $\frac{4V}{6+n}$. Find n?



4. A parallel plate capacitor of capacitance $200\ \mu F$ is charged by a battery of emf 100 V. The battery is now disconnected and temperature of the plates is equal to atmospheric temperature. The plates are now connected by a thin wire of negligible heat capacity. Asume 50% of their stored energy increases their temperatue till the capacitor gets completely discharged and energy equally distributes over the plates. If thermal capacity of each plate is $0.5\ JK^{-1}$ and coefficient of linear expansion is $2\times10^{-5}\ °C^{-1}$, percentage increase in the volume of the plates is :

(A) 0.001% (B) 0.002% (C) 0.003% (D) 0.004%

5. Two large conducting plates having surface charge densities 4σ and $-\sigma$ respectively, are fixed 'd' distance apart. A small test charge q of mass m is attached to two identical non-conducting springs as shown in figure with spring in natural length. Then q will [neglect gravity] :



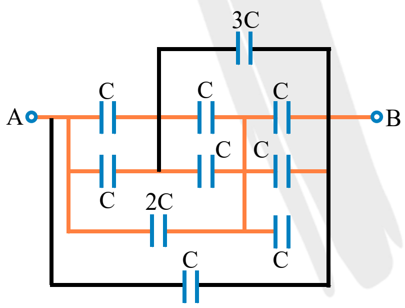
(A) Perform S.H.M. with angular frequency $\sqrt{\dfrac{2k}{m}}$

(B) Perform S.H.M. with amplitude $\dfrac{5\sigma q}{2k\varepsilon_0}$

(C) Not perform S.H.M., but will have a periodic motion

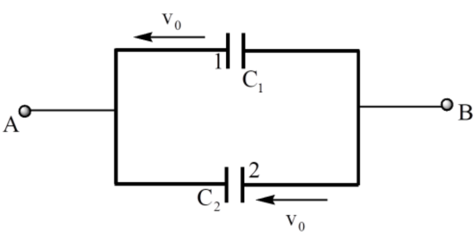
(D) Perform S.H.M. with amplitude $\dfrac{5\sigma q}{4k\varepsilon_0}$

6. Find the equivalent capacitance between A and B in μF, if $C = 5\ \mu F$. If your answer is $\alpha\beta$ then find the value of $\alpha+\beta$. (expression in two digit number)

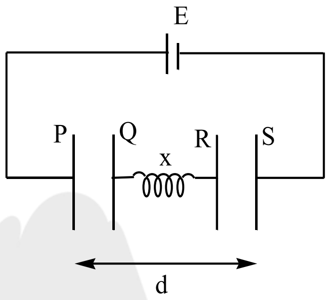


(A) 4 (B) 6 (C) 8 (D) 10

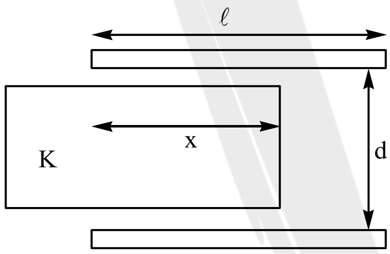
7. Two identical capacitors having plate separation 'd' are connected parallel to each other across points A and B as shown in the figure. A charge q is supplied to the system by connecting a battery across A and B and battery is removed. Now first plate of first capacitor and second plate of second capacitor starts moving with constant velocity υ_o towards left. The magnitude of current flowing in the loop during this process at this instant is $\frac{q\upsilon_o}{pd}$. Find the value of 'p' taking all quantities are in S.I units.



8. Two parallel plate capacitors with area A are connected through a conducting spring of natural length ℓ in series as shown. Plates P and S have fixed positions at separation d. now the plates are connected by a battery of emf E as shown. If the extension in the spring in equilibrium is equal to the separation between the plates, the spring constant k is $k=\frac{\alpha\varepsilon_0 AE^2}{\beta(d-\ell)^3}$. Find $\alpha+\beta$?



9. A capacitor is constructed from two square plates of sides ℓ and separation $d(<<\ell)$, as suggested in figure. The plates carry charges $+Q_0$ and $-Q_0$. A block of metal has a widht ℓ, a length ℓ and thickness slightly less than d. it is inserted a distance x into the capacitor. The charges on the plates are not disturbed as the block slides in. in a static situation, a metal prevents an electric field from penetrating inside it.



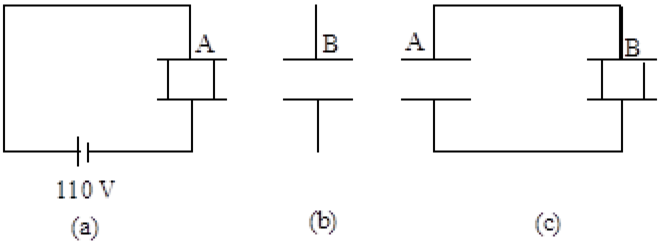
(A) The stored energy as a function of x is $\frac{Q_0^2(\ell-x)d}{2\varepsilon_0\ell^3}$

(B) The direction and magnitude of the force that acts on the metallic block is $\frac{Q_0^2 d}{2\varepsilon_0\ell^3}$ to the right

(C) The area of the advancing front face of the block is essentially equal to ℓd. Considering the force on the block as acting on this face, the stress (force per area) on it is $\frac{Q_0^2}{2\varepsilon_0\ell^4}$

(D) The energy density in the electric field between the capacitor plates in terms of Q_0, ℓ, d and ε_0 is $\frac{Q_0^2}{2\varepsilon_0\ell^4}$

10. Two parallel plate capacitors A and B have the same separation $d = 8.85 \times 10^{-4}\,m$ between the plates. The plate areas of A and B are $0.04\,m^2$ and $0.02\,m^2$ 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.



(A) The dielectric slab is placed inside A as shown in figure (a). A is then charged to a potential difference of 110 V. The capacitance of A and the energy stored in it are $C_A = 2 \times 10^{-9}\,F$ and $U_A = 1.21 \times 10^{-5}\,J$ respectively.

(B) The battery is disconnected and then the dielectric slab is removed from A. The work done by the external agency in removing the slab from A is $4.84 \times 10^{5}\,J$

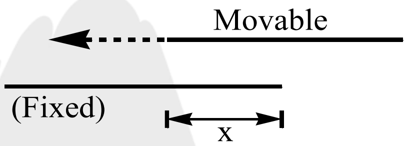
(C) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected as shown in figure (c). The energy stored in the system is $U = 1.1 \times 10^{-5}\,J$

(D) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected as shown in figure (c). The energy stored in the system is $U = 2.2 \times 10^{-5}\,J$

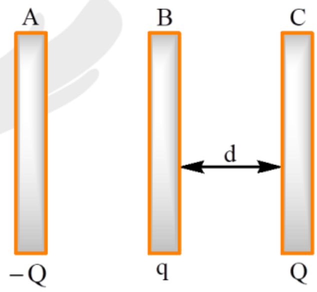
Proficiency Test-2

1. Between the plates of a parallel-plate capacitor, there is a metallic plate whose thickness takes up 60% of the capacitor gap. When that plate is absent the capacitor is connected to a dc voltage source of voltage = 100 V. The metallic plate is slowly extracted from gap. Find the mechanical work (in μJ) performed in the process of plate extraction.

2. A parallel-plate capacitor consists of a fixed plate and a movable plate that is allowed to slide in the direction parallel to the plates. Let x be the distance of overlap, as shown in the figure. The sepation between the plates is fixed. Assume that the plates are electrically isolated, so that their charges $\pm Q$ are constant. Force on the movable plate is proportional to x^{-n}. Find n?



3. Two fixed very large conducting plates A and B of area S carry charges $-Q$ and q respectively where $Q > q > 0$. A third identical plate C carrying a charge Q is released at distance d from B. Third plate collides with B. Assume collision is elastic and time of collision is sufficient to re-distribute charge among B and C (Neglect gravity) :



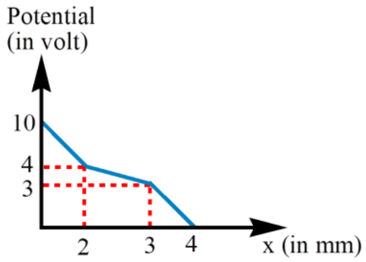
(A) Force acting on plate C before collision is $\dfrac{(Q-q)Q}{2\varepsilon_0 S}$

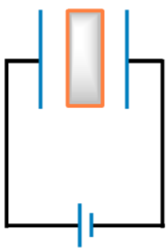
(B) Force acting on plate C after collision is $\dfrac{(q/2)^2}{2\varepsilon_0 S}$

(C) Subsequent to collision kinetic energy of plate C increases

(D) Subsequent to collision electrostatic potential energy between the plates remain constant

4. A capacitor filled partially with dielectric material of dielectric constant 'k'. Its electric potential v/s distance from left plate (x) graph is as shown. Distance between the two plates is 4 mm. Find the dielectric constant of medium.



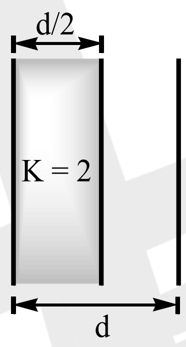


(A) 1 (B) 2 (C) 3 (D) 4

5. An electrometer is charged to 3 kV. Then the electrometer is touched with an initially neutral-metal ball, mounted on an insulating rod, and then the metal ball is taken away and earthed. The process is done for 10 times, and finally the electrometer reads 1.5 kV. After this, at least how many times must the above process be repeated in order that the electrometer reads less than 1 kV?

(A) 2 (B) 4 (C) 6 (D) 8

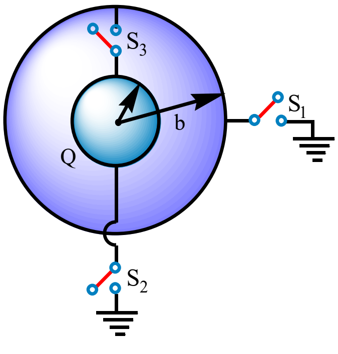
6. A certain series RC circuit is formed using a resistance R, a capacitor without dielectric having a capacitance C = 2 F and a battery of emf E = 3 V. The circuit is completed and it is allowed to attain the steady state. After this, at t = 0, half the thickness of the capacitor is filled with a dielectric of constant K = 2 as shown in the figure. The system is again allowed to attain a steady state. What will be the heat generated in the circuit between t = 0 and $t = \infty$?



(A) 3 J (B) 6 J (C) 9 J (D) 12 J

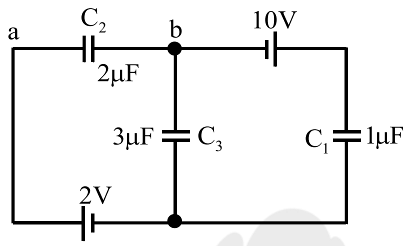
7. The figure shows a conducting sphere 'A' of radius 'a' which is surrounded by a neutral conducting spherical shell B of radius 'b' (>a). Initially switches S_1, S_2 and S_3 are open and sphere 'A' carries a charge Q. First the switch 'S_1' is closed to connect the shell B with the ground and then opened. Now the switch 'S_2' is closed so that the sphere 'A' is grounded and then S_2 is opened. Finally, the switch 'S_3' is closed to connect the spheres together. Find the heat which is produced after closing the switch S_3 is

[Consider b = 4 cm, a = 2 cm and $Q = 8\ \mu C$]

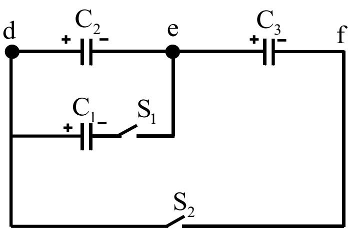


(A) 0.4 J (B) 0.8 J (C) 1.2 J (D) 1.8 J

8. In the circuit shown in figure (A), the capacitors and batteries are ideal and circuit is at steady state. The capacitors C_1, C_2 and C_3 are disconnected from the circuit shown in figure (A) with their charges intact and reconnected as in figure (B) with polarities as indicated. Initially charges on capacitor C_1, C_2 & C_3 before connecting to the circuit A was zero on each



Figure(A)



Figure(B)

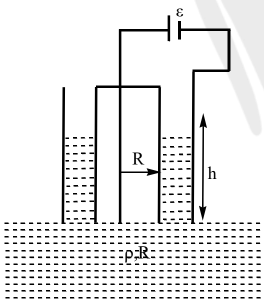
(A) On closing switches S_1 and S_2 the potential difference $(V_d - V_e)$ between the points d and e becomes 2.0 V

(B) The charge on the plate C_3 connected to e after closing the switches is $-6\mu C$

(C) In figure A, the work done by 2 V battery is $50\mu J$

(D) The work done by the 10 V battery in charging the capacitors is $90\mu J$

9. A cylindrical capacitor connected to a battery of emf ε touches the surface of water with its lower end as shown. The separation 'd' between the capacitor electrodes is substantially less than its inner radius R(>>d). The capillary effects are to be neglected. Then choose the correct option (s). (Density of water = ρ , dielectric constant of water = K) [Treat water as insulator]



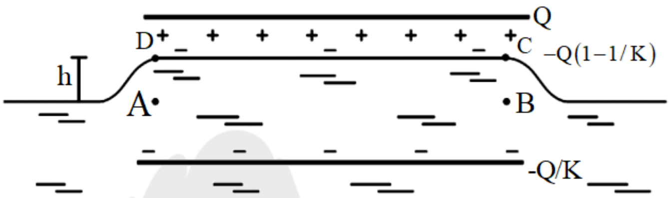
(A) The electric force acting on the surface of water is $F = \dfrac{\varepsilon_0 \pi R \varepsilon^2 (k-1)}{2d}$

(B) The electric force acting on the surface of water is $F = \dfrac{\varepsilon_0 \pi R \varepsilon^2 (k-1)}{d}$

(C) The height upto which the water level will rise in the gap is $h = \dfrac{\varepsilon_0 \varepsilon^2 (k-1)}{2\rho g d^2}$

(D) The height upto which the water level will rise in the gap is $h=\dfrac{\varepsilon_0\varepsilon^2(k-1)}{\rho g d^2}$

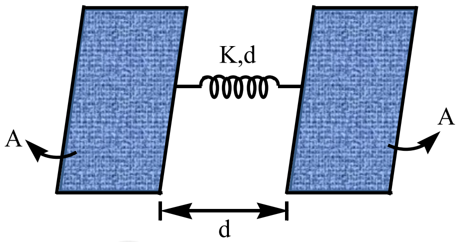
10. A parallel-plate capacitor is placed in such a way that its plates are horizontal and the lower plate is dipped into a liquid of dielectric constant K and density ρ. Each plswsswsswate has an area A. The plates are now connected to a battery which supplies a positive charge of magnitude Q to the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



If your answer is $\dfrac{(k^n-1)\sigma^2}{2\varepsilon_0 k^m \rho g}$, Report m + n.

Proficiency Test-3

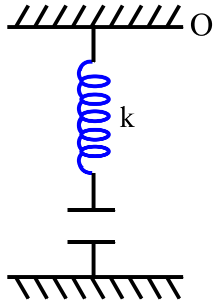
1. Consider the figure, initial dinstance between plates is 'd' and 'A' is area of plates. In this state spring is at its natural length. Now, charges $+Q$ and $-Q$ are given to plates and system is allowed to reach mechanical equilibrium. Find potential difference between plates in this state of equilibrium.



(A) $V = \frac{Qd}{A\varepsilon_0}\left(1 - \frac{Q^2}{2\varepsilon_0 AKd}\right)$ (B) $V = \frac{Qd}{2A\varepsilon_0}\left(1 - \frac{Q^2}{2\varepsilon_0 AKd}\right)$

(C) $V = \frac{Qd}{A\varepsilon_0}\left(1 - \frac{Q^2}{4\varepsilon_0 AKd}\right)$ (D) $V = \frac{Qd}{A\varepsilon_0}\left(1 - \frac{Q^2}{\varepsilon_0 AKd}\right)$

2. A parallel plate capacitor initially having plate separation d and capacitance C in air is connected by means of a spring of spring constant k to a point O, the plates are assumed to be massless, and the lower plate is also fixed. A charge q now is given to the capacitor. The capacitance of capacitor (assuming that the spring is non-conducting) becomes :



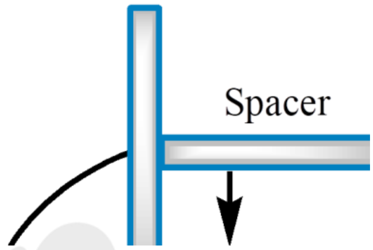
(A) $\frac{C}{\left(1 - \frac{q^2 A}{Ckd^2}\right)}$ (B) $\frac{C}{\left(1 - \frac{q^2 A}{2Ckd^2}\right)}$ (C) C (D) None of these

3. A charged capacitor of capacitance C and having charge Q is to be connected with another uncharged capacitor of capacitance C' as shown till steady state is reached. Then the value of C' for heat liberated through the wires to be minimum :

(A) zero (B) C

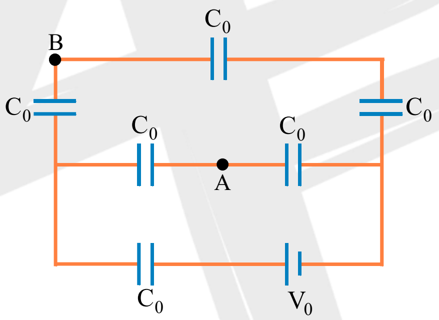
(C) $\frac{C}{2}$ (D) 2C

4. A capacitor is to be designed to operate, with constant capacitance, even when temperature varies. The distance between plates is adjusted by spacer to compensate temperature effect. Let α_1 and α_2 be the coefficient of linear thermal expansion of plate and spacer respectively. Find the ratio of $\frac{\alpha_2}{\alpha_1}$, so that no change in capacitance of capacitor with change in temperature.



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

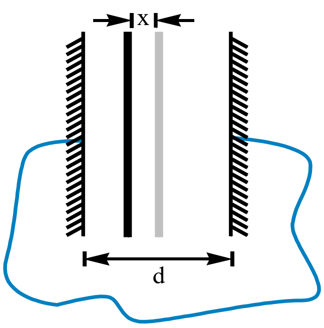
5. In the arrangement shown in figure, find the potential difference $V_B - V_A$ (in volt). (Take $V_0 = 55\,V$)



(A) 2.5 V (B) 5 V (C) 7.5 V (D) 10 V

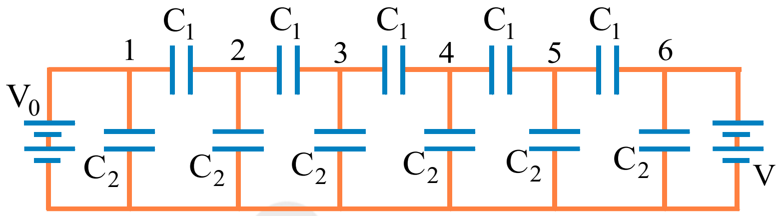
6. In the middle of a charged parallel plate capacitors a plate was placed. Charge on the plate is q. Now the plate is moved parallel to itself by a distance x. What is the charge flowing through the external circuit of the capacitor if the distance between its plates equal to d?

Take $q = 8\,\mu C,\ x = 1\text{ mm},\ d = 4\text{ mm}$.



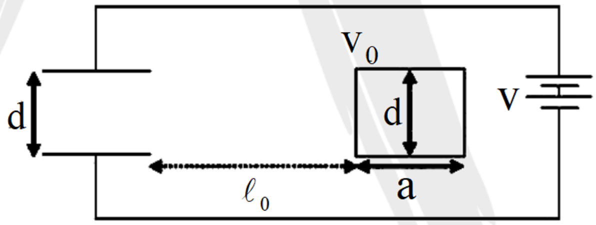
(A) $1\mu C$ (B) $2\mu C$ (C) $3\mu C$ (D) $4\mu C$

7. In the circuit shown, ratio of capacitors is $\frac{C_2}{C_1}=\frac{4}{3}$ and terminal voltage of the battery connected at the left end is V_0. If the terminal voltage of the battery connected at the right most end is in such a way that the potentials of nodes 1, 2, 3, 4, 5 and 6 are in a geometric progression, of forms $V_0\ x^y$, then the value of $|x|+|y|$ is : (Note : x and y are integers)



(A) 2 (B) 4 (C) 6 (D) 8

8. A parallel plates capacitor is made of square conducting plates of side a and the separation between plates is d. The capacitor is connected with battery of emf V volt as shown in the figure. There is a dielectric slab of dimension $a\times a\times d$ with dielectric constant k. At t = 0, dielectric slab is given velocity v_0 towards capacitor as shown in the figure. (Neglect the effect of gravity and electrostatic force acting on the dielectric when dielectric is outside of capacitor. Also ignore any type of frictional force acting on the dielectric during its motion) let 'x' be the length of dielectric inside the capacitor at any time 't'. $[l_0 >> a]$



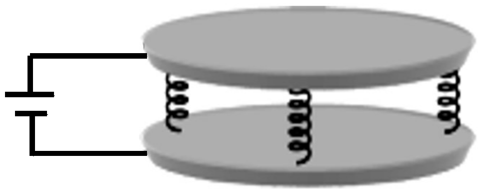
(A) Motion of dielectric slab is periodic but not simple harmonic motion

(B) Motion of dielectric slab is simple harmonic motion

(C) At any time, the slope of graph of total energy verses x is twice the slope of graph of potential energy verses x.

(D) The value of maximum energy stored in the system is $\frac{1}{2}mv_0^2+\frac{\varepsilon_0 a^2V^2}{2d}(2k\text{-}1)$

9. Mechanical and electrical processes are sometimes strongly coupled. Very important examples are systems containing piezoelectric materials, e.g. quartz resonator. Here we investigate a somewhat simpler situation. There are two metal plates with area S and mass m each. One plate is situated on top of the other one. Plates are connected to each other with springs, whose total equivalent spring constant is k and are made of insulator. The lower plate is mounted on a steady base. Equilibrium distance between the plates is X_0



Plates are now connected to a constant high voltage source, so that they form a capacitor. Electrostatic force between the plates causes an additional shift of the upper plate. The equilibrium distance between the plates is now X_1. Then

(A) Voltage applied to the plates V is $X_1\sqrt{\frac{2k\ X_0-X_1}{S\varepsilon_0}}$

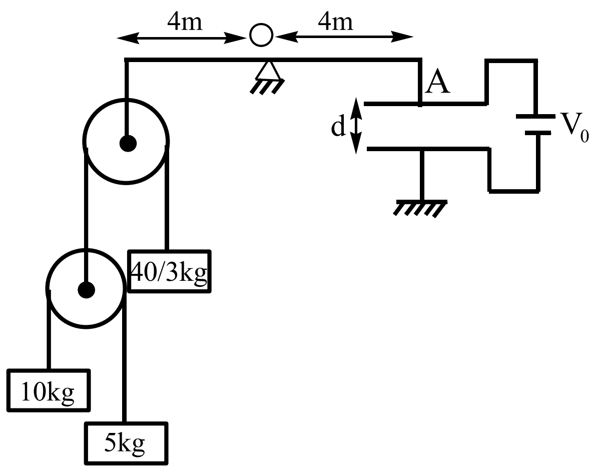
(B) Voltage applied to the plates V is $X_1\sqrt{\frac{k\ X_0-X_1}{S\varepsilon_0}}$

(C) the angular frequency of upper plate for small oscillations is $\omega=\sqrt{\frac{k}{m}\left(3-\frac{X_0}{X_1}\right)}$, keeping the voltage V constant.

(D) the angular frequency of upper plate for small oscillations is $\omega=\sqrt{\frac{k}{m}\left(3-2\frac{X_0}{X_1}\right)}$, keeping the voltage V constant.

10. A capacitance balance is shown in the figure. The balance has a block pulley system attached on one side and a capacitor that has a variable gap width on the other side. Assume upper plate of the capacitor has negligible mass. When the separation between the plate is $\frac{1}{\sqrt{5}}$ meter, the attractive force between the plates balances the pulley block system. Then find value of V_0 in volts (EMF of battery).

(Take area of the plate $=\frac{20}{3\varepsilon_0}m^2$) (Take $g=10\,m/s^2$)



ANSWER KEY

EXERCISE-1

1.	(100)	**2.**	(BD)	**3**	(A)	**4.**	(B)	**5.**	(5)	**6.**	(160)
7.	(ABD)	**8.**	(A)	**9.**	(C)	**10.**	(ABC)				

EXERCISE-2

1.	(100)	**2.**	(B)	**3**	(5)	**4.**	(AC)	**5.**	(ABD)	**6.**	(ABCD)
7.	(ACD)	**8.**	(1800)			**9.**	(3)	**10.**	(ABD)		

EXERCISE-3

1.	(5)	**2.**	(11)	**3**	(A)	**4.**	(A)	**5.**	(AC)	**6.**	(B)	**7.**	(BCD)
8.	(BC)	**9.**	(AB)	**10.**	(C)	**11.**	$\frac{CK_1K_2}{K_2-K_1}\ln\frac{K_2}{K_1}$; where $C=\frac{\varepsilon_0 A}{d}$						
12.	(BC)	**13.**	(C)	**14.**	(11)	**15.**	(C)						

EXERCISE-4

1.	(A)	**2.**	(B)	**3**	(1)	**4.**	(A)	**5.**	(A)	**6.**	(C)	**7.**	(ACD)
8.	(BC)	**9.**	(ABCD)			**10.**	(AC)	**11.**	(AB)	**12.**	(ABD)	**13.**	(AC)
14.	(A)	**15.**	(B)	**16.**	(C)	**17.**	(D)	**18.**	(A)	**19.**	(ABCD)		

EXERCISE-5

1.	(A)	**2.**	(D)	**3**	(ACD)	**4.**	(AB)	**5.**	(BC)	**6.**	(ACD)	**7.**	(CD)
8.	(B)	**9.**	(C)	**10.**	(C)	**11.**	(BD)	**12.**	(B)	**13.**	(A)	**14.**	(A)
15.	(D)	**16.**	(D)	**17.**	(D)	**18.**	(A)						
19.	(A-t; B-r,s; C-p; D-q)			**20.**	(C)								

EXERCISE-6 (JEE MAINS)

1.	(A)	**2.**	(C)	**3**	(C)	**4.**	(C)	**5.**	(D)	**6.**	(B)	**7.**	(A)
8.	(A)	**9.**	(B)	**10.**	(D)	**11.**	(C)	**12.**	(B)	**13.**	(C)	**14.**	(D)
15.	(C)	**16.**	(B)	**17.**	(A)	**18.**	(C)	**19.**	(B)	**20.**	(2)	**21.**	(4)
22.	(243)	**23.**	(3)	**24.**	(3)	**25.**	(2)	**26.**	(864)	**27.**	(16)	**28.**	(161)
29.	(12)	**30.**	(A)	**31.**	(A)	**32.**	(6)	**33.**	(A)	**34.**	(60)	**35.**	(C)
36.	(10)	**37.**	(240)	**38.**	(A)	**39.**	(A)	**40.**	(C)	**41.**	(105)	**42.**	(3)
43.	(6)	**44.**	(225)	**45.**	(55)	**46.**	(144)	**47.**	(1)				

Proficiency Test-1

1.	(B)	**2.**	(6)	**3**	(5)	**4.**	(C)	**5.**	(AD)	**6.**	(C)	**7.**	(2)
8.	(35)	**9.**	(ABCD)			**10.**	(ABC)						

Proficiency Test-2

1.	(150)	**2.**	(2)	**3**	(ABCD)	**4.**	(C)	**5.**	(C)	**6.**	(A)	**7.**	(D)
8.	(ABD)	**9.**	(BC)	**10.**	(02.00)								

Proficiency Test-3

1.	(A)	**2.**	(B)	**3**	(A)	**4.**	(B)	**5.**	(B)	**6.**	(B)	**7.**	(D)
8.	(ACD)	**9.**	(AD)	**10.**	(4)								

SOLUTIONS

EXERCISE-6 (JEE MAINS)

30. $Q = CV$

$$V = \frac{1}{C}Q$$

Straight line with slope $= \frac{1}{C}$

$$\text{Slope } = \frac{1}{C} = \frac{1}{2 \times 10^{-6}} = 5 \times 10^{5}$$

31. Capacitance of isolated Conducting sphere

$= 4\pi\varepsilon_0 R_1$

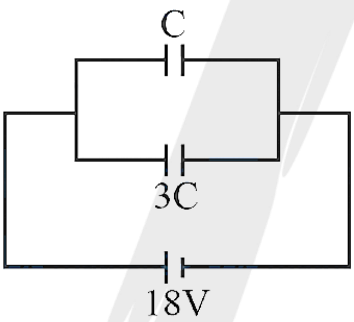
By enclosing inside another sphere of radius

R_2, new capacitance $= \dfrac{4\pi\varepsilon_0 R_1 R_2}{(R_2 - R_1)}$

Given: $\frac{4\pi\varepsilon_0 R_1 R_2}{(R_2 - R_1)} = n \times 4\pi\varepsilon_0 R_1$

$$\Rightarrow \frac{R_2}{R_1} = n\frac{R_2}{R_1} - n \Rightarrow \frac{R_2}{R_1} = \frac{n}{(n-1)}$$

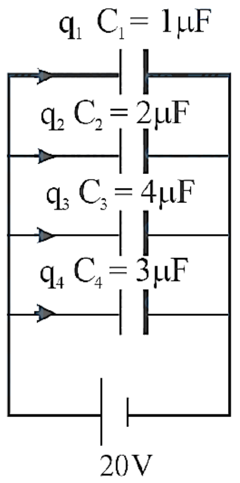
32.



Initial charge on $C = 18CV$
initial charge on $3C = 54CV$
Let final common potential difference $= V'$

$$9CV' + 3CV' = 18CV + 54CV$$

$$\Rightarrow 12CV' = 72CV \Rightarrow V' = 6\text{ V}$$



33.

Total charge $= q_1 + q_2 + q_2 + q_4$

$= 1 \times 20 + 2 \times 20 + 4 \times 20 + 3 \times 20 = 200\mu C$

$= 1 \times 20 + 2 \times 20 + 4 \times 20 + 3 \times 20 = 200\mu C$

34.

Capacitance of each capacitor

$$C_1 = \frac{A3\epsilon_0}{\frac{1}{2}} = 6A \in_0$$

$$C_2 = A4\epsilon_0 = 4 A \in_0$$

Equivalent capacitance

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} \Rightarrow \frac{24}{10} A \in_0$$

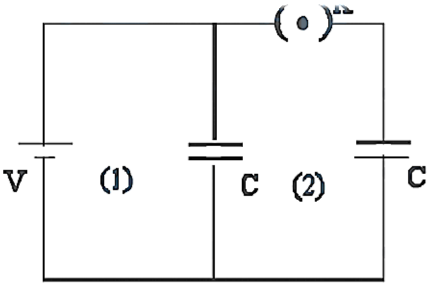
$$q_{net} = C_{eq}(\Delta V) \Rightarrow 240 A \in_0$$

$$\Delta V_2 = \frac{240 A \in_0}{4 A \in_0} = 60 V$$

($\Delta V_2 =$ Potential drop across C_2)

$V_{foil} = 60$ V

35.



(1) Switch is closed

$C_{eq} = 2C$

Energy $E_1 = \frac{1}{2}C_{eq}V^2$

$= \frac{1}{2}2C \times V^2$

$E_1 = CV^2$

(ii) When switch is opened charge on right capacitor remain CV while potential on left capacitor remain same
Dielectric K = 5

$C' = KC$

$C' = 5C$

$E_2 = \frac{1}{2}(5C)V^2 + \frac{(CV)^2}{2(5C)}$

$E_2 = \frac{5CV^2}{2} + \frac{CV^2}{10}$

$\frac{E_1}{E_2} = \frac{5}{13}$

$E_2 = \frac{13CV^2}{5}$

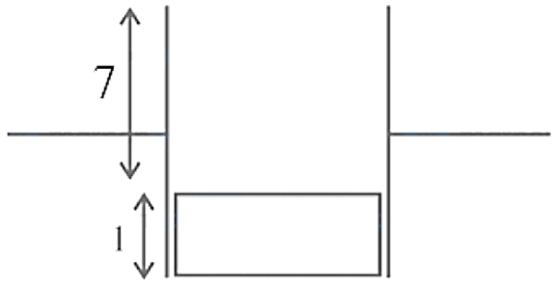
$\frac{E_1}{E_2} = \frac{CV^2}{\frac{13CV^2}{5}} = \frac{5}{13}$

36. $q = CVV_{100\Omega}$

$= (1.1 \times 10^{-6})\left(\frac{10}{R+r}R\right)$

$= 1.1 \times 10^{-6}\left(\frac{10}{110} \times 100\right)$

$= 10\mu C$

37. 

$$C_{eff} = \left[\frac{\varepsilon_0(7\times4)}{4/10} + \frac{5\varepsilon_0(1\times4)}{4/10}\right] \times 10^{-2}$$

$$C_{eff} = 1.2\varepsilon_0$$

$$\text{Energy } = \frac{1}{2}C_{eff}V^2$$

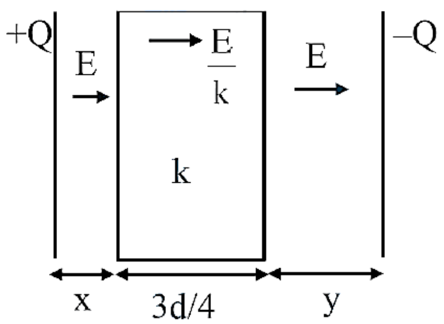
$$= \frac{1}{2}(1.2)\varepsilon_0(20)(20) = 240\varepsilon_0$$

38. 

$$C_{eq} = \frac{C(KC)}{C+KC} = \frac{KC}{K+1}$$

$$24 = \frac{K40}{K+1}$$

$$[\,K = 1\cdot5]$$

39. 

$$x + y + \frac{3d}{4} = d$$

$$x + y = \frac{d}{4}$$

$$\frac{A\epsilon_0}{d} = C_0$$

$$\Delta V = Ex + \frac{E}{k} \times \frac{3d}{4} + Ey$$

$$= \frac{3Ed}{4k} + E(x+y)$$

$$\Delta V = E\left[\frac{3\,d}{4k} + \frac{d}{4}\right]$$

$$\Delta V = \frac{\sigma}{\epsilon_0}\left[\frac{3\,d+dk}{4k}\right] = \frac{Qd}{A\epsilon_0}\left[\frac{3+k}{4k}\right]$$

$$\frac{Q}{\Delta V} = C = \frac{A\epsilon_0}{d}\left[\frac{4k}{3+k}\right] = \frac{4kCC_0}{k+3}$$

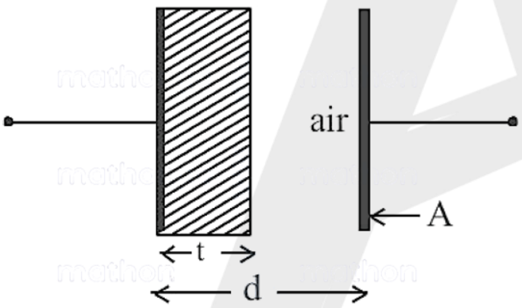
40. Electric field between plates $E = \frac{q_1 - q_2}{2\,A\epsilon_0}$

$$V = Ed = \frac{q_1 - q_2}{2\,A\epsilon_0}d$$

41. $C_0 = \frac{\epsilon_0\,A}{d} = 15Pf$

$$C = \frac{K\epsilon_0\,A}{2\,d} = \frac{3.5}{2} \times 15pF = \frac{105}{4}pF$$

42.



This can be seen as two capacitors in series combination so

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

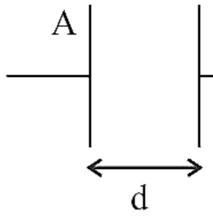
$$= \frac{1}{\frac{K\,\epsilon_0\,A}{t}} + \frac{1}{\frac{\epsilon_0 A}{d-t}}$$

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

$$= \frac{1 \times 10^{-3}}{5\epsilon_0 \times 40 \times 10^{-4}} + \frac{1 \times 10^{-3}}{\epsilon_0 40 \times 10^{-4}}$$

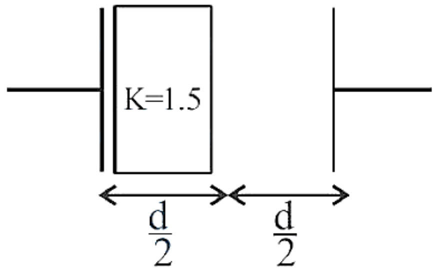
$$\frac{1}{C_{eq}} = \frac{1}{20\epsilon_0} + \frac{1}{4\epsilon_0}$$

$$C_{eq} = \frac{20 \times 4\epsilon_0}{24} = \frac{10\epsilon_0}{3}\;F$$



$$\frac{\epsilon_0 A}{d} = 5\mu F$$

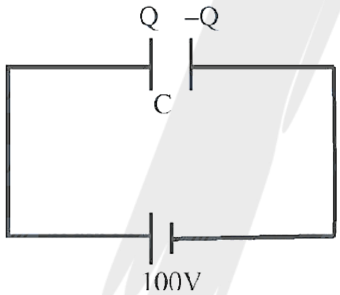
43.



$$C_{new} = \frac{\epsilon_0 \ A}{\frac{\left(\frac{d}{2}\right)}{1.5} + \frac{\left(\frac{d}{2}\right)}{1}}$$

$$= \frac{\epsilon_0 \ A}{\left(\frac{d}{3} + \frac{d}{2}\right)} = \frac{6 \ \epsilon_0 \ A}{5 \ d}$$

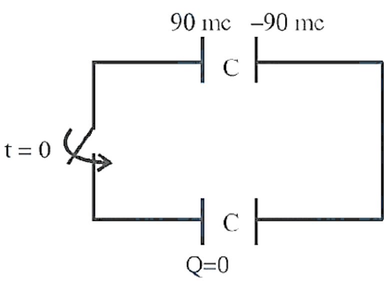
$$= \frac{6}{5} \times 5\mu F = 6\mu F$$

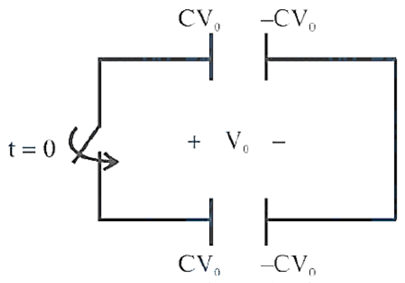


$C = 900\mu F$

$Q = CV = 900 \times 10^{-6} \times 100 = 9 \times 10^{-2} = 90MC$

Now

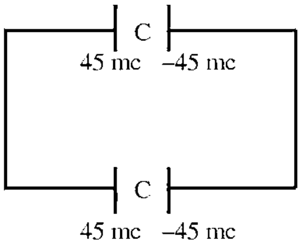




Common potential will be developed across both capacitors by kVL
Total charge on left plates of capacitors should be conserved.

$$90\text{mc} + 0 = 2\text{cv}_0$$

$$\text{cv}_0 = 45\text{mc}$$



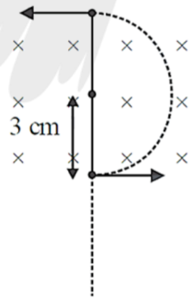
Heat dissipated = U-U [Change in energy stored in the capacitors]

44. $\frac{1}{2}\frac{(90\text{mc})^2}{900\mu\text{F}} - 2 \times \frac{1}{2}\frac{(45\text{mc})^2}{900\mu\text{F}}\left[\text{U} = \frac{\text{Q}^2}{2\text{c}}\right]$

No Solution

$= 2.25$ Joule

$$\text{r} = \frac{\text{mv}}{\text{qB}} = \frac{\sqrt{2\text{km}}}{\text{qB}}, \text{m} = \frac{\text{r}^2\text{q}^2\text{B}^2}{2\text{k}}$$



$$\text{m} = \frac{\frac{1}{100} \times \frac{3}{100} \times 2 \times 2 \times 4 \times 10^{-3} \times 4 \times 10^{-3} \times 10^{-12}}{2 \times (100) \times 10^{-6}}$$

$= 144 \times 10^{-18}$ kg

45. Potential of a conducting sphere is $V = \frac{KQ}{R}$ (Solid as well as hollow)

$V_1 = V_2$ and $R_1 = R_2$

$\therefore Q_1 = Q_2$