Chapter 15

Electrostatic Potential and Capacitance

1. Two point P and Q are maintained at the potentials of 10 V and –4 V respectively. The work done in moving 100 electrons from P to Q is **[AIEEE-2009]**

(1) 9.60×10^{-17} J (2) -2.24×10^{-16} J

(3) 2.24×10^{-16} J (4) -9.60×10^{-17} J

2. *This question contains Statement-1 and statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.*

Statement 1 : For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

Statement 2 : The net work done by a conservative force on an object moving along a closed loop is zero. **[AIEEE-2009]**

(1) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statment-1.

(2) Statment-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.

(3) Statement-1 is false, Statement-2 is true.

(4) Statement-1 is true, Statement-2 is false.

3. Let C be the capacitance of a capacitor discharging through a resistor R. Suppose t_1 is the time taken for the energy stored in the capacitor to reduce to half its initial value and t_2 is the time taken for the charge to reduce to one-fourth its initial value. Then the ratio $\frac{t_1}{t_2}$ will be **[AIEEE-2010]**

(1) 2 (2) 1

(3) $\frac{1}{2}$ (4) $\frac{1}{4}$

4. *This question has Statement 1 and Statement 2. Of the four choices given after the statements, choose the one that best describes the two Statements.*

An insulating solid sphere of radius R has a uniformly positive charge density r. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point out side the sphere. The electric potential at infinity is zero.

Statement 1 : When a charge 'q' is taken from the centre of the surface of the sphere, its potential energy changes by $\frac{q\rho}{3\varepsilon_0}$.

Statement 2 : The electric field at a distance $r(r < R)$ from the centre of the sphere is $\frac{\rho r}{3\varepsilon_0}$.

[AIEEE-2012]

(1) Statement 1 is true Statement 2 is false

(2) Statement 1 is false Statement 2 is true

(3) Statement 1 is true Statement 2 is true, Statement 2 is the correct explanation of Statement 1.

(4) Statement 1 is true, Statement 2, is true; Statement 2 is not the correct explanation of Statement 1.

5. Two capacitors C_1 and C_2 are charged to 120 V and 200 V respectively. It is found that by connecting them together the potential on each one can be made zero. Then **[JEE (Main)-2013]**

(1) $5C_1 = 3C_2$ (2) $3C_1 = 5C_2$

(3) $3C_1 + 5C_2 = 0$ (4) $9C_1 = 4C_2$

6. A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at a distance L from the end A is **[JEE (Main)-2013]**

(1) $\frac{Q}{8\pi\varepsilon_0 L}$ (2) $\frac{3Q}{4\pi\varepsilon_0 L}$

(3) $\frac{Q}{4\pi\varepsilon_0 L \ln 2}$ (4) $\frac{Q \ln 2}{4\pi\varepsilon_0 L}$

7. Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_O$, where V_O is the potential at the origin and V_A the potential at x = 2 m is **[JEE (Main)-2014]**

(1) 120 J (2) –120 J

(3) –80 J (4) 80 J

8. A parallel plate capacitor is made of two circular plates separated by a distance 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]

(1) 6×10^{-7} C/m^2 (2) 3×10^{-7} C/m^2

(3) 3×10^4 C/m^2 (4) 6×10^4 C/m^2

9. A uniformly charged solid sphere of radius R has potential V_0 (measured with respect to ¥) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}, \frac{5V_0}{4}, \frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then **[JEE (Main)-2015]**

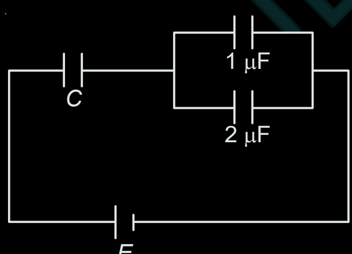
(1) $R_1 = 0$ and $R_2 > (R_4 - R_3)$

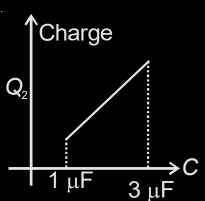
(2) R_1 ¹ 0 and $(R_2 - R_1) > (R_4 - R_3)$

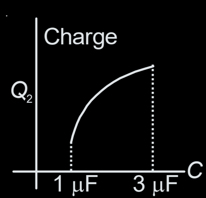
(3) $R_1 = 0$ and $R_2 < (R_4 - R_3)$

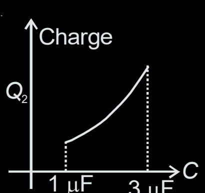
(4) $2R < R_4$

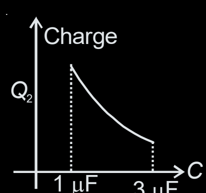
10. In the given circuit, charge Q_2 on the 2 mF capacitor changes as C is varied from 1 mF to 3 mF. Q_2 as a function of C is given properly by (Figures are drawn schematically and are not to scale) **[JEE (Main)-2015]**



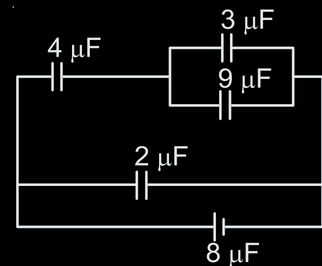
(1) 

(2) 

(3) 

(4) 

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



(1) 360 N/C (2) 420 N/C

(3) 480 N/C (4) 240 N/C

12. A capacitance of 2 mF is required in an electrical circuit across a potential difference of 1.0 kV. A large number of 1 mF capacitors are available which can withstand a potential difference of not more than 300 V.The minimum number of capacitors required to achieve this is

[JEE (Main)-2017]

(1) 2 (2) 16

(3) 24 (4) 32

13. Three concentric metal shells A, B and C of respective radii a, b and c $(a < b < c)$ have surface charge densities +s, –s and +s respectively. The potential of shell B is

[JEE (Main)-2018]

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

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

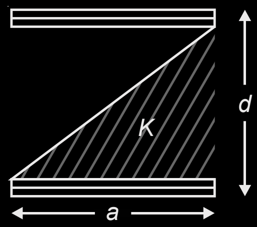
14. A parallel plate capacitor of capacitance 90 pF is connected to a battery of emf 20 V. If a dielectric material of dielectric constant $K = \frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be **[JEE (Main)-2018]**

(1) 1.2 nC (2) 0.3 nC

(3) 2.4 nC (4) 0.9 nC

15. 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

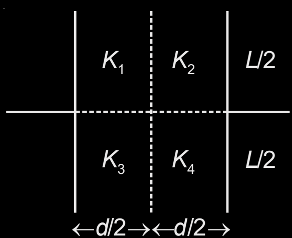
[JEE (Main)-2019]



(1) $\frac{K\varepsilon_0 a^2}{d(K-1)}\ln K$ (2) $\frac{K\varepsilon_0 a^2}{d}\ln K$

(3) $\frac{K\varepsilon_0 a^2}{2d(K+1)}$ (4) $\frac{1}{2}\frac{K\varepsilon_0 a^2}{d}$

16. A parallel plate capacitor with square plates is filled with four dielectrics of dielectric constants K_1, K_2, K_3, K_4 arranged as shown in the figure. The effective dielectric constant K will be **[JEE (Main)-2019]**



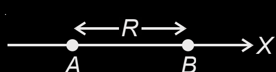
(1) $K = \frac{(K_1+K_2)(K_3+K_4)}{2(K_1+K_2+K_3+K_4)}$

(2) $K = \frac{(K_1+K_2)(K_3+K_4)}{K_1+K_2+K_3+K_4}$

(3) $K = \frac{(K_1+K_3)(K_2+K_4)}{K_1+K_2+K_3+K_4}$

(4) $K = \frac{K_1K_2}{K_1+K_2} + \frac{K_3K_4}{K_3+K_4}$

17. Two electric dipoles, A, B with respective dipole moments $\vec{d}_A = -4qa\hat{i}$ and $\vec{d}_B = -2qa\hat{i}$ are placed on the x-axis with a separation R, as shown in the figure **[JEE (Main)-2019]**



The distance from A at which both of them produce the same potential is

(1) $\frac{\sqrt{2}R}{\sqrt{2}-1}$ (2) $\frac{\sqrt{2}R}{\sqrt{2}+1}$

(3) $\frac{R}{\sqrt{2}-1}$ (4) $\frac{R}{\sqrt{2}+1}$

18. A charge Q is distributed over three concentric spherical shells of radii a, b, c ($a < b < c$) such that their surface charge densities are equal to one another. The total potential at a point at distance r from their common centre, where $r < a$, would be **[JEE (Main)-2019]**

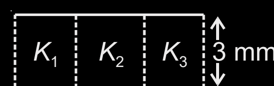
(1) $\frac{Q(a+b+c)}{4\pi\varepsilon_0(a^2+b^2+c^2)}$

(2) $\frac{Q}{4\pi\varepsilon_0(a+b+c)}$

(3) $\frac{Q(a^2+b^2+c^2)}{4\pi\varepsilon_0(a^3+b^3+c^3)}$

(4) $\frac{Q}{12\pi\varepsilon_0}\frac{ab+bc+ca}{abc}$

19. 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]**



(1) 36 (2) 14

(3) 12 (4) 4

20. Four equal point charges Q each are placed in the xy plane at (0, 2), (4, 2), (4, –2) and (0, –2). The work required to put a fifth charge Q at the origin of the coordinate system will be

[JEE (Main)-2019]

(1) $\frac{Q^2}{2\sqrt{2}\pi\varepsilon_0}$ (2) $\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{3}}\right)$

(3) $\frac{Q^2}{4\pi\varepsilon_0}$ (4) $\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{5}}\right)$

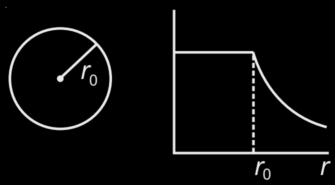
21. A parallel plate capacitor having capacitance 12 pF is charged by a battery to a potential difference of 10 V between its plates. The charging battery is now disconnected and a porcelain slab of dielectric constant 6.5 is slipped between the plates. The work done by the capacitor on the slab is

[JEE (Main)-2019]

(1) 560 pJ (2) 692 pJ

(3) 508 pJ (4) 600 pJ

22. The given graph shows variation (with distance r from centre) of **[JEE (Main)-2019]**



(1) Potential of a uniformly charged spherical shell

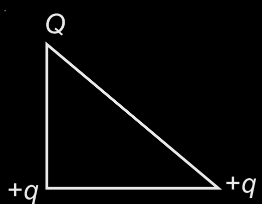
(2) Electric field of a uniformly charged sphere

(3) Electric field of uniformly charged spherical shell

(4) Potential of a uniformly charged sphere

23. Three charges Q, $+q$ and $+q$ are placed at the vertices of a right-angle isosceles triangles as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is

[JEE (Main)-2019]

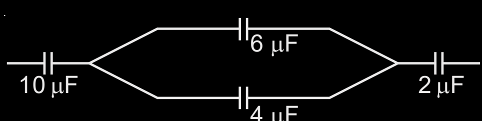


(1) $\frac{-\sqrt{2}q}{\sqrt{2}+1}$ (2) $+q$

(3) $-2q$ (4) $\frac{-q}{1+\sqrt{2}}$

24. In the figure shown below, the charge on the left plate of the 10 mF capacitor is –30 mC. The charge on the right plate of the 6 mF capacitor is

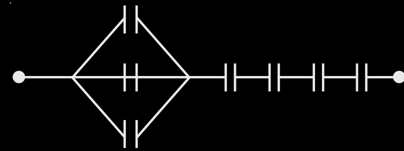
[JEE (Main)-2019]

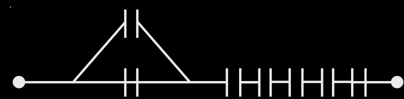


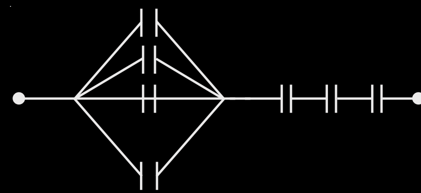
(1) +18 mC (2) –12 mC

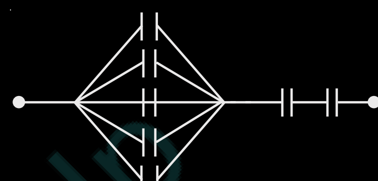
(3) +12 mC (4) –18 mC

25. Seven capacitors, each of capacitance 2 mF, 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]**

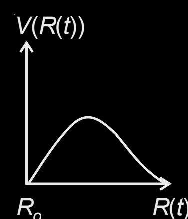
(1) 

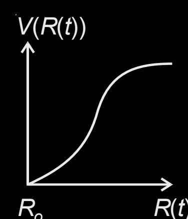
(2) 

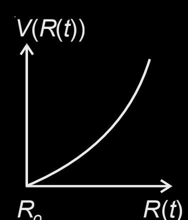
(3) 

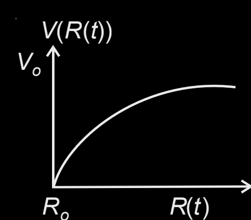
(4) 

26. There is a uniform spherically symmetric surface charge density at a distance R_0 from the origin. The charge distribution is initially at rest and starts expanding because of mutual repulsion. The figure that represents best the speed $V(R(t))$ of the distribution as a function of its instantaneous radius $R(t)$ is **[JEE (Main)-2019]**

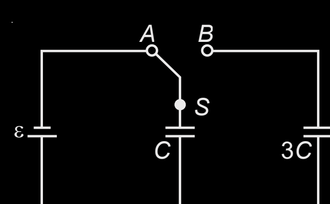
(1) 

(2) 

(3) 

(4) 

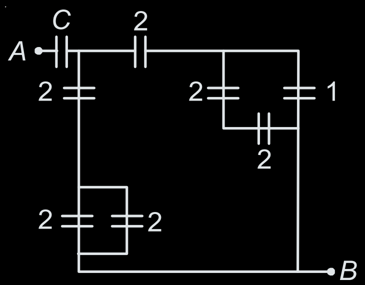
27. In the figure shown, after the switch 'S' is turned from position 'A' to position 'B', the energy dissipated in the circuit in terms of capacitance 'C' and total charge 'Q' is **[JEE (Main)-2019]**



(1) $\frac{3}{8}\frac{Q^2}{C}$ (2) $\frac{1}{8}\frac{Q^2}{C}$

(3) $\frac{5}{8}\frac{Q^2}{C}$ (4) $\frac{3}{4}\frac{Q^2}{C}$

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



(1) $\frac{7}{11}\mu$F (2) 4 mF

(3) $\frac{6}{5}\mu$F (4) $\frac{7}{10}\mu$F

29. A parallel plate capacitor with plates of area 1 m^2 each, are at a separation of 0.1 m. If the electric field between the plates is 100 N/C, the magnitude of charge on each plate is: **[JEE (Main)-2019]**

$\left(\text{Take } \varepsilon_0 = 8.85\times10^{-12}\frac{C^2}{N\,m^2}\right)$

(1) 8.85×10^{-10} C (2) 9.85×10^{-10} C

(3) 6.85×10^{-10} C (4) 7.85×10^{-10} C

30. Voltage rating of a parallel plate capacitor is 500 V. Its dielectric can withstand a maximum electric field of 10^6 V/m. The plate area is 10^{-4} m^2. What is the dielectric constant if the capacitance is 15 pF?

(Given, $e_0 = 8.86 \times 10^{-12}$ C^2/Nm^2)

[JEE (Main)-2019]

(1) 3.8 (2) 4.5

(3) 8.5 (4) 6.2

31. A solid conducting sphere, having a charge Q, is surrounded by an uncharged conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of $-4\ Q$, the new potential difference between the same two surfaces is

[JEE (Main)-2019]

(1) $-2\ V$ (2) V

(3) $2\ V$ (4) $4\ V$

32. The electric field in a region is given by $\vec{E} = (Ax + B)\hat{i}$, where E is in NC^{-1} and x is in metres. The values of constants are A = 20 SI unit and B = 10 SI unit. If the potential at x = 1 is V_1 and that at $x = -5$ is V_2, then $V_1 - V_2$ is : **[JEE (Main)-2019]**

(1) 180 V (2) –520 V

(3) 320 V (4) –48 V

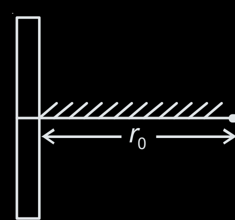
33. A parallel plate capacitor has 1 mF capacitance. One of its two plates is given +2 mC charge and the other plate, +4 mC charge. The potential difference developed across the capacitor is :

[JEE (Main)-2019]

(1) 5 V (2) 1 V

(3) 3 V (4) 2 V

34. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (v) of the point charge, as a function of instantaneous distance r from line charge, is proportional to : **[JEE (Main)-2019]**



(1) $v \propto \sqrt{\ln\left(\frac{r}{r_0}\right)}$ (2) $v \propto e^{+r/r_0}$

(3) $v \propto \ln\left(\frac{r}{r_0}\right)$ (4) $v \propto \left(\frac{r}{r_0}\right)$

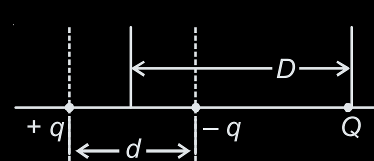
35. A capacitor with capacitance 5 mF is charged to 5 mC. If the plates are pulled apart to reduce the capacitance to 2 mF, how much work is done?

[JEE (Main)-2019]

(1) 2.55×10^{-6} J (2) 6.25×10^{-6} J

(3) 3.75×10^{-6} J (4) 2.16×10^{-6} J

36. A system of three charges are placed as shown in the figure



If $D >> d$, the potential energy of the system is best given by **[JEE (Main)-2019]**

(1) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{D^2}\right]$

(2) $\frac{1}{4\pi\varepsilon_0}\left[+\frac{q^2}{d}+\frac{qQd}{D^2}\right]$

(3) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}+\frac{2qQd}{D^2}\right]$

(4) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{2D^2}\right]$

37. The parallel combination of two air filled parallel plate capacitors of capacitance C and nC is connected to a battery of voltage, V. When the capacitors are fully charged, the battery is removed and after that a dielectric material of dielectric constant K is placed between the two plates of the first capacitor. The new potential difference of the combined system is **[JEE (Main)-2019]**

(1) $\frac{(n+1)V}{(K+n)}$ (2) $\frac{V}{K+n}$

(3) V (4) $\frac{nV}{K+n}$

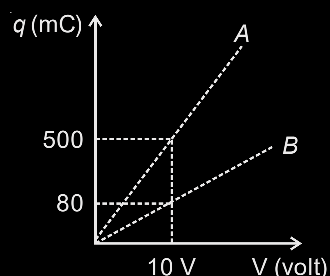
38. A uniformly charged ring of radius $3a$ and total charge q is placed in xy-plane centred at origin. A point charge q is moving towards the ring along the z-axis and has speed v at $z = 4a$. The minimum value of v such that it crosses the origin is : **[JEE (Main)-2019]**

(1) $\sqrt{\frac{2}{m}}\left(\frac{1}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (2) $\sqrt{\frac{2}{m}}\left(\frac{1}{5}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

(3) $\sqrt{\frac{2}{m}}\left(\frac{4}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (4) $\sqrt{\frac{2}{m}}\left(\frac{2}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

39. Figure shows charge (q) versus voltage (V) graph for series and parallel combination of two given capacitors. The capacitances are :

[JEE (Main)-2019]



(1) 40 μF and 10 μF (2) 20 μF and 30 μF

(3) 60 μF and 40 μF (4) 50 μF and 30 μF

40. In free space, a particle A of charge 1 mC is held fixed at a point P. Another particle B of the same charge and mass 4 mg is kept at a distance of 1 mm from P. If B is released, then its velocity at a distance of 9 mm from P is : **[JEE (Main)-2019]**

$\left[\text{Take } \frac{1}{4\pi\varepsilon_0} = 9\times10^9\ \text{Nm}^2\text{C}^{-2}\right]$

(1) 2.0×10^3 m/s (2) 6.32×10^4 m/s

(3) 1.5×10^2 m/s (4) 1.0 m/s

41. A point dipole $\vec{p} = -p_0\hat{x}$ is kept at the origin. The potential and electric field due to this dipole on the y-axis at a distance d are, respectively :

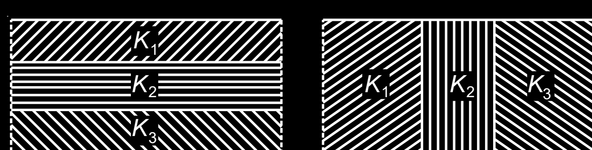
(Take V = 0 at infinity) **[JEE (Main)-2019]**

(1) $\frac{|\vec{p}|}{4\pi\varepsilon_0 d^2}, \frac{\vec{p}}{4\pi\varepsilon_0 d^3}$ (2) $\frac{|\vec{p}|}{4\pi\varepsilon_0 d^2}, \frac{-\vec{p}}{4\pi\varepsilon_0 d^3}$

(3) $0, \frac{-\vec{p}}{4\pi\varepsilon_0 d^3}$ (4) $0, \frac{\vec{p}}{4\pi\varepsilon_0 d^3}$

42. Two identical parallel plate capacitors, of capacitance C each, have plates of area A, separated by a distance d. The space between the plates of the two capacitors, is filled with three dielectrics, of equal thickness and dielectric constants K_1, K_2 and K_3. The first capacitor is filled as shown in fig. I, and the second one is filled as shown in fig **II**.

If these two modified capacitors are charged by the same potential V, the ratio of the energy stored in the two, would be (E_1 refers to capacitor (I) and E_2 to capacitor (II)): **[JEE (Main)-2019]**



(I) (II)

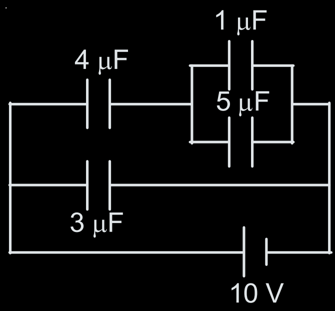
(1) $\frac{E_1}{E_2} = \frac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{K_1K_2K_3}$

(2) $\frac{E_1}{E_2} = \frac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{9\,K_1K_2K_3}$

(3) $\frac{E_1}{E_2} = \frac{9\,K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

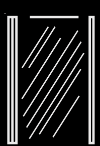
(4) $\frac{E_1}{E_2} = \frac{K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

43. In the given circuit, the charge on 4 mF capacitor will be **[JEE (Main)-2019]**



(1) 5.4 mC (2) 9.6 mC

(3) 13.4 mC (4) 24 mC

44. 

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 varies as $k(x) = K(1 + ax)$ where 'x' is the distance measured from one of the plates. If $(ad) << 1$, the total capacitance of the system is best given by the expression **[JEE (Main)-2020]**

(1) $\frac{AK\varepsilon_0}{d}(1+\alpha d)$

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

(3) $\frac{AK\varepsilon_0}{d}\left(1+\frac{\alpha d}{2}\right)$

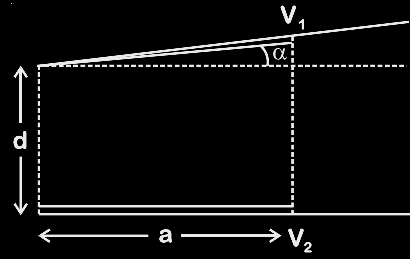
(4) $\frac{A\varepsilon_0 K}{d}\left(1+\left(\frac{\alpha d}{2}\right)^2\right)$

45. Effective capacitance of parallel combination of two capacitors C_1 and C_2 is 10 mF. 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]**

(1) 1.6 mF (2) 3.2 mF

(3) 4.2 mF (4) 8.4 mF

46. A capacitor is 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]**



(1) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{3\alpha a}{2d}\right)$ (2) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{2d}\right)$

(3) $\frac{\varepsilon_0 a^2}{d}\left(1+\frac{\alpha a}{d}\right)$ (4) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{4d}\right)$

47. Consider two charged metallic spheres S_1 and S_2 of radii R_1 and R_2, respectively. The electric fields E_1 (on S_1) and E_2 (on S_2) on their surfaces are such that $E_1/E_2 = R_1/R_2$. Then the ratio V_1 (on S_1)/V_2(on S_2) of the electrostatic potentials on each sphere is **[JEE (Main)-2020]**

(1) $(R_1/R_2)^2$ (2) (R_2/R_1)

(3) $\left(\frac{R_1}{R_2}\right)^3$ (4) R_1/R_2

48. A 10 mF capacitor is fully charged to a potential difference of 50 V. After removing the source voltage it is connected to an uncharged capacitor in parallel. Now the potential difference across them becomes 20 V. The capacitance of the second capacitor is **[JEE (Main)-2020]**

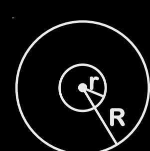
(1) 20 mF

(2) 10 mF

(3) 15 mF

(4) 30 mF

49. A charge Q is distributed over two concentric conducting thin spherical shells radii r and R ($R > r$). If the surface charge densities on the two shells are equal, the electric potential at the common centre is **[JEE (Main)-2020]**



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

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

50. Two isolated conducting spheres S_1 and S_2 of radius $\frac{2}{3}R$ and $\frac{1}{3}R$ have 12 mC and –3 mC charges, respectively, and are at a large distance from each other. They are now connected by a conducting wire. A long time after this is done the charges on S_1 and S_2 are respectively

[JEE (Main)-2020]

(1) 4.5 mC on both

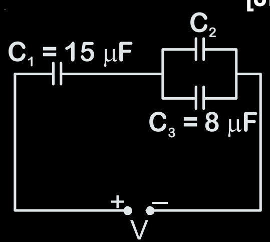
(2) +4.5 mC and –4.5 mC

(3) 6 mC and 3 mC

(4) 3 mC and 6 mC

51. In the circuit shown in the figure, the total charge is 750 mC and the voltage across capacitor C_2 is 20 V. Then the charge on capacitor C_2 is

[JEE (Main)-2020]



(1) 650 mC (2) 590 mC

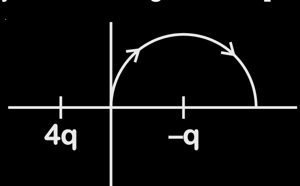
(3) 160 mC (4) 450 mC

52. Concentric metallic hollow spheres of radii R and $4R$ hold charges Q_1 and Q_2 respectively. Given that surface charge densities of the concentric spheres are equal, the potential difference $V(R) - V(4R)$ is **[JEE (Main)-2020]**

(1) $\frac{3Q_2}{4\pi\varepsilon_0 R}$ (2) $\frac{3Q_1}{16\pi\varepsilon_0 R}$

(3) $\frac{Q_2}{4\pi\varepsilon_0 R}$ (4) $\frac{3Q_1}{4\pi\varepsilon_0 R}$

53. A two point charges $4q$ and $-q$ are fixed on the x-axis at $x = -\frac{d}{2}$ and $x = \frac{d}{2}$, respectively. If a third point charge 'q' is taken from the origin to $x = d$ along the semicircle as shown in the figure, the energy of the charge will **[JEE (Main)-2020]**



(1) Decrease by $\frac{q^2}{4\pi\varepsilon_0 d}$

(2) Decrease by $\frac{4q^2}{3\pi\varepsilon_0 d}$

(3) Increase by $\frac{2q^2}{3\pi\varepsilon_0 d}$

(4) Increase by $\frac{3q^2}{4\pi\varepsilon_0 d}$

54. A capacitor C is fully charged with voltage V_0. After disconnecting the voltage source, it is connected in parallel with another uncharged capacitor of capacitance $\frac{C}{2}$. The energy loss in the process after the charge is distributed between the two capacitors is **[JEE (Main)-2020]**

(1) $\frac{1}{4}CV_0^2$ (2) $\frac{1}{3}CV_0^2$

(3) $\frac{1}{6}CV_0^2$ (4) $\frac{1}{2}CV_0^2$

55. Two capacitors of capacitances C and $2C$ are charged to potential differences V and $2V$, respectively. These are then connected in parallel in such a manner that the positive terminal of one is connected to the negative terminal of the other. The final energy of this configuration is

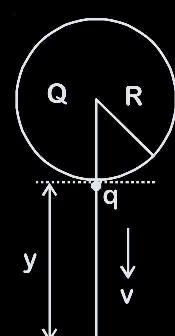
[JEE (Main)-2020]

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

(3) Zero (4) $\frac{25}{6}CV^2$

56. A solid sphere of radius R carries a charge $Q + q$ distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q. If it acquires a speed v when it has fallen through a vertical height y (see figure), then (assume the remaining portion to be spherical).

[JEE (Main)-2020]



(1) $v^2 = y\left[\dfrac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

(2) $v^2 = 2y\left[\dfrac{qQR}{4\pi\varepsilon_0 (R+y)^3 m} + g\right]$

(3) $v^2 = y\left[\dfrac{qQ}{4\pi\varepsilon_0 R^2 ym} + g\right]$

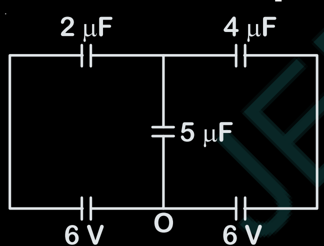
(4) $v^2 = 2y\left[\dfrac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

57. A parallel plate capacitor has plate of length 'l', width 'w' and separation of plates is 'd'. It is connected to a battery of emf V. A dielectric slab of the same thickness 'd' and of dielectric constant $k = 4$ is being inserted between the plates of the capacitor. At what length of the slab inside plates, will the energy stored in the capacitor be two times the initial energy stored? **[JEE (Main)-2020]**

(1) $\dfrac{\ell}{4}$ (2) $\dfrac{\ell}{2}$

(3) $\dfrac{2\ell}{3}$ (4) $\dfrac{\ell}{3}$

58. In the circuit shown, charge on the 5 mF capacitor is **[JEE (Main)-2020]**



(1) 16.36 mC (2) 18.00 mC

(3) 5.45 mC (4) 10.90 mC

59. A 60 pF capacitor is fully charged by a 20 V supply. It is then disconnected from the supply and is connected to another uncharged 60 pF 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]

60. A 5 mF capacitor is charged fully by a 220 V supply. It is then disconnected from the supply and is connected in series to another uncharged 2.5 mF capacitor. If the energy change during the charge redistribution is $\dfrac{X}{100}$ J then value of X to the nearest integer is _____. **[JEE (Main)-2020]**

61. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be

[JEE (Main)-2021]

(1) 1 : 2

(2) 2 : 1

(3) 1 : 4

(4) 4 : 1

62. 512 identical drops of mercury are charged to a potential of 2 V each. The drops are joined to form a single drop. The potential of this drop is _________ V. **[JEE (Main)-2021]**

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

(1) $\dfrac{\cos\beta}{\sin\alpha}$ (2) $\dfrac{\cos\beta}{\cos\alpha}$

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

64. The average translational kinetic energy of N_2 gas molecules at ___ °C becomes equal to the K.E. of an electron accelerated from rest through a potential difference of 0.1 volt. (Given $k_B = 1.38 \times 10^{-23}$ J/K) (Fill the nearest integer).

[JEE (Main)-2021]

65. 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]

66. 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 $\dfrac{3}{4}d$, 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) $C' = \dfrac{4+K}{3}C_0$ (2) $C' = \dfrac{4}{3+K}C_0$

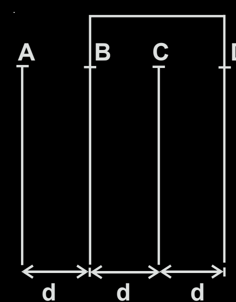
(3) $C' = \dfrac{3+K}{4K}C_0$ (4) $C' = \dfrac{4K}{K+3}C_0$

67. A parallel plate capacitor of capacitance 200 mF is connected to a battery of 200 V. A dielectric slab of dielectric constant 2 is now inserted into the space between plates of capacitor while the battery remains connected. The change in the electrostatic energy in the capacitor will be ___ J.

[JEE (Main)-2021]

68. Four identical rectangular plates with length, l = 2 units and breadth, b = $\frac{3}{2}$ units are arranged as shown in figure. The equivalent capacitance between A and C is $\frac{x\varepsilon_0}{d}$ units. The value of x is _______. (Round off to the nearest integer)

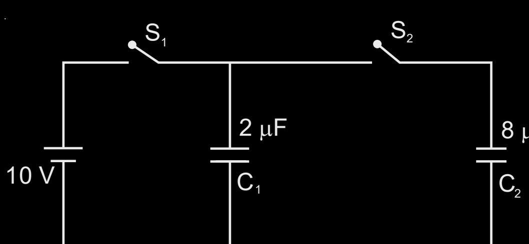
[JEE (Main)-2021]



69. A parallel plate capacitor whose capacitance C is 14 pF is charged by a battery to a potential difference V = 12 V between its plates. The charging battery is now disconnected and a porcelain 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)-2021]**

70. A 2 mF 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 8 mF. The charge on C_2 in equilibrium condition is______mC. (Round off to the nearest Integer) **[JEE (Main)-2021]**



71. 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 $e_0 = 8.85 \times 10^{-12}$ F.m^{-1}

The value of 'x' to the nearest integer is ___.

[JEE (Main)-2021]

72. A parallel plate capacitor with plate area 'A' and distance of separation '*d*' is filled with a dielectric. What is the capacity of the capacitor when permittivity of the dielectric varies as

[JEE (Main)-2021]

$$\varepsilon(x) = \varepsilon_0 + kx, \text{ for}\left(0 < x \le \frac{d}{2}\right)$$

$$\varepsilon(x) = \varepsilon_0 + k(d - x), \text{ for}\left(\frac{d}{2} \le x \le d\right)$$

(1) $\left(\varepsilon_0 + \frac{kd}{2}\right)^{2/kA}$ (2) $\frac{kA}{2}\ln\left(\frac{2\varepsilon_0}{2\varepsilon_0 - kd}\right)$

(3) $\frac{kA}{2\ln\left(\frac{2\varepsilon_0 + kd}{2\varepsilon_0}\right)}$ (4) 0

73. If q_f is the free charge on the capacitor plates and q_b is the bound charge on the dielectric slab of dielectric constant k placed between the capacitor plates, then bound charge q_b can be expressed as

[JEE (Main)-2021]

(1) $q_b = q_f\left(1 + \frac{1}{\sqrt{k}}\right)$ (2) $q_b = q_f\left(1 - \frac{1}{\sqrt{k}}\right)$

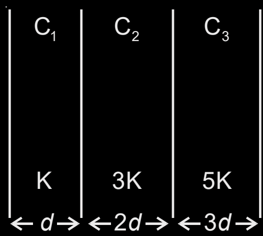
(3) $q_b = q_f\left(1 + \frac{1}{k}\right)$ (4) $q_b = q_f\left(1 - \frac{1}{k}\right)$

74. Two capacitors of capacities 2C and C are joined in parallel and charged up to potential V. The battery is removed and the capacitor of capacity C is filled completely with a medium of dielectric constant K. The potential difference across the capacitors will now be **[JEE (Main)-2021]**

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

(3) $\frac{V}{K}$ (4) $\frac{V}{K+2}$

75. In the reported figure, a capacitor is formed by placing a compound dielectric between the plates of parallel plate capacitor. The expression for the capacity of the said capacitor will be : (Given area of plate = A) **[JEE (Main)-2021]**



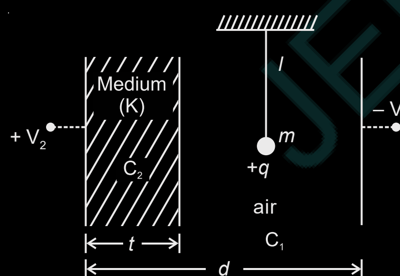
(1) $\frac{15}{6}\frac{K\varepsilon_0 A}{d}$

(2) $\frac{15}{34}\frac{K\varepsilon_0 A}{d}$

(3) $\frac{25}{6}\frac{K\varepsilon_0 A}{d}$

(4) $\frac{9}{6}\frac{K\varepsilon_0 A}{d}$

76. A simple pendulum of mass '*m*', length '*l*' and charge '+*q*' suspended in the electric field produced by two conducting parallel plates as shown. The value of deflection of pendulum in equilibrium position will be **[JEE (Main)-2021]**



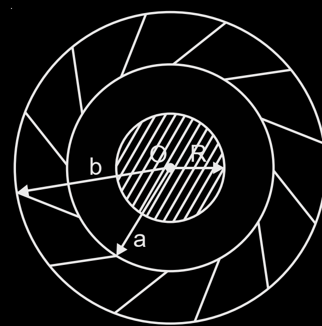
(1) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_2(V_2-V_1)}{(C_1+C_2)(d-t)}\right]$

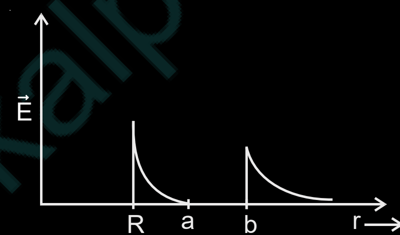
(2) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_1(V_2-V_1)}{(C_1+C_2)(d-t)}\right]$

(3) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_1(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$

(4) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_2(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$

77. A solid metal sphere of radius R having charge q is enclosed inside the conducting concentric spherical shell of inner radius a and outer radius b as shown in figure. The approximate variation of electric field $\vec{E}$ as a function of distance r from centre O is given by: **[JEE (Main)-2021]**



(1)


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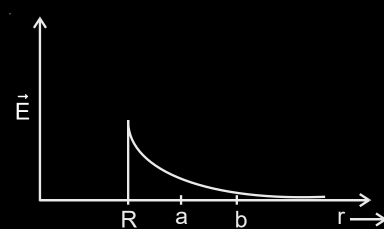

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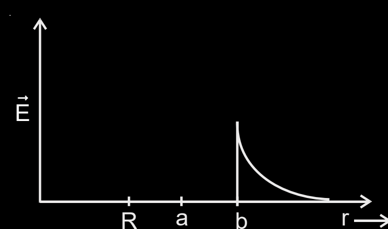

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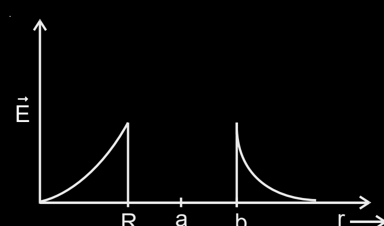


78. The two thin coaxial rings, each of radius 'a' and having charges +Q and –Q respectively are separated by a distance of 's'. The potential difference between the centres of the two rings is: **[JEE (Main)-2021]**

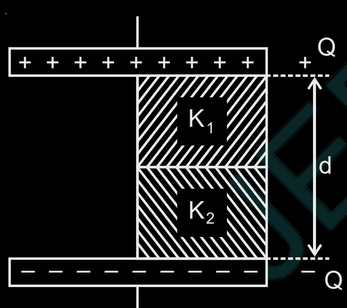
(1) $\frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{a}-\frac{1}{\sqrt{s^2+a^2}}\right]$

(2) $\frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{\sqrt{s^2+a^2}}\right]$

(3) $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{\sqrt{s^2+a^2}}\right]$

(4) $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a}-\frac{1}{\sqrt{s^2+a^2}}\right]$

79. A parallel-plate capacitor with plate area A has separation d between the plates. Two dielectric slabs of dielectric constant K_1 and K_2 of same area A/2 and thickness d/2 are inserted in the space between the plates. The capacitance of the capacitor will be given by : **[JEE (Main)-2021]**



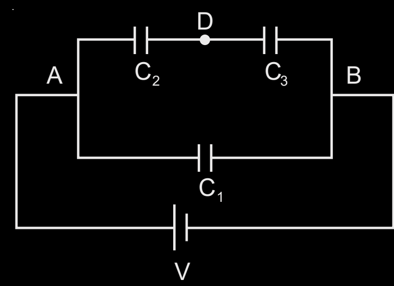
(1) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{K_1+K_2}{K_1K_2}\right)$

(2) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{K_1K_2}{2(K_1+K_2)}\right)$

(3) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{2(K_1+K_2)}{K_1K_2}\right)$

(4) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{K_1K_2}{K_1+K_2}\right)$

80. Three capacitors C_1 = 2 mF, C_2 = 6 mF and C_3 = 12 mF are connected as shown in figure. Find the ratio of the charges on capacitors C_1, C_2 and C_3 respectively: **[JEE (Main)-2021]**



(1) 2 : 3 : 3

(2) 1 : 2 : 2

(3) 2 : 1 : 1

(4) 3 : 4 : 4

81. A parallel plate capacitor is formed by two plates each of area 30π cm^2 separated by 1 mm. A material of dielectric strength 3.6×10^7 Vm^{-1} is filled between the plates. If the maximum charge that can be stored on the capacitor without causing any dielectric breakdown is 7×10^{-6} C, the value of dielectric constant of the material is :

[Use $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ \text{Nm}^2\ \text{C}^{-2}$]

[JEE (Main)-2022]

(1) 1.66

(2) 1.75

(3) 2.25

(4) 2.33

82. The equivalent capacitance between points *A* and *B* in below shown figure will be ________ μF.

[JEE (Main)-2022]

83. Two metallic plates form a parallel plate capacitor. The distance between the plates is 'd'. A metal sheet of thickness $\frac{d}{2}$ and of area equal to area of each plate is introduced between the plates. What will be the ratio of the new capacitance to the original capacitance of the capacitor? **[JEE (Main)-2022]**

(1) 2 : 1

(2) 1 : 2

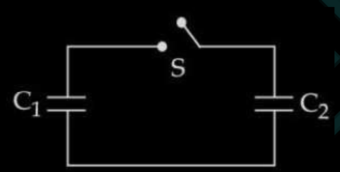
(3) 1 : 4

(4) 4 : 1

84. 27 identical drops are charged at 22 V each. They combine to form a bigger drop. The potential of the bigger drop will be ______ V. **[JEE (Main)-2022]**

85. Two capacitors having capacitance C_1 and C_2 respectively are connected as shown in figure. Initially, capacitor C_1 is charged to a potential difference V volt by a battery. The battery is then removed and the charged capacitor C_1 is now connected to uncharged capacitor C_2 by closing the switch S. The amount of charge on the capacitor C_2, after equilibrium, is

[JEE (Main)-2022]



(1) $\frac{C_1C_2}{(C_1+C_2)}V$

(2) $\frac{(C_1+C_2)}{C_1C_2}V$

(3) $(C_1 + C_2)V$

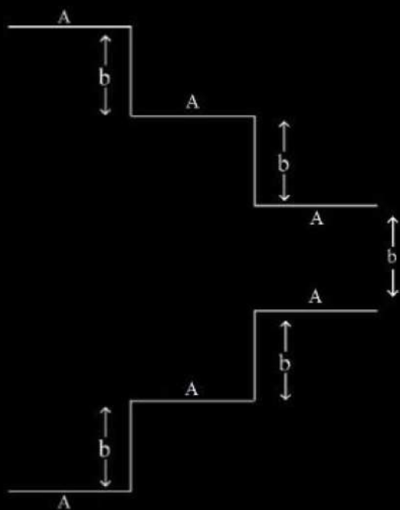
(4) $(C_1 - C_2)V$

86. A capacitor of capacitance 50 pF is charged by 100 V source. It is then connected to another uncharged identical capacitor. Electrostatic energy loss in the process is ________ nJ.

[JEE (Main)-2022]

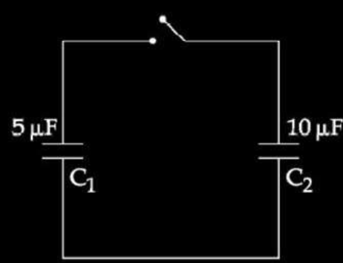
87. A parallel plate capacitor is made up of stair like structure with a plate area A of each stair and that is connected with a wire of length b, as shown in the figure. The capacitance of the arrangement is $\frac{x}{15}\frac{\varepsilon_0 A}{b}$, the value of x is ______?

[JEE (Main)-2022]



88. A capacitor C_1 of capacitance 5 μF is charged to a potential of 30 V using a battery. The battery is then removed and the charged capacitor is connected to an uncharged capacitor C_2 of capacitance 10 μF as shown in figure. When the switch is closed charge flows between the capacitors. At equilibrium, the charge on the capacitor C_2 is ____ μC.

[JEE (Main)-2022]



89. A parallel plate capacitor filled with a medium of dielectric constant 10, is connected across a battery and is charged. The dielectric slab is replaced by another slab of dielectric constant 15. Then the energy of capacitor will : **[JEE (Main)-2022]**

(1) Increased by 50%

(2) Decrease by 15%

(3) Increase by 25%

(4) Increase by 33%

90. If the electric potential at any point (x, y, z) m in space is given by $V = 3x^2$ volt.

The electric field at the point (1, 0, 3) m will be

[JEE (Main)-2022]

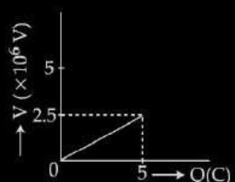
(1) $3\ Vm^{-1}$, directed along positive x-axis

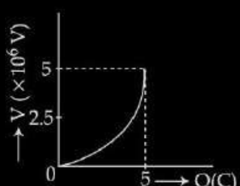
(2) $3\ Vm^{-1}$, directed along negative x-axis

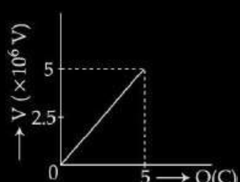
(3) $6\ Vm^{-1}$, directed along positive x-axis

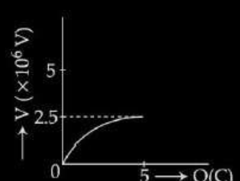
(4) $6\ Vm^{-1}$, directed along negative x-axis

91. A condenser of 2 μF capacitance is charged steadily from 0 to 5 C. 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]**

(1) 

(2) 

(3) 

(4) 

92. The total charge on the system of capacitors $C_1 = 1\ \mu F$, $C_2 = 2\ \mu F$, $C_3 = 4\ \mu F$ and $C_4 = 3\ \mu F$ connected in parallel is :

(Assume a battery of 20 V is connected to the combination) **[JEE (Main)-2022]**

(1) 200 μC (2) 200 C

(3) 10 μC (4) 10 C

93. 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 materials are separated by a conducting foil F. The voltage of the conducting foil is ____ V. **[JEE (Main)-2022]**

94. 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]

95. A slab of dielectric constant K has the same cross-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.)

[JEE (Main)-2022]

(1) $\frac{4KC_0}{3+K}$ (2) $\frac{3KC_0}{3+K}$

(3) $\frac{3+K}{4KC_0}$ (4) $\frac{K}{4+K}$

96. Given below are two statements.

Statement I : Electric potential is constant within and at the surface of each conductor.

Statement II : Electric field just outside a charged conductor is perpendicular to the surface of the conductor at every point.

In the light of the above statements, choose the most appropriate answer from the options given below.

[JEE (Main)-2022]

(1) Both statement I and statement II are correct

(2) Both statement I and statement II are incorrect

(3) Statement I is correct but statement II is incorrect

(4) Statement I is incorrect but statement II is correct

97. 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) $\frac{2(q_1 - q_2)}{C}$

98. 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]**

(1) $\frac{n}{n-1}$

(2) $\frac{2n}{2n+1}$

(3) $\frac{n+1}{n}$

(4) $\frac{2n+1}{n}$

99. Two uniformly charged spherical conductors A and B of radii 5 mm and 10 mm are separated by a distance of 2 cm. If the spheres are connected by a conducting wire, then in equilibrium condition, the ratio of the magnitude of the electric fields at the surface of the sphere A and B will be **[JEE (Main)-2022]**

(1) 1:2

(2) 2:1

(3) 1:1

(4) 1:4

100. Two capacitors, each having capacitance 40 μF 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 24 μF. The value of K will be : **[JEE (Main)-2022]**

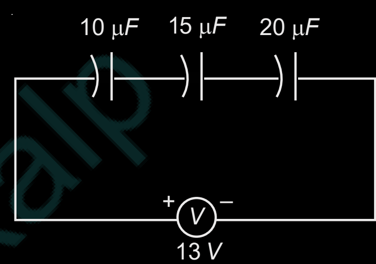
(1) 1.5

(2) 2.5

(3) 1.2

(4) 3

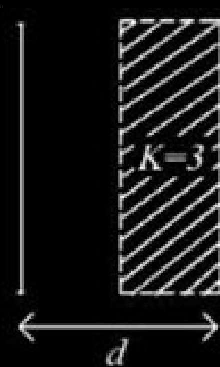
101. The charge on capacitor of capacitance 15 μF in the figure given below is



[JEE (Main)-2022]

(1) 60 μC
(2) 130 μC
(3) 260 μC
(4) 585 μC

102. A parallel plate capacitor with plate area A and plate separation d = 2 m has a capacitance of 4 mF. The new capacitance of the system if half of the space between them is filled with a dielectric material of dielectric constant K = 3 (as shown in figure) will be **[JEE (Main)-2022]**



(1) 2 μF

(2) 32 μF

(3) 6 μF

(4) 8 μF

103. Sixty four conducting drops each of radius 0.02 m and each carrying a charge of 5 μC are combined to form a bigger drop. The ratio of surface density of bigger drop to the smaller drop will be:

[JEE (Main)-2022]

(1) 1 : 4

(2) 4 : 1

(3) 1 : 8

(4) 8 : 1

104. A force of 10 N acts on a charged particle placed between two plates of a charged capacitor. If one plate of capacitor is removed, then the force acting on that particle will be **[JEE (Main)-2022]**

(1) 5 N

(2) 10 N

(3) 20 N

(4) Zero

105. 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 **[JEE (Main)-2022]**

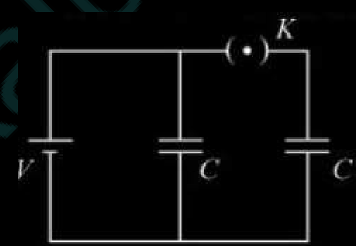
106. If the charge on a capacitor is increased by 2 C, the energy stored in it increases by 44%. The original charge on the capacitor is (in C)

[JEE (Main)-2022]

(1) 10 (2) 20

(3) 30 (4) 40

107. 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]**



(1) $\frac{1}{10}$ (2) $\frac{2}{5}$

(3) $\frac{5}{13}$ (4) $\frac{5}{26}$

❑ ❑ ❑

Chapter 15

Electrostatic Potential and Capacitance

1. Answer (3)

$Q = 100e = -100 \times 1.6 \times 10^{-19} = -1.6 \times 10^{-17}$C

$\Delta V = -14$ V

$\therefore \quad W = Q\Delta V = 14 \times 1.6 \times 10^{-17} = 2.24 \times 10^{-16}$ J

2. Answer (1)

$W_e = -q(V_f - V_i)$ It depends on initial and final point only, because electrostatic field is a conservative field.

3. Answer (4)

$$U = \frac{q^2}{2C} = \frac{(q_0)^2}{2C}e^{-2t/RC} = U_0 e^{-2t/RC}$$

$$q = q_0 e^{-t/RC}$$

When charge becomes $\frac{1}{4}$ times, energy becomes $\frac{1}{16}$ times.

So, t_1 = one half life, while t_2 = 4 half lives

4. Answer (2)

5. Answer (2)

For this, charge must be same $Q = C_1V_1 = C_2V_2$

$\Rightarrow \quad 120C_1 = 200C_2$

$\Rightarrow \quad 3C_1 = 5C_2$

6. Answer (4)

$$V = \int \frac{kdq}{L+x}$$

$$V = \frac{kQ}{L}\int_O^L \frac{dL}{L+x} = \frac{kQ}{L}\ln 2$$

$$V = \frac{Q}{4\pi\varepsilon_0 L}\ln 2$$

7. Answer (3)

$$dV = -\vec{E}\cdot\vec{dx}$$

$$\int_{V_O}^{V_A} dV = -\int_0^2 30x^2 dx$$

$$V_A - V_O = -[10x^3]_0^2 = -80 \text{ J}$$

8. Answer (1)

$$E = \frac{\sigma}{K\varepsilon_0}$$

$\sigma = K\varepsilon_0 E$

$= 2.2 \times 8.85 \times 10^{-12} \times 3 \times 10^4 \approx 6 \times 10^{-7}$ C/m^2

9. Answer (3, 4)

$$V_0 = k\frac{Q}{R} \qquad \text{...(i)}$$

$$V_I = \frac{kQ}{2R^3}(3R^2 - r^2)$$

$$V = \frac{3}{2}V_0 \Rightarrow R_1 = 0$$

$$\frac{5}{4}\frac{kQ}{R} = kQ\frac{(3R^2 - r^2)}{2R^3}$$

$$\Rightarrow R_2 = \frac{R}{\sqrt{2}}$$

$$\frac{3}{4}\frac{kQ}{R} = \frac{kQ}{R^3}$$

$$\Rightarrow R_3 = \frac{4R}{3}$$

$$\frac{1}{4}\frac{kQ}{R} = \frac{kQ}{R_4}$$

$$\Rightarrow R_4 = 4R \Rightarrow R_4 > 2R$$

10. Answer (2)

$$C_{aq}=\frac{3C}{3+C} \quad \text{...(i)}$$

Total charges $q=\left(\frac{3C}{3+C}\right)E$ ...(ii)

Charge upon capacitor 2 μF,

$$q'=\frac{2}{3}\times\frac{3CE}{(3+C)}=\frac{2CE}{3+C}=\frac{2E}{1+\frac{3}{C}}$$

Now, $\frac{dQ}{dC}>0, \frac{dQ^2}{dC^2}<0$

11. Answer (2)

C_{net} = 5 μF

Q_{net} = 5 × 8 = 40

$Q_{4\ \mu F}$ = 24

$Q_{9\ \mu F}$ = 18

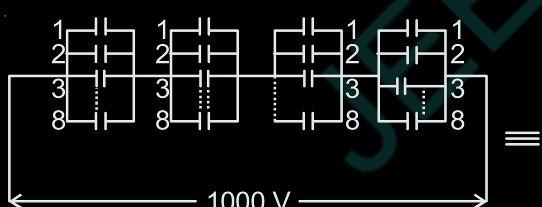
$Q = Q_{4\ \mu F} + Q_{9\ \mu F}$ = 42 μC

$$E=\frac{kQ}{r^2}=\frac{9\times10^4\times42\times10^{-6}}{30\times30}=420 \text{ N/C}$$

12. Answer (4)

Following arrangement will do the needful :

8 capacitors of 1μF in parallel with four such branches in series.



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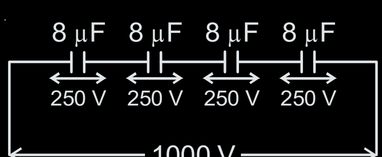
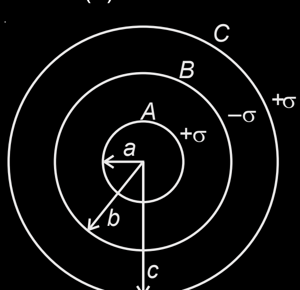


13. Answer (2)



$$V_B=\left[\frac{\sigma4\pi a^2}{4\pi\varepsilon_0 b}-\frac{\sigma4\pi b^2}{4\pi\varepsilon_0 b}+\frac{\sigma4\pi c^2}{4\pi\varepsilon_0 c}\right]$$

$$V_B=\frac{\sigma}{\varepsilon_0}\left[\frac{a^2-b^2}{b}+c\right]$$

14. Answer (1)

$C' = KC_0$

$Q = KC_0V$

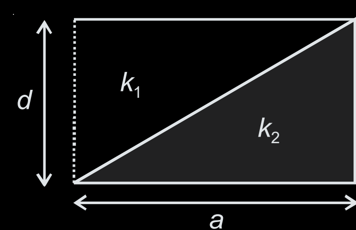
$$Q_{induced}=Q\left(1-\frac{1}{K}\right)$$

$$=\frac{5}{3}\times90\times10^{-12}\times20\left(1-\frac{3}{5}\right)$$

= 1.2 nC

15. Answer (1)

$$C_{eq}=\frac{\varepsilon_0\ k_1k_2a^2\ln\frac{k_1}{k_2}}{(k_1-k_2)d}$$



$$\Rightarrow C_{eq}=\frac{\varepsilon_0\ ka^2\ln\frac{1}{k}}{d(1-k)}$$

as k_1 = 1, k_2 = k

$$\Rightarrow C_{eq}=\frac{\varepsilon_0\ ka^2}{d(k-1)}\ln k$$

16. Answer (4)

$$C_{eq}=\frac{C_1C_2}{C_1+C_2}+\frac{C_3C_4}{C_3+C_4},\ C_1=K_1\ C,\quad C=\frac{\varepsilon_0A/2}{d/2}$$

Similarly

$C_2 = K_2C$

$C_3 = K_3C$

$C_4 = K_4C$

$$K_{eq.}\left(\frac{\varepsilon_0 A}{d}\right)=\left(\frac{K_1K_2}{K_1+K_2}+\frac{K_3K_4}{K_3+K_4}\right)\frac{\varepsilon_0 A/2}{d/2}$$

$$\Rightarrow K_{eq.}=\frac{K_1K_2}{K_1+K_2}+\frac{K_3K_4}{K_3+K_4}$$

17. Answer (2)

$$V\propto\frac{1}{d^2}$$

$$\frac{4qa}{x^2}=\frac{2qa}{(R-x)^2}$$

$$(R-x)=\frac{x}{\sqrt{2}}$$

$$\frac{\sqrt{2}R}{\left(\sqrt{2}+1\right)}=x$$

18. Answer (1)

$$Q=\sigma 4\pi\left[a^2+b^2+c^2\right]$$

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

$$=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q(a+b+c)}{(a^2+b^2+c^2)}$$

19. Answer (3)

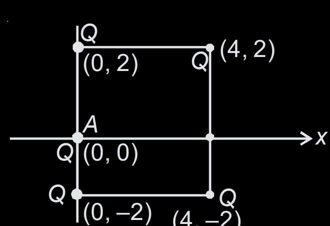
$C = C_1 + C_2 + C_3$

$$\frac{\varepsilon_0 KA}{d}=\frac{\varepsilon_0 K_1A}{3d}+\frac{\varepsilon_0 K_2A}{3d}+\frac{\varepsilon_0 K_3A}{3d}$$

$$\Rightarrow K=\frac{K_1+K_2+K_3}{3}=\frac{10+12+14}{3}=12$$

20. Answer (4)

$$V_A=\frac{kQ}{2}+\frac{kQ}{2}+\frac{kQ}{2^2+4^2}+\frac{kQ}{\sqrt{2^2+4^2}}$$



$$V_A=\frac{kQ}{2}+\frac{kQ}{2}+\frac{kq}{\sqrt{2^2+4^2}}+\frac{kQ}{\sqrt{2^2+4^2}}$$

$$V_A=kQ+\frac{2kQ}{2\sqrt{5}}$$

$$PE=kQ^2\left(1+\frac{1}{\sqrt{5}}\right)=\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{5}}\right)$$

21. Answer (3)

$$U_{in}=\frac{1}{2}\times 12\times 10^{-12}\times 100$$

$\Rightarrow\ U_{in} = 600$ pJ

and, $Q = 120$ pC

$$U_{final}=\frac{1}{2}\times\frac{120\times 120\times 10^{-24}\times 2}{12\times 10^{-12}\times 13}$$

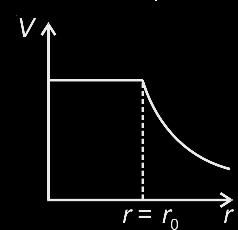
$\Rightarrow\ U_{final} = 92.3$ pJ

$U_{initial} - U_{final} = \Delta W \simeq 508$ pJ

22. Answer (1)

For spherical shell $V=\dfrac{K.q}{r_0},\ r\le r_0$

$$=\frac{Kq}{r},\ r>r_0$$



23. Answer (1)

$$0=U=\frac{kq^2}{a}+\frac{kQq}{a}+\frac{kQq}{\sqrt{2}a}$$

$$-q=Q\left(1+\frac{1}{\sqrt{2}}\right)$$

$$Q=\frac{-q(\sqrt{2})}{\sqrt{2}+1}$$

24. Answer (1)

Let charge be Q_1 & Q_2

$$\frac{Q_1}{6}=\frac{Q_2}{4}$$

$\Rightarrow\ Q_1 + Q_2 = 30$

$\Rightarrow\ Q_1 = 18\ \mu C,\ Q_2 = 12\ \mu C$

25. Answer (1)

$$C = \frac{C_1C_2}{C_1+C_2}, \text{ where } C_1 = 6\ \mu F$$

$$\frac{1}{C_2} = \frac{4}{2} \Rightarrow C_2 = \frac{1}{2}\ \mu F$$

$$C = \frac{6\times\frac{1}{2}}{6+\frac{1}{2}} = \frac{6}{13}\ \mu F$$

26. Answer (4)

$$\because \quad \frac{Q^2}{4\pi\varepsilon_0 R_0} = \frac{Q^2}{4\pi\varepsilon_0 R} + \frac{1}{2}mv^2$$

$$\Rightarrow \quad v = \sqrt{\frac{Q^2}{4\pi\varepsilon_0}\times\frac{2}{m}\left[\frac{1}{R_0}-\frac{1}{R}\right]}$$

So v increases and attains a finite value after large time.

27. Answer (1)

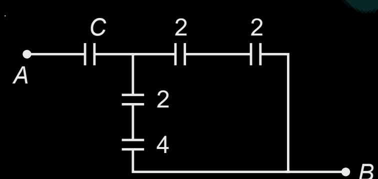
$\Delta H = \Delta U$

$$= \frac{1}{2}\times\frac{C\times 3C}{C+3C}(V^2)$$

$$= \frac{1}{2}\times\frac{3}{4}CV^2 = \frac{3}{8}CV^2$$

$$\Delta H = \frac{3}{8}\frac{Q^2}{C}$$

28. Answer (1)



$$\frac{\frac{7}{3}C}{C+\frac{7}{3}} = \frac{1}{2}$$

$\Rightarrow \quad 14C = 3C + 7$

$$\Rightarrow \quad C = \frac{7}{11}\mu F$$

29. Answer (1)

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

$Q = EA\epsilon_0 = 100 \times 1 \times 8.85 \times 10^{-12}$ C

$= 8.85 \times 10^{-10}$ C

30. Answer (3)

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

$$E = \frac{V}{d}$$

$$15\times 10^{-12} = \frac{k\times 8.86\times 10^{-12}\times 10^{-4}\times 10^{6}}{500}$$

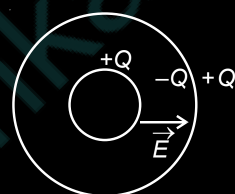
$k = 8.5$

31. Answer (2)

In case-1

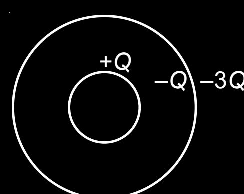
Electric field between spherical surface

$$\vec{E} = \frac{KQ}{r^2}$$



In case-2

Electric field between surfaces remain unchanged.



$\therefore$ Potential difference between them remain unchanged too.

32. Answer (1)

$$dV = -\vec{E}\cdot\vec{dr} = -(Ax+B)dx$$

$$\int_{V_2}^{V_1} dV = \int_{-5}^{1} -(Ax+B)dx$$

$$V_1 - V_2 = \left(-A\frac{x^2}{2} - Bx\right)_{-5}^{1}$$

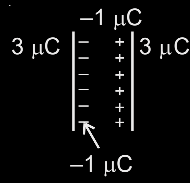
$$= \left(-\frac{A}{2} - B\right) + \left(\frac{A}{2}25 + B(-5)\right)$$

$= 12A - 6B = 240 - 60 = 180$ V

33. Answer (2)

$$V = \frac{q}{C} = \frac{1\,\mu C}{1\,\mu F}$$

$$= 1\text{ V}$$



34. Answer (1)

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$\int_{V_G}^{V_P} dV = \int -\frac{\lambda}{2\pi\varepsilon_0 r}\,dr$$

$$\Rightarrow \quad V_P - V_G = \frac{\lambda}{2\pi\varepsilon_0}\ln\frac{r}{r_0}$$

$$\frac{1}{2}mv^2 = q(V_P - V_G)$$

$$\Rightarrow \quad v \propto \left[ln\left(\frac{r}{r_0}\right)\right]^{\frac{1}{2}}$$

35. Answer (3)

$$U_i = \frac{Q^2}{2C_1}$$

$$U_f = \frac{Q^2}{2C_2}$$

$$W = \frac{Q^2}{2}\left[\frac{1}{C_2} - \frac{1}{C_1}\right] = \frac{(5)^2}{2}\left[\frac{1}{2} - \frac{1}{5}\right]$$

$W = 3.75\ \mu J$

36. Answer (1)

$$U = -\frac{Kq^2}{d} + QV$$

$$V = -\frac{KP}{D^2} = -\frac{Kqd}{D^2}$$

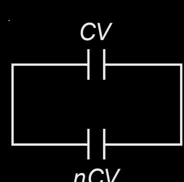
$$U = -\frac{Kq^2}{d} - \frac{KQqd}{D^2}$$

37. Answer (1)

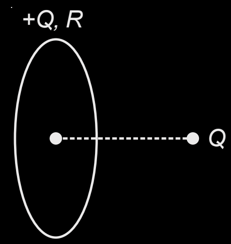
Initially $Q = CV(1 + n)$

$\therefore \quad C_{eq} = (K + n)C$

$$\therefore \quad V = \frac{CV(1+n)}{(K+n)C} = \frac{V(1+n)}{(K+n)}$$



38. Answer (4)



Potential at any point of the charged ring

$$V_P = \frac{KQ}{\sqrt{R^2 + x^2}}$$

The minimum velocity (v_0) should just sufficient to reach the point charge at the center, therefore

$$\frac{1}{2}mv_0^2 = Q[V_C - V_P]$$

$$= Q\left[\frac{KQ}{3a} - \frac{KQ}{5a}\right]$$

$$v_0^2 = \frac{4KQ^2}{15\,ma} = \frac{4}{15}\frac{1}{4\pi\varepsilon_0}\frac{q^2}{ma}$$

$$\therefore \quad v_0 = \sqrt{\frac{2}{m}}\left(\frac{2q^2}{15 \times 4\pi\varepsilon_0 a}\right)^{\frac{1}{2}}$$

39. Answer (1)

Equivalent capacitance for series combination

$$C' = \frac{C_1C_2}{C_1 + C_2}$$

For parallel combination $C'' = C_1 + C_2$

Also $C'' > C'$

$$C_1 + C_2 = \frac{500}{10} = 50\ \mu F$$

and $\dfrac{C_1C_2}{C_1 + C_2} = \dfrac{80}{10} = 8\ \mu F$

$\therefore \quad C_1C_2 = 400\ \mu F$

Solving $C_1 = 40\ \mu F$ $C_2 = 10\ \mu F$

40. Answer (2)

$m_B = 4\ \mu gram$
$= 4 \times 10^{-9}$ kg

$$U_i = \frac{kq_1q_2}{r_1} \qquad U_f = \frac{kq_1q_2}{r_2}$$

Conservation of energy

$$\frac{kq_1q_2}{r_1} = \frac{kq_1q_2}{r_2} + \frac{1}{2}mv^2$$

$$v^2 = \frac{2kq_1q_2}{m}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$= \frac{2\times 9\times 10^9 \times 10^{-12}}{4\times 10^{-9}\times 10^{-3}}\left[1-\frac{1}{9}\right] = 4 \times 10^9$$

$$v = \sqrt{40}\times 10^4 \text{ m/s} = 6.32\times 10^4 \text{ m/s}$$

41. Answer (3)

$$\vec{E} = K\frac{\vec{p}}{r^3}\sqrt{3\cos^2\theta + 1}$$

$$\Rightarrow \theta = \pi/2 \quad (0,\ d,\ 0)$$

$$\therefore \quad \vec{E} = \frac{-k\vec{p}}{d^3}$$

42. Answer (3)

$$\frac{1}{C_1} = \frac{d}{3A\varepsilon_0}\left(\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3}\right)$$

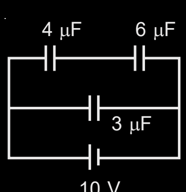
$$C_1 = \frac{3A\varepsilon_0\,(K_1K_2K_3)}{d\,(K_1K_2 + K_2K_3 + K_3K_1)}$$

$$C_2 = \frac{A\varepsilon_0}{3d}(K_1 + K_2 + K_3)$$

$$\frac{E_1}{E_2} = \frac{C_1}{C_2} = \frac{3K_1K_2K_3}{(K_1K_2 + K_2K_3 + K_3K_1)} \times \frac{3}{(K_1 + K_2 + K_3)}$$

$$\Rightarrow \quad \frac{E_1}{E_2} = \frac{9K_1K_2K_3}{(K_1 + K_2 + K_3)(K_1K_2 + K_2K_3 + K_3K_1)}$$

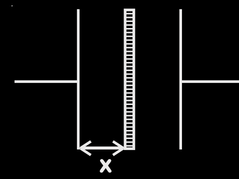
43. Answer (4)



$$Q_{(4\ \mu F)} = \left(\frac{4\times 6}{4+6}\right)\times 10\ \mu C$$

$$= 24\ \mu C$$

44. Answer (3)



$$k = K(1+\alpha x)$$

$$C_{el} = \frac{\varepsilon_0 K(1+\alpha x)A}{dx}$$

$$\therefore \quad \int d\left(\frac{1}{C}\right) = \frac{1}{C_{el}} = \int_0^d \left(\frac{dx}{\varepsilon_0 KA(1+\alpha x)}\right)$$

$$\Rightarrow \frac{1}{C} = \frac{1}{\varepsilon_0 KA\alpha}\left[\ln(1+\alpha x)\right]_0^d$$

$$\Rightarrow \frac{1}{C} = \frac{1}{\varepsilon_0 KA\alpha}\ln(1+\alpha d)$$

$$= \frac{1}{\varepsilon_0 KA\alpha}\left[\alpha d - \frac{\alpha^2 d^2}{2}\right]$$

$$= \frac{d}{\varepsilon_0 KA}\left[1 - \frac{\alpha d}{2}\right]$$

$$\therefore C = \frac{\varepsilon_0 KA}{d\left(1-\frac{\alpha d}{2}\right)} \quad \Rightarrow C = \frac{\varepsilon_0 KA}{d}\left(1+\frac{\alpha d}{2}\right)$$

45. Answer (1)

In parallel combination, $C_1 + C_2 = 10\ \mu F$

When connected across 1 V battery, then

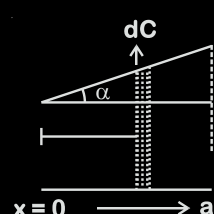
$$\frac{U_1}{U_2} = \frac{1}{4} \Rightarrow \frac{C_1}{C_2} = \frac{1}{4}$$

$\therefore$ $C_2 = 8\ \mu F$ $\qquad$ $C_1 = 2\ \mu F$

$\therefore$ In series combination,

$$C_{\text{equivalent}} = \frac{C_1C_2}{C_1 + C_2} = \frac{16}{10} = 1.6\ \mu F$$

46. Answer (2)



y = tan αx

$$\therefore \quad dC = \frac{adx\ 60}{d + x\tan\alpha}$$

$$\therefore \quad C_{eq} = \int dc = a\varepsilon_0 \int_{x=0}^{x=a} \frac{dx}{x\tan\alpha + d}$$

[By Binomial expansion]

$$\Rightarrow \quad C_{eq} = \frac{a\varepsilon_0}{d}\int_0^a \left(1 - \frac{x\tan\alpha}{d}\right)dx = \frac{a\varepsilon_0}{d}\left(x - \frac{x^2\tan\alpha}{d\,2}\right)_0^a$$

$$\Rightarrow \quad C_{eq} = \frac{a^2\varepsilon_0}{d}\left(1 - \frac{a\tan\alpha}{2d}\right) = \frac{\varepsilon_0 a^2}{d}\left(1 - \frac{\alpha a}{2d}\right)$$

47. Answer (1)

Let ρ_1 and ρ_2 are the charge densities of two sphere. Then,

$$E_1 = \frac{\rho_1 R_1}{3\varepsilon_0} \text{ and } E_0 = \frac{\rho_2 R_2}{3\varepsilon_0}$$

$$\because \quad \frac{E_1}{E_2} = \frac{\rho_1 R_1}{\rho_2 R_2} = \frac{R_1}{R_2}$$

$$\therefore \quad \rho_1 = \rho_2 = \rho$$

So, $V_1 = \dfrac{\rho R_1^2}{3\varepsilon_0}$ and $V_2 = \dfrac{\rho R_2^2}{3\varepsilon_0}$

$$\therefore \quad \frac{V_1}{V_2} = \left(\frac{R_1}{R_2}\right)^2$$

48. Answer (3)

$$V_{\text{final}} = \frac{C_1 V}{C_1 + C_2}$$

$$C_2 = 15\ \mu F$$

49. Answer (1)

Let charges on shells be q_1 and q_2

$q_1 + q_2 = Q$ ....(i)

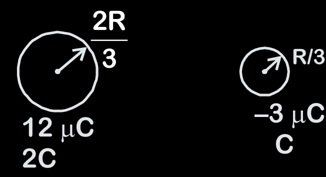
$$\frac{q_1}{4\pi r^2} = \frac{q_2}{4\pi R^2} \quad \text{....(ii)}$$

We get $q_1 = \dfrac{r^2}{r^2 + R^2}Q,\ q_2 = \dfrac{R^2}{r^2 + R^2}Q$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r} + \frac{q_2}{R}\right)$$

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

50. Answer (3)



$C_{eq} = 3C$, $Q_{total} = 12 – 3$

$= 9\ \mu C$

$$\therefore \quad q_1 = \frac{2C}{3C} \times 9 = 6\ \mu C$$

$q_2 = 3\ \mu C$

51. Answer (2)

$Q_3 = C_3 V_3$

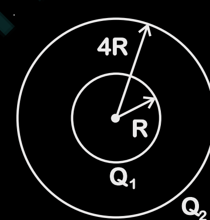
$V_3 = 20$ V

$Q_3 = 160\ \mu C$

$Q = Q_2 + Q_3$

$Q_2 = 590\ \mu C$

52. Answer (2)



$$\because \quad \frac{Q_1}{R^2} = \frac{Q_2}{16R^2}$$

$$\Rightarrow \quad Q_2 = 16Q_1$$

$$\left(\frac{KQ_1}{R} + \frac{KQ_2}{4R}\right) - \left(\frac{KQ_1}{4R} + \frac{KQ_2}{4R}\right) = V_1 - V_2$$

$$\Rightarrow \quad V_1 - V_2 = \frac{3}{4} \times \frac{Q_1}{4\pi\varepsilon_0 R} = \frac{3Q_1}{16\pi\varepsilon_0 R}$$

53. Answer (2)

$$\Delta u = \frac{4q^2}{4\pi\varepsilon_0}\left[\frac{1}{3d/2} - \frac{1}{d/2}\right]$$

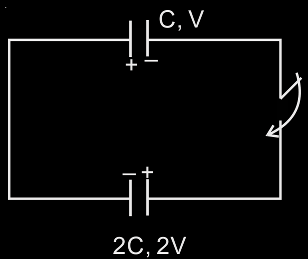
$$\Delta u = -\frac{4q^2}{3\pi\varepsilon_0 d}$$

54. Answer (3)

$$\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}V_0^2 \qquad = \frac{1}{6}CV_0^2$$

55. Answer (1)

$$V_{\text{common}} = \frac{4CV - CV}{3C} = V$$



$$C_{eq} = C + 2C = 3C$$

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

56. Answer (4)

$$\frac{1}{2}mv^2 = mgy + \Delta U_{\text{elec.}}$$

$$\Delta U_{\text{elec.}} = kQq\left[\frac{1}{R} - \frac{1}{(R+y)}\right]$$

$$\Rightarrow \quad v^2 = 2y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$$

57. Answer (4)

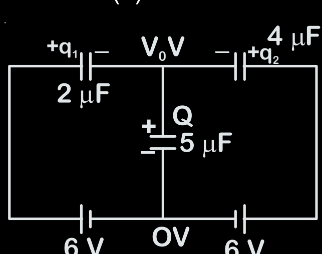
$$U = \frac{1}{2}CV^2$$

$$\frac{U_1}{U_2} = 2 \ \Rightarrow\ \frac{C_1}{C} = 2$$

$$\frac{kx + (\ell - x)}{\ell} = 2$$

$$x = \frac{\ell}{3}$$

58. Answer (1)



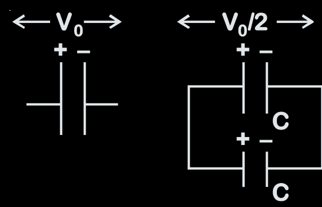
$$Q = q_1 + q_2$$

$$5V_0 = 2(6 - V_0) + 4(6 - V_0)$$

$$V_0 = \frac{36}{11}V$$

$$Q = 5V_0 = \frac{180}{11}\mu C$$

59. Answer (6)



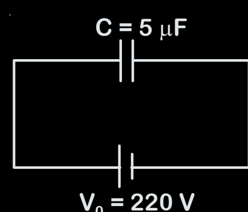
$$U_i = \frac{1}{2}CV_0^2$$

$$U_f = \frac{1}{2}2C.\left(\frac{V_0}{2}\right)^2$$

$$H = U_i - U_f = \frac{1}{4}CV_0^2 = \frac{1}{4}\times 60\times 10^{-12}\times 400\times 10^9\,nJ$$

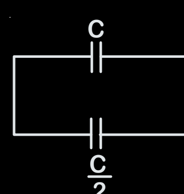
$$= 6\text{ nJ}$$

60. Answer (4)



$$Q_0 = CV_0$$

Now battery is disconnected and a capacitor of $\frac{C}{2}$ is connected to C then



Total charge $= Q_0$

$$C_{eq.} = \frac{3C}{2}$$

$$\therefore\ \Delta E = \frac{Q_0^2}{2C} - \frac{2Q_0^2}{3C\times 2} \ \Rightarrow\ \Delta E = \frac{Q_0^2}{2C}\left(\frac{1}{3}\right)$$

$$\Rightarrow \Delta E = \frac{1}{6} \times 220 \times 220 \times 5 \times 10^{-6} \approx 4 \times 10^{-2}\text{ J}$$

$\therefore \quad X = 4$

61. Answer (3)

$C_1 = \dfrac{C}{2}$ for series

$C_2 = C + C = 2C$ for parallel

$$\therefore \quad \frac{C_1}{C_2} = \frac{\frac{C}{2}}{2C} = \frac{1}{4}$$

62. Answer (128)

$$\frac{Kq}{r} = V_0$$

$V = \dfrac{KQ}{R}$, where Q = nq and $R = n^{\frac{1}{3}}r$

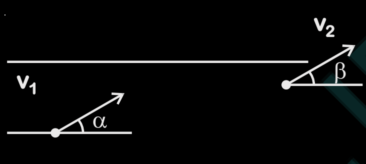
$$V = n^{\frac{2}{3}}V_0$$

$= 128$ volts

63. Answer (3)

$v_1\cos\alpha = v_2\cos\beta$

$$\frac{K_1}{K_2} = \frac{v_1^2}{v_2^2} = \frac{\cos^2\beta}{\cos^2\alpha}$$



64. Answer (500)

$$3 \times \frac{1}{2}k_BT = (1.6 \times 10^{-19})(0.1) \cong 773\text{ K} = 500°\text{C}$$

65. Answer (243.00)

$$U = \frac{(C)Q^2}{R}$$

For smaller drop, $U_s = \dfrac{(C)(Q_0)^2}{r}$

For bigger drop, $U_B = \dfrac{(C)(27Q_0)^2}{3r}$

$$\Rightarrow U_B = \frac{27 \times 27}{3}U_s = 243U_s$$

66. Answer (4)

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$$

$$= \frac{\varepsilon_0 A}{d - \frac{3d}{4} + \frac{3d}{4K}} = \frac{\varepsilon_0 A}{\frac{d}{4} + \frac{3d}{4K}}$$

$$= \frac{4K \times \varepsilon_0 A}{(K+3)d}$$

$$= \frac{4K}{K+3}C_0$$

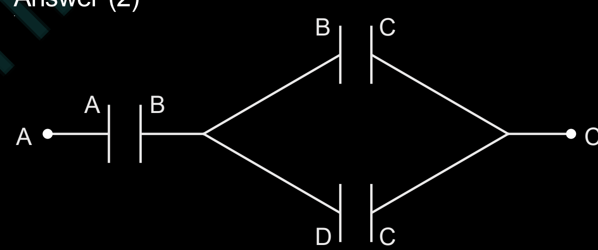
67. Answer (4)

$$U_{\text{initial}} = \frac{1}{2} \times (200 \times 10^{-6}) \times (200)^2$$

$$U_{\text{final}} = \frac{1}{2}(200 \times 10^{-6} \times 2) \times (200)^2$$

$$\Delta U = \frac{1}{2} \times 200 \times 10^{-6} \times 4 \times 10^4 = 4\text{ J}$$

68. Answer (2)



$$C_{AB} = \frac{C.2C}{C + 2C} = \frac{2}{3}.\frac{\varepsilon_0 lb}{d} = \frac{2\varepsilon_0}{d}$$

69. Answer (864)

$$U_i = \frac{1}{2}CV^2 = 1008\text{ pJ}$$

After releasing the slab it will have maximum K.E.(which is also equal to M.E.) while crossing mean position.

$$U_f = \frac{Q^2}{2C'} = \frac{C^2V^2}{2C'} = \frac{1}{2}\frac{CV^2}{k} = 144\text{ pJ}$$

M.E. $= U_i - U_f$

$= 864$ pJ

70. Answer (16)

$Q_1 = C_1V = 20\ \mu\text{C}$

$$Q_2 = \left(\frac{Q_1 + Q_2}{C_1 + C_2}\right).C_2 = 16\ \mu\text{C}$$

71. Answer (161)

$$C=\frac{\varepsilon_0 A}{d-t+t/k}$$

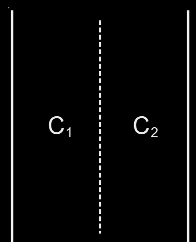
$$=\frac{8.85\times10^{-12}\times100}{10-5+5/10}=1.609\times10^{-10}\text{ F}$$

$= 160.9 \times 10^{-12} = 161$ pF

72. Answer (3)

$$\varepsilon(x)=\varepsilon_0+kx,\ \text{ for }\ 0\le x\le\frac{d}{2}$$

and $\varepsilon(x)=\varepsilon_0+k(d-x)$ for $\frac{d}{2}\le x\le d$



$C_1 = C_2$

$$\frac{1}{C_1}=\int_0^{d/2}\frac{dx}{(\varepsilon_0+kx)A}$$

$$\Rightarrow\ \frac{1}{C_1}=\frac{1}{Ak}\ln\left(\frac{\varepsilon_0+k\frac{d}{2}}{\varepsilon_0}\right)\ \Rightarrow C_1=\frac{Ak}{\ln\left(1+\frac{kd}{2\varepsilon_0}\right)}$$

$$\therefore\ C=\frac{C_1}{2}=\frac{Ak}{2\ln\left(\frac{2\varepsilon_0+kd}{2\varepsilon_0}\right)}$$

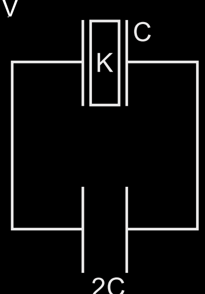
73. Answer (4)

We know

$$q_b=q_f\left(1-\frac{1}{k}\right)$$

74. Answer (1)

$Q_{total} = 3C \times V$



$$\therefore\ V_f=\frac{3CV}{(2C+KC)}$$

$$=\frac{3}{K+2}\times V$$

75. Answer (2)

$$C_1=\frac{K\varepsilon_0 A}{d}$$

$$C_2=\frac{3K\varepsilon_0 A}{2d}$$

$$C_3=\frac{5K\varepsilon_0 A}{3d}$$

$$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$$

$$\frac{1}{C_{eq}}=\frac{d}{K\varepsilon_0 A}+\frac{2d}{3K\varepsilon_0 A}+\frac{3d}{5K\varepsilon_0 A}$$

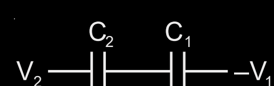
$$\frac{1}{C_{eq}}=\frac{d}{K\varepsilon_0 A}\left[1+\frac{2}{3}+\frac{3}{5}\right]$$

$$=\frac{d}{15K\varepsilon_0 A}[15+10+9]$$

$$C_{eq}=\frac{15K\varepsilon_0 A}{34d}$$

76. Answer (4)

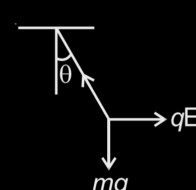
Potential across capacitor, $C_1=\frac{C_2(V_1+V_2)}{(C_1+C_2)}$



Field in the region of $C_1=\frac{C_2(V_1+V_2)}{(C_1+C_2)(d-t)}$

$T\cos\theta = mg$

$T\sin\theta = qE$

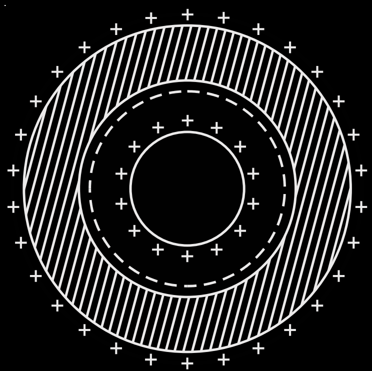


$$\tan\theta=\frac{qE}{mg}$$

$$\tan\theta=\frac{qC_2(V_1+V_2)}{(C_1+C_2)(d-t)mg}$$

77. Answer (1)

Charge resides on the outer surface of metal surface.



For $0 \le r \le R$, $E = 0$

$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ for $R \le r < a$

$E = 0$ for $a < r < b$

$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ for $b < r$

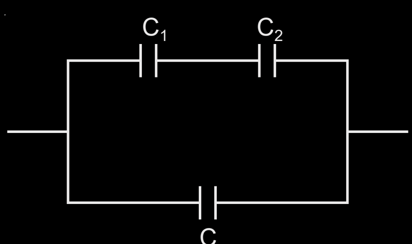
78. Answer (1)

$$\Delta V = \left[\frac{Q}{4\pi\varepsilon_0 a} - \frac{Q}{4\pi\varepsilon_0\sqrt{a^2+s^2}}\right] - \left[\frac{-Q}{4\pi\varepsilon_0 a} + \frac{Q}{4\pi\varepsilon_0\sqrt{a^2+s^2}}\right]$$

$$= \frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{\sqrt{s^2+a^2}}\right]$$

79. Answer (4)

Equivalent capacitor circuit is



$$C_1 = \frac{K_1\varepsilon_0 A}{d}$$

$$C_2 = \frac{K_2\varepsilon_0 A}{d}$$

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

$$C_{eq} = \frac{K_1K_2\varepsilon_0 A}{(K_1+K_2)d} + \frac{\varepsilon_0 A}{2d}$$

80. Answer (2)

Charge on C_1, $q_1 = C_1V = 2V\ \mu C$

Charge on C_2 and C_3 are same

$\therefore\ q_2 = q_3 = C_{eq}V$

$= 4V\mu C$

$\therefore\ q_1 : q_2 : q_3 = 1 : 2 : 2$

81. Answer (4)

Field inside the dielectric $= \dfrac{\sigma}{k\varepsilon_0}$

According to the given information,

$$\frac{\sigma}{k\varepsilon_0} = 3.6\times10^7$$

$$\Rightarrow \frac{\frac{Q}{A}}{k\varepsilon_0} = 3.6\times10^7$$

$\Rightarrow k = 2.33$

82. Answer (6)

$$C_{eq} = \frac{(3\times8)\times8}{(3\times8)+8}$$

$$= \frac{24\times8}{32}$$

$= 6\ \mu F$

83. Answer (1)

$$C_{eq} = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2k}} = \frac{\varepsilon_0 A}{\frac{d}{2}} = \frac{2\varepsilon_0 A}{d}$$

If $C = \dfrac{\varepsilon_0 A}{d}$

$$\Rightarrow C_{eq} = 2C \text{ or } \frac{C_{new}}{C_{old}} = \frac{2}{1}$$

84. Answer (198)

Let the charge on one drop is q and its radius is r.

So for one drop $V = \dfrac{kq}{r}$

For 27 drops merged new charge will be $Q = 27q$ and new radius is $R = 3r$

So new potential is

$$V' = \frac{kQ}{R} = 9\frac{kq}{r} = 9 \times 22\ \text{V}$$

$= 198$ V

85. Answer (1)

$$V_{\text{common}} = \frac{C_1 V}{C_1 + C_2}$$

$\Rightarrow$ Charge on capacitor C_2

$= C_2\, V_{\text{common}}$

$$= \frac{C_1 C_2 V}{C_1 + C_2}$$

$\Rightarrow$ Option (1)

86. Answer (125)

Electrical energy lost = $\frac{1}{2}\left(\frac{1}{2}CV^2\right)$

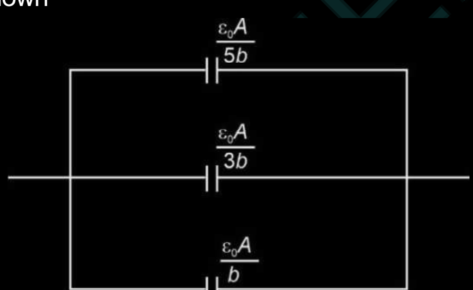
$$= \frac{1}{2} \times \frac{1}{2} \times 50 \times 10^{-12} \times (100)^2$$

$$= \frac{500}{4}\ \text{nJ}$$

= 125 nJ

87. Answer (23)

The circuit is equivalent to 3 capacitors in parallel as shown



$$C_{eq} = \frac{\varepsilon_0 A}{b}\left(1 + \frac{1}{3} + \frac{1}{5}\right) = \frac{23}{15}\frac{\varepsilon_0 A}{b}$$

$\Rightarrow$ $x = 23$

88. Answer (100)

Let the charge q is flown in the circuit.

So using Kirchoff's law

$$\frac{q}{10} = \frac{150 - q}{5}$$

$q = 100\ \mu$C

89. Answer (1)

$$U = \frac{1}{2}(kC_0)V^2$$

$$\Rightarrow \frac{U'}{U} = 1.5$$

$\Rightarrow$ Energy increases by 50%

90. Answer (4)

$$\vec{E} = -\frac{dV}{dx}\hat{i}$$

$$\vec{E} = -6x\hat{i}$$

So, $\vec{E}$ at (1, 0, 3) is

$$\vec{E} = -6\hat{i}\ \text{V/m}$$

91. Answer (1)

$Q = CV$

As capacitance is constant $Q \propto V$

and $V_f = \frac{Q_f}{C} = \frac{5}{2 \times 10^{-6}} = 2.5 \times 10^6$ V

So correct graph will be (1)

92. Answer (1)

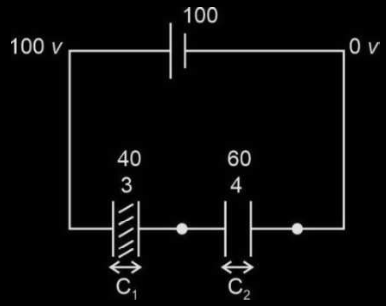
Equivalent $C = \Sigma C_i$

$= 10\ \mu$F

$\Rightarrow$ Charge $Q = CV$

$= 200\ \mu$C

93. Answer (60)



$$\frac{C_1}{C_2}=\frac{3\times t_2}{t_1\times 4}=\frac{3}{2}$$

$$\frac{q}{C_1}=v_1, \frac{q}{C_2}=v_2$$

$$\frac{v_1}{v_2}=\frac{C_2}{C_1}=\frac{2}{3}$$

94. Answer (240)

$d_1 = 4 \times 10^{-3}$

$A_1 = 8 \times 4 \times 10^{-4}\ \text{m}^2$

$V = 20\ \text{V}$

$d_2 = 4 \times 10^{-3}$,

$A_2 = 4 \times 1 \times 10^{-4}\ \text{m}^2$

$$C_{eq}=\frac{(A_1+5A_2-A_2)\varepsilon_0}{d}=\frac{3(16)\times 10^{-4}}{4\times 10^{-3}}\varepsilon_0$$

$$\varepsilon=\frac{1}{2}C_{eq}V^2=\frac{3}{2}\left(\frac{4}{10}\right)(400)\varepsilon_0=240\varepsilon_0$$

95. Answer (1)

$$C_0=\frac{\varepsilon_0 A}{d}$$

$$C=\frac{\varepsilon_0 A}{d-\frac{3d}{4}+\frac{3d}{4K}}=\frac{4\varepsilon_0 AK}{3d+Kd}$$

$$=\frac{4KC_0}{3+K}$$

96. Answer (1)

Since $\vec{E}_{\text{net}}=\vec{0}$ in the bulk of a conductor

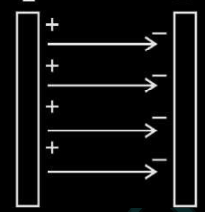
$\Rightarrow$ Potential would be constant.

$\Rightarrow$ Statement I is correct.

Since a conductor's surface is equipotential, $\vec{E}$ just outside is perpendicular to the surface.

97. Answer (3)

$\frac{q_1-q_2}{2}$ $\quad -\frac{(q_1-q_2)}{2}$



$$E=\frac{q_1-q_2}{2\varepsilon_0 A}$$

$$V=\frac{(q_1-q_2)d}{2\varepsilon_0 A}$$

$$=\frac{q_1-q_2}{2C}$$

98. Answer (1)

Initially $= C_0 = 4\pi\varepsilon_0 R_1$

finally $\frac{4\pi\varepsilon_0 R_1 R_2}{R_2-R_1}=nC_0=4\pi\varepsilon_0 nR_1$

$$\frac{R_2}{R_2-R_1}=n$$

$$1-\frac{R_1}{R_2}=\frac{1}{n}$$

$$\frac{R_1}{R_2}=\frac{n-1}{n}$$

$$\frac{R_2}{R_1}=\frac{n}{n-1}$$

99. Answer (2)

After connection

$\sigma_1 R_1 = \sigma_2 R_2$

Now $E=\frac{\sigma}{\varepsilon_0}$

$$\Rightarrow \frac{E_1}{E_2} = \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

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

100. Answer (1)

$$\frac{40K \times 40}{40K + 40} = 24$$

$40K = 24\ (K + 1)$

$40K = 24K + 24$

$16K = 24$

$$K = \frac{24}{16} = \frac{3}{2} = 1.5$$

101. Answer (1)

$$C_{eq} = \frac{120}{26}\mu\text{F}$$

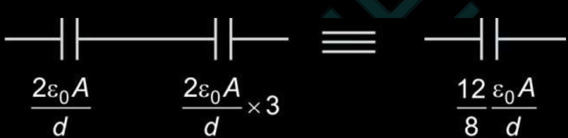
$$\Rightarrow \quad Q_{\text{flown}} \text{ or } Q = \frac{13 \times 120}{26}\mu\text{C} = 60\ \mu\text{C}$$

$\Rightarrow$ Charge on 15 μF capacitor = 60 μC

As all the capacitors are in series.

102. Answer (3)

Equivalent circuit is



$$\text{Now } \frac{\varepsilon_0 A}{d} = 4\ \mu\text{F}$$

$$\Rightarrow \frac{12}{8}\frac{\varepsilon_0 A}{d} = 6\ \mu\text{F}$$

103. Answer (2)

$q' = 64q$ ... (i)

$A' = 16\ A$ ... (ii)

Dividing (i) & (ii),

$\sigma' = 4\sigma$

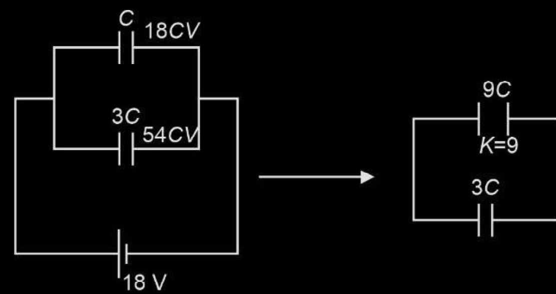
$$\Rightarrow \frac{\sigma'}{\sigma} = \frac{4}{1}$$

104. Answer (1)

E between two plates is $\frac{\sigma}{\varepsilon_0}$ and due to one plate is $\frac{\sigma}{2\varepsilon_0}$ so the force will be halved

So new force $F = 5$ N

105. Answer (6)



$$V_{\text{common}} = \frac{18CV + 54CV}{3C + 9C} = 6 \text{ V}$$

106. Answer (1)

Let initially the charge is q so

$$\frac{1}{2}\frac{q^2}{C} = U_i$$

$$\text{And } \frac{1}{2}\frac{(q+2)^2}{C} = U_f$$

$$\text{Given } \frac{U_f - U_i}{U_i} \times 100 = 44$$

$$\frac{(q+2)^2 - q^2}{q} = 0.44$$

$\Rightarrow \quad q = 10C$

107. Answer (C)

$$E_1 = \frac{1}{2}(2C)V^2$$

$\Rightarrow \quad E_1 = CV^2$ ...(i)

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

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

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

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