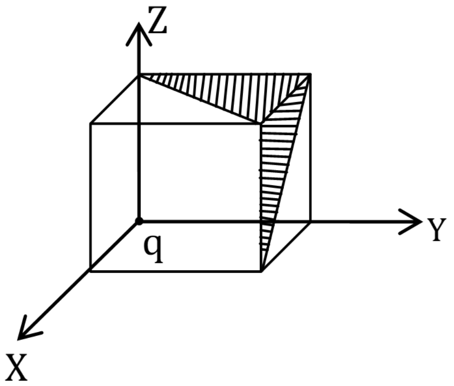
Topic : Electrostatics and capacitors

1. A charge $'q'$ is placed at one corner of a cube as shown in figure. The flux of electrostatic field $\vec{E}$ though the shaded area is:



A. $\dfrac{q}{48\epsilon_o}$

B. $\dfrac{q}{8\epsilon_o}$

C. $\dfrac{q}{24\epsilon_o}$

D. $\dfrac{q}{4\epsilon_o}$

2. Two electrons having charge $(-e)$ each are fixed at a distance '$2\mathrm{d}$'. A third charge proton placed at the midpoint is displaced slightly by a distance x $(\mathrm{x}<<\mathrm{d})$ perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency:
$(\mathrm{m} =$ mass of charged particle)

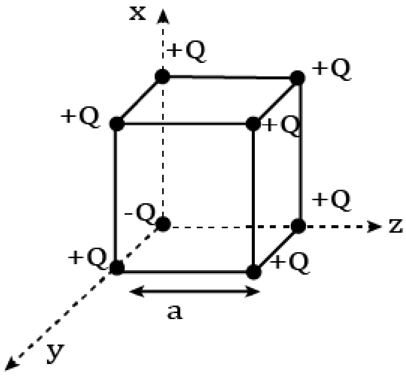
A. $\left(\dfrac{e^2}{2\pi\varepsilon_o m d^3}\right)^{1/2}$

B. $\left(\dfrac{\pi\varepsilon_o m d^3}{2e^2}\right)^{1/2}$

C. $\left(\dfrac{2\pi\varepsilon_o m d^3}{e^2}\right)^{1/2}$

D. $\left(\dfrac{2e^2}{\pi\varepsilon_o m d^3}\right)^{1/2}$

3. A cube of side a has point charges, $+Q$ located at each of its vertices, except at the origin, where the charge is $-Q$. The electric field at the centre of the cube is :



A. $\frac{2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

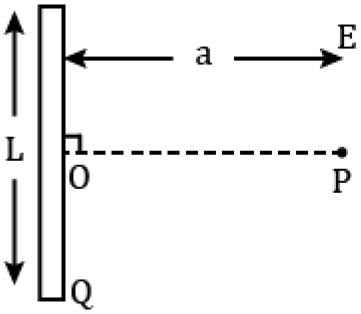
B. $\frac{Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

C. $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

D. $\frac{-Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

4. Find the electric field E at point P (as shown in figure) on the perpendicular bisector of a uniformly charged thin wire of length L carrying a charge Q.

The distance of the point P from the centre of the rod is $a = \frac{\sqrt{3}}{2}L$.



A. $\dfrac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$

B. $\dfrac{\sqrt{3}Q}{4\pi\varepsilon_0 L^2}$

C. $\dfrac{Q}{3\pi\varepsilon_0 L^2}$

D. $\dfrac{Q}{4\pi\varepsilon_0 L^2}$

5. Find out the surface charge density at the intersection of point $x = 3\ \mathrm{m}$ plane and $x - \mathrm{axis}$ in the region of uniform line charge of $8\ \mathrm{nC/m}$ lying along the $z - \mathrm{axis}$ in free space.

A. $47.88\ \mathrm{C/m}$

B. $0.07\ \mathrm{nC\ m^{-2}}$

C. $0.424\ \mathrm{nC\ m^{-2}}$

D. $4.0\ \mathrm{nC\ m^{-2}}$

6. Given below are two statements.

Statement I : An electric dipole is placed at the centre of a hollow sphere. The flux of electric field through the sphere is zero, but electric field is not zero anywhere in the sphere.

Statement II : If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at a point on the spherical surface of radius $r\ (< R)$ is zero, but the electric flux passing through this closed spherical surface of radius r is not zero.

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

A. Statement I is true, but statement II is false.

B. Statement I is false, but statement II is true.

C. Both statement I and statement II are true.

D. Both statement I and statement II are false.

7. An oil drop of radius $2\ \mathrm{mm}$ with a density $3\ \mathrm{g\ cm^{-3}}$ is held stationary under a constant electric field $3.55 \times 10^5\ \mathrm{V\ m^{-1}}$ in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess? (Consider $g = 9.81\ \mathrm{m\ s^{-2}}$)

A. 1.73×10^{10}

B. 48.8×10^{11}

C. 1.73×10^{12}

D. 17.3×10^{10}

8. A solenoid of 1000 turns per metre has a core with relative permeability of 500. Insulated windings of the solenoid carry an electric current of $5\ \mathrm{A}$. The magnetic flux density produced by the solenoid is -

(Permeability of free space $= 4\pi \times 10^{-7}\ \mathrm{H/m}$)

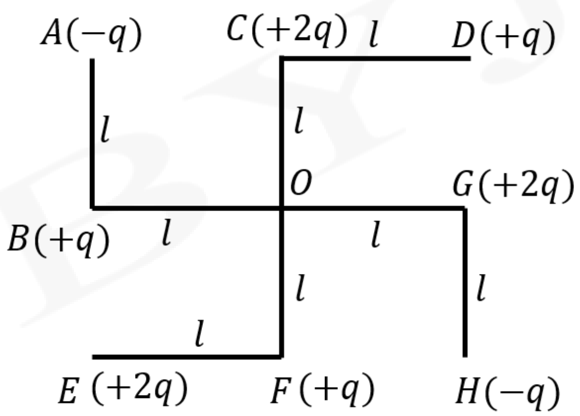
A. $2\pi \times 10^{-3}\ \mathrm{T}$

B. $\frac{\pi}{5}\mathrm{T}$

C. $\pi \times 10^{-4}\ \mathrm{T}$

D. $\pi\ \mathrm{T}$

9. What will be the magnitude of electric field at point O as shown in figure? Each side of the figure is l and perpendicular to each other ?



A. $\frac{1}{4\pi\epsilon_0}\frac{q}{l^2}$

B. $\frac{1}{4\pi\epsilon_0}\frac{q}{(2l^2)}\left(2\sqrt{2}-1\right)$

C. $\frac{q}{4\pi\epsilon_0(2l)^2}$

D. $\frac{1}{4\pi\epsilon_0}\frac{2q}{2l^2}\left(\sqrt{2}\right)$

10. An electric field of $1000 \mathrm{~V/m}$, is applied to an electric dipole moment of $10^{-29} \; C \cdot m$. What is the potential energy of the electric dipole?

A. $-20 \times 10^{-18} J$

B. $-7 \times 10^{-27} J$

C. $-10 \times 10^{-29} J$

D. $-9 \times 10^{-20} J$

11. A certain charge Q is divided into two parts, q and $Q-q$. How should the charges be divided so that q and $Q-q$ placed at a certain distance apart, experience maximum electrostatic repulsion?

A. $Q = \frac{q}{2}$

B. $Q = 2q$

C. $Q = 4q$

D. $Q = 3q$

12. An electric dipole is placed on $x-$axis in proximity to a line charge of linear charge density $3.0 \times 10^{-6} \mathrm{~C/m}$. Line charge is placed on $z-$axis and positive and negative charge of dipole is at a distance of $10 \mathrm{~mm}$ and $12 \mathrm{~mm}$ from the origin respectively. If total force of $4 \mathrm{~N}$ is exerted on the dipole, find out the amount of positive or negative charge of the dipole.

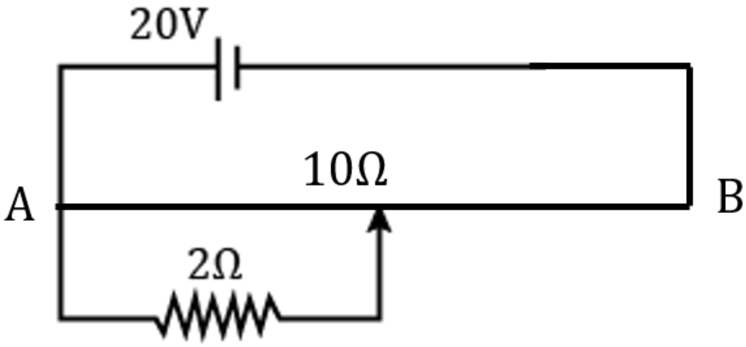
A. $815.1 \mathrm{~nC}$

B. $8.8 \mu\mathrm{C}$

C. $0.485 \mathrm{~mC}$

D. $4.44 \mu\mathrm{C}$

13. The given potentiometer has its wire of resistance $10\ \Omega$. When the sliding contact is in the middle of the potentiometer wire, the potential drop across $2\ \Omega$ resistor is :



A. $10\ \mathrm{V}$

B. $5\ \mathrm{V}$

C. $\frac{40}{9}\mathrm{V}$

D. $\frac{40}{11}\mathrm{V}$

14. Two identical tennis balls each having mass $'m'$ and charge $'q'$ are suspended from a fixed point by threads of length $'l'$. What is the equilibrium separation when each thread makes a small angle θ with the vertical ?

A. $x=\left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{2}}$

B. $x=\left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$

C. $x=\left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g}\right)^{\frac{1}{3}}$

D. $x=\left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{\frac{1}{3}}$

15. 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 :

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

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

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

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

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

A. $2:1$

B. $1:4$

C. $3:1$

D. $3:2$

17. 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 capacitors connected in series. Calculate the ratio of capacitors, $\frac{C_2}{C_1}$.

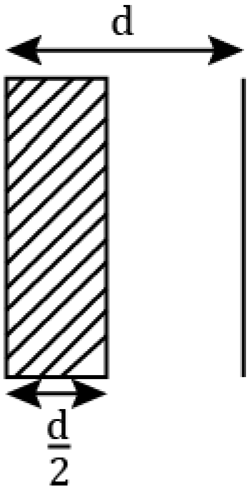
A. $\frac{15}{11}$

B. $\frac{29}{15}$

C. $\frac{15}{4}$

D. Imaginary

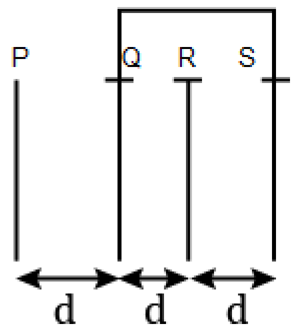
18. In a parallel plate capacitor set up, the plate area of capacitor is $2\ \mathrm{m}^2$ and the plates are separated by $1\ \mathrm{m}$. If the space between the plates are filled with a dielectric material of thickness $0.5\ \mathrm{m}$ and area $2\ \mathrm{m}^2$ (see figue) the capacitance of the set-up will be $n\epsilon_0$. The value of n is
(Dielectric constant of the material $= 3.2$) (Round off to the Nearest Integer)



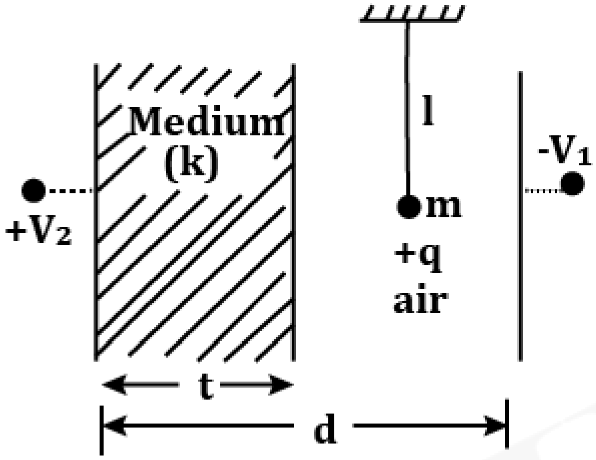
19. A parallel plate capacitor whose capacitance C is $14\ \mathrm{pF}$ is charged by a battery to a potential difference $V = 12\ \mathrm{V}$ between its plates. The charging battery is now disconnected and a porcelain plate with $k = 7$ is inserted between the plates, then the porcelain plate would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

20. Four identical rectangular plates with length, $l = 2\ \mathrm{cm}$ and breadth, $b = 3/2\ \mathrm{cm}$ are arranged as shown in the figure. The equivalent capacitance between P and R is $\frac{x \times 10^{-2} \epsilon_0}{d}$ where d is the distance between the plates in cm. The value of x is ______.

(Round off to the nearest integer)



21. A simple pendulum of mass $'m'$, length $'l'$ and charge $'+q'$ suspended in the electric field produced by two conducting parallel plates as shown in the figure. The value of deflection of pendulum in equilibrium position will be (C_1 and C_2 are the capacitance of capacitors formed by parallel plates, without medium in between and with medium in between, respectively.)



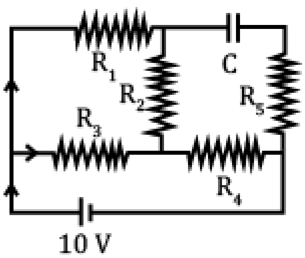
A. $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_1(V_2-V_1)}{(C_1+C_2)(d-t)}\right]$

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

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

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

22. An ideal cell of emf $10\ \mathrm{V}$ is connected in circuit shown in figure. Each resistance is $2\ \Omega$. The potential difference (in V) across the capacitor when it is fully charged is



23. AC voltage, $V(t) = 20\sin(\omega t)$, of frequency $50\ \mathrm{Hz}$, is applied to a parallel plate capacitor. The separation between the plates is $2\ \mathrm{mm}$ and the area of the plates is $1\ \mathrm{m}^2$. The amplitude of the oscillating displacement current, for the applied AC voltage is -

Take $\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F/m}$

A. $21.14\ \mu\mathrm{A}$

B. $83.37\ \mu\mathrm{A}$

C. $27.79\ \mu\mathrm{A}$

D. $55.58\ \mu\mathrm{A}$

24. A current of $5\ \mathrm{A}$ is passing through a non-linear magnesium wire of cross-section $0.04\ \mathrm{m}^2$. At every point, the direction of current density is at an angle of 60°, with the unit vector of area of cross-section. The magnitude of electric field at every point of the conductor is :

Resistivity of magnesium is $44 \times 10^{-8}\ \Omega\text{-m}$.

A. $11 \times 10^{-2}\ \mathrm{V/m}$

B. $11 \times 10^{-7}\ \mathrm{V/m}$

C. $11 \times 10^{-5}\ \mathrm{V/m}$

D. $11 \times 10^{-3}\ \mathrm{V/m}$

25. 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 follows:

$\epsilon(x) = \epsilon_0 + kx$, for $\left(0 < x \leq \frac{d}{2}\right)$

$\epsilon(x) = \epsilon_0 + k(d - x)$, for $\left(\frac{d}{2} \leq x \leq d\right)$

A. $\left(\epsilon_0 \frac{kd}{2}\right)^{\frac{2}{k\,a}}$

B. $\dfrac{kA}{2\,ln\left(\frac{2\epsilon_0 + kd}{2\epsilon_0}\right)}$

C. 0

D. $\frac{kA}{2} ln\left(\frac{2\epsilon_0}{2\epsilon_0 - kd}\right)$

26. 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

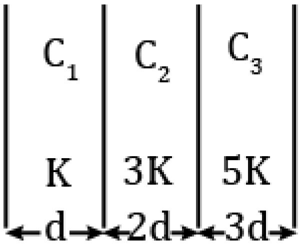
A. $q_b = q_f\left(1 - \frac{1}{\sqrt{K}}\right)$

B. $q_b = q_f\left(1 - \frac{1}{K}\right)$

C. $q_b = q_f\left(1 + \frac{1}{\sqrt{K}}\right)$

D. $q_b = q_f\left(1 + \frac{1}{K}\right)$

27. 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 $= A$)



A. $\frac{15}{34} \frac{K\varepsilon_0 A}{d}$

B. $\frac{15}{6} \frac{K\varepsilon_0 A}{d}$

C. $\frac{25}{6} \frac{K\varepsilon_0 A}{d}$

D. $\frac{9}{6} \frac{K\varepsilon_0 A}{d}$

28. 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 :

A. $\frac{V}{K+2}$

B. $\frac{V}{K}$

C. $\frac{3V}{K+2}$

D. $\frac{3V}{K}$

29. The material filled between the plates of a parallel plate capacitor has resistivity $200\ \Omega\mathrm{m}$. The value of capacitance of the capacitor is $2\ pF$. If a potential difference of $40\ \mathrm{V}$ is applied across the plates of the capacitor, then the value of leakage current flowing out of the capacitor is :
[Given the value of relative permitivity of material $(k = 50)$]

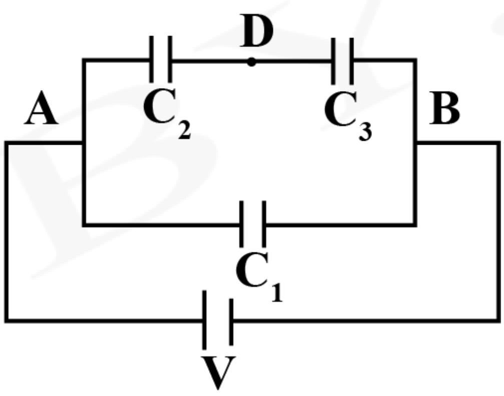
A. $9.0\ \mathrm{mA}$

B. $0.9\ \mathrm{mA}$

C. $0.9\ \mu\mathrm{A}$

D. $9.0\ \mu\mathrm{A}$

30. Three capacitors $C_1 = 2\mu\mathrm{F},\ C_2 = 6\mu\mathrm{F}$ and $C_3 = 12\mu\mathrm{F}$ are connected as shown in figure. Find the ratio of the charges on capacitors $C_1,\ C_2$ and C_3 respectively



A. $3:4:4$

B. $2:3:3$

C. $2:1:1$

D. $1:2:2$