Electrostatics JEE Main PYQ - 2

Total Time: 1 Hour : 15 Minute **Total Marks:** 120

Instructions

Instructions

1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Electrostatics

1. Two electrons each are fixed at a distance '2d'. A third charge proton placed at the midpoint is displaced slightly by a distance x (x << d) perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency : (m = mass of charged particle) (+4, -1)

   a. $\left(\frac{q^2}{2\pi\varepsilon_0 m d^3}\right)^{\frac{1}{2}}$

   b. $\left(\frac{2q^2}{\pi\varepsilon_0 m d^3}\right)^{\frac{1}{2}}$

   c. $\left(\frac{\pi\varepsilon_0 m d^3}{2q^2}\right)^{\frac{1}{2}}$

   d. $\left(\frac{2\pi\varepsilon_0 m d^3}{q^2}\right)^{\frac{1}{2}}$

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2. A parallel plate capacitor has plate area 100 m² and plate separation of 10 m. The space between the plates is filled up to a thickness 5 m with a material of dielectric constant of 10. The resultant capacitance of the system is 'x' pF. The value of $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}. The value of 'x' to the nearest integer is __________. (+4, -1)

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3. An oil drop of radius 2 mm with a density 3 g cm^{-3} is held stationary under a constant electric field 3.55×10^5 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 m/s² (+4, -1)

   a. 17.3×10^{10}

   b. 1.73×10^{10}

   c. 1.73×10^{12}

   d. 48.8×10^{11}

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4. A particle of mass 1 mg and charge q is lying at the mid-point of two stationary particles kept at a distance '2 m' when each is carrying same charge 'q'. If the free charged particle is displaced from its equilibrium position through distance (+4, -1)

'x' ($x << 1$ m). The particle executes SHM. Its angular frequency of oscillation will be ________ $\times 10^5$ rad/s if $q^2 = 10$ C^2.

5. What will be the magnitude of electric field at point O as shown in the figure? (+4, -1)
Each side of the figure is l and mutually perpendicular.

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

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

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

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

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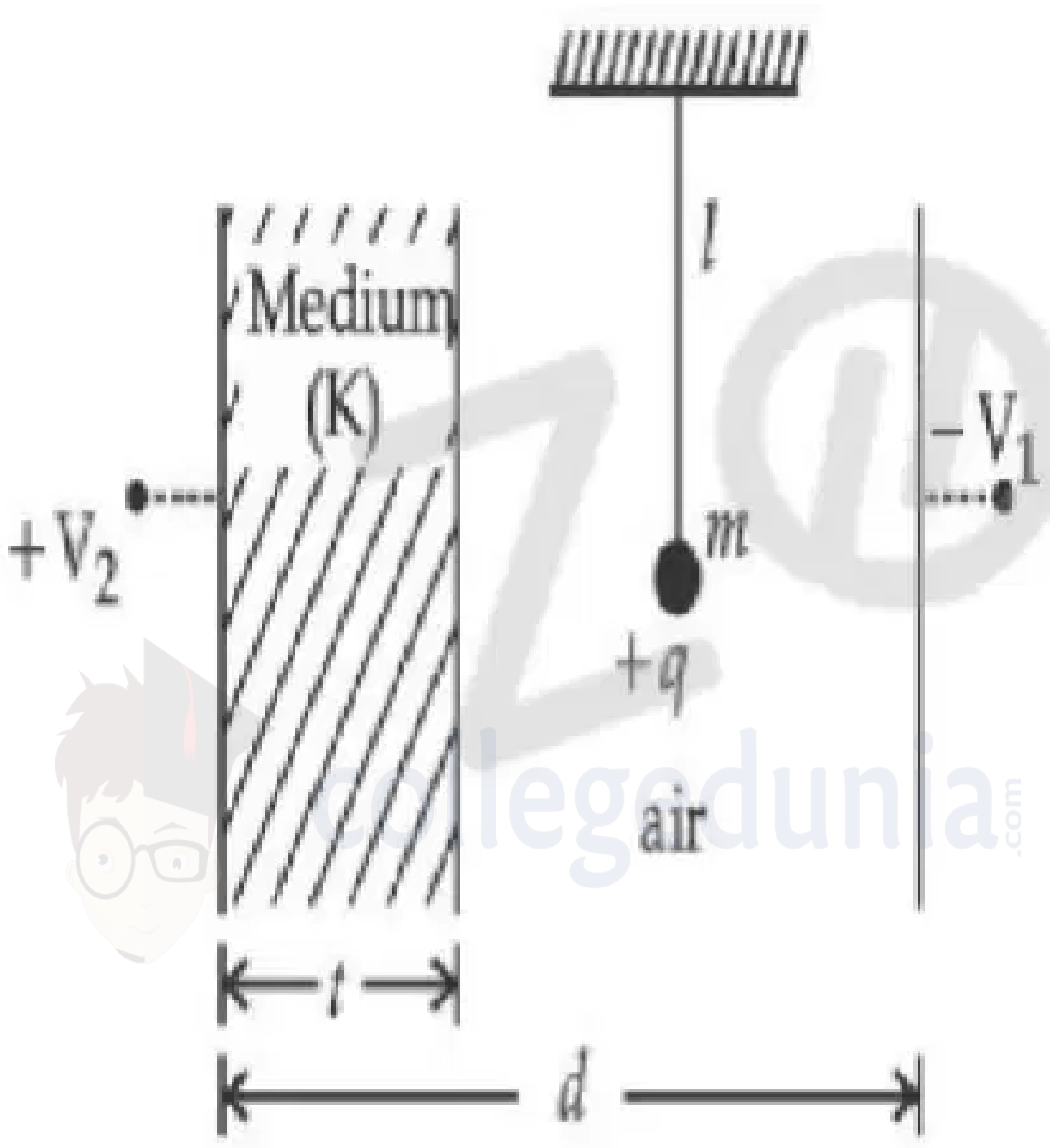
6. A simple pendulum of mass 'm', length 'l' and charge '+q' suspended in the electric field produced by two conducting parallel plates as shown. The value of deflection of pendulum in equilibrium position will be: (+4, -1)



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

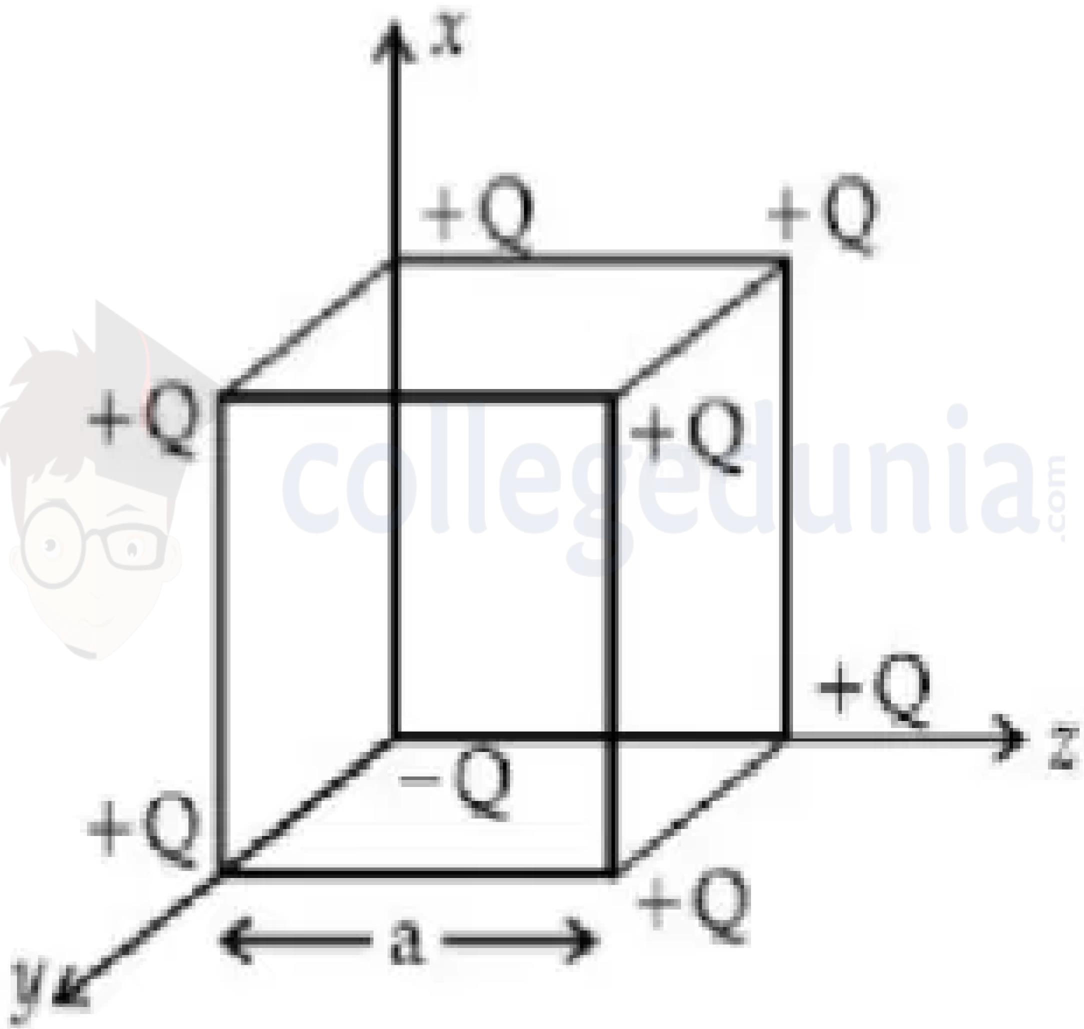
b. $\tan^{-1}\left[\frac{q}{mg} \times \frac{C_2(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$

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

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

7. An infinite number of point charges, each carrying 1 μC charge, are placed along the y-axis at y = 1 m, 2 m, 4 m, 8 m ……….. . The total force on a 1 C point charge, placed at the origin, is x $\times 10^3$ N. The value of x, to the nearest integer, is ________. [Take $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm²/C²] (+4, -1)

8. 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 cube is : (+4, -1)



a. $-\frac{Q}{3\sqrt{3}\pi\epsilon_0 a^2}(\hat{i}+\hat{j}+\hat{k})$

b. $\frac{Q}{3\sqrt{3}\pi\epsilon_0 a^2}(\hat{i}+\hat{j}+\hat{k})$

c. $-\frac{2Q}{3\sqrt{3}\pi\epsilon_0 a^2}(\hat{i}+\hat{j}+\hat{k})$

d. $\frac{2Q}{3\sqrt{3}\pi\epsilon_0 a^2}(\hat{i}+\hat{j}+\hat{k})$

9. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be : (+4, -1)

a. 1 : 2

b. 2 : 1

c. 4 : 1

d. 1 : 4

10. The electric field is $\vec{E}=\left(\frac{3}{5}E_0\hat{i}+\frac{4}{5}E_0\hat{j}\right)$. The ratio of flux through surface of area 0.2 m^2 (parallel to y-z plane) to that of area 0.3 m^2 (parallel to x-z plane) is a : b, where a = _________. (+4, -1)

11. 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. (+4, -1)

12. 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 ? (+4, -1)

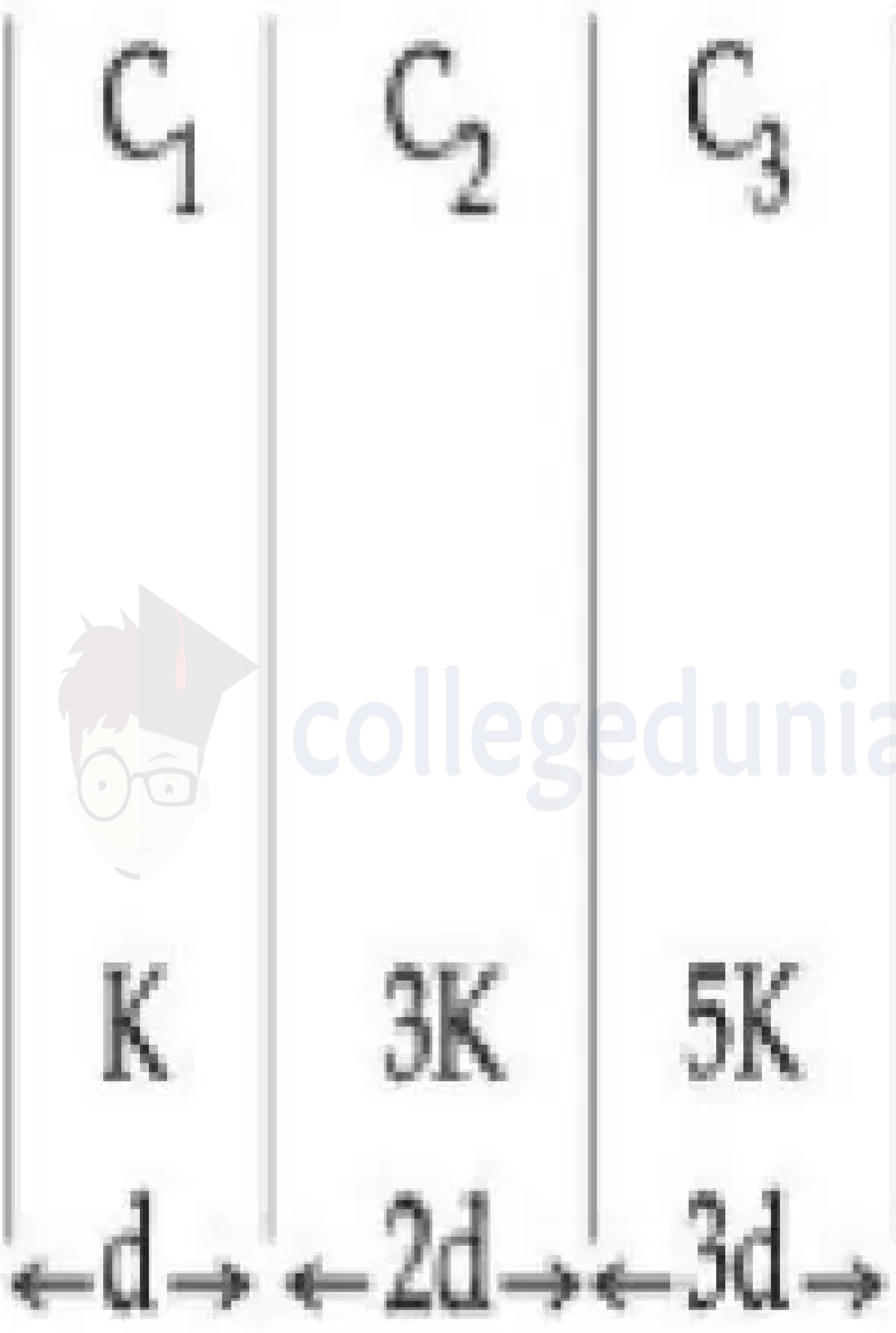
a. $x=\left(\frac{q^2l^2}{2\pi\epsilon_0 m^2 g}\right)^{1/3}$

b. $x=\left(\frac{q^2l}{2\pi\epsilon_0 mg}\right)^{1/3}$

c. $x=\left(\frac{q^2l}{2\pi\epsilon_0 mg}\right)^{1/2}$

d. $x=\left(\frac{q^2l^2}{2\pi\epsilon_0 m^2 g^2}\right)^{1/3}$

13. 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) (+4, -1)



a. $\frac{25}{6}\frac{K\epsilon_0 A}{d}$

b. $\frac{15}{34} \frac{K\epsilon_0 A}{d}$

c. $\frac{9}{6} \frac{K\epsilon_0 A}{d}$

d. $\frac{15}{6} \frac{K\epsilon_0 A}{d}$

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14. 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 : (+4, -1)

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

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

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

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

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15. Two identical conducting spheres with negligible volume have 2.1 nC and −0.1 nC charges, respectively. They are brought into contact and then separated by a distance of 0.5 m. The electrostatic force acting between the spheres is ________ $\times$ 10^{-9} N. [Given : $4\pi\epsilon_0 = \frac{1}{9\times10^9}$ SI unit] (+4, -1)

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16. Two small spheres each of mass 10 mg are suspended from a point by threads 0.5 m long. They are equally charged and repel each other to a distance of 0.20 m. The charge on each of the sphere is $\frac{a}{21} \times 10^{-8}$ C. The value of 'a' will be ________ . [Given g=10 ms^{-2}] (+4, -1)

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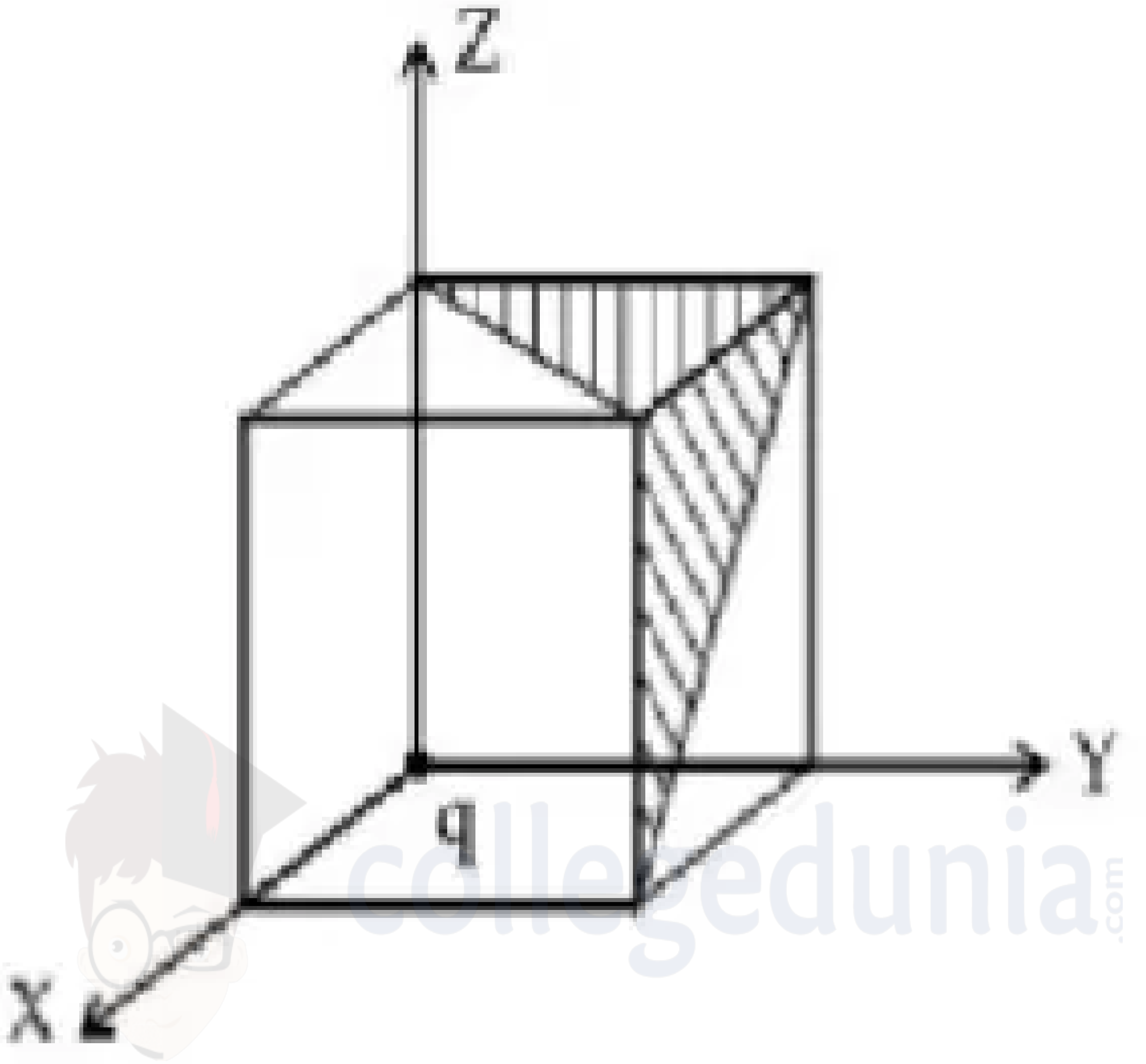
17. A charge 'q' is placed at one corner of a cube as shown in figure. The flux of electrostatic field $\vec{E}$ through the shaded area is: (+4, -1)



a. $\frac{q}{4\epsilon_0}$

b. $\frac{q}{8\epsilon_0}$

c. $\frac{q}{24\epsilon_0}$

d. (Option seems to be missing from OCR)

18. A parallel plate capacitor of capacitance 200 μF 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. (+4, -1)

19. Choose the incorrect statement : (+4, -1)

(a) The electric lines of force entering into a Gaussian surface provide negative flux.

(b) A charge 'q' is placed at the centre of a cube. The flux through all the faces will be the same.

(c) In a uniform electric field net flux through a closed Gaussian surface containing no net charge, is zero.

(d) When electric field is parallel to a Gaussian surface, it provides a finite non-zero flux.

Choose the most appropriate answer from the options given below :

a. (a) and (c) Only

b. (b) and (d) Only

c. (c) and (d) Only

d. (d) Only

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20. Two particles A and B having charges $20\,\mu C$ and $-5\,\mu C$ respectively are held fixed with a separation of $5\,\mathrm{cm}$. At what position a third charged particle should be placed so that it does not experience a net electric force ? (+4, -1)

a. At midpoint between two charges

b. At $5\,\mathrm{cm}$ from $-5\,\mu C$ on the right side

c. At $5\,\mathrm{cm}$ from $20\,\mu C$ on the left side of system

d. At $1.25\,\mathrm{cm}$ from a $-5\,\mu C$ between two charges

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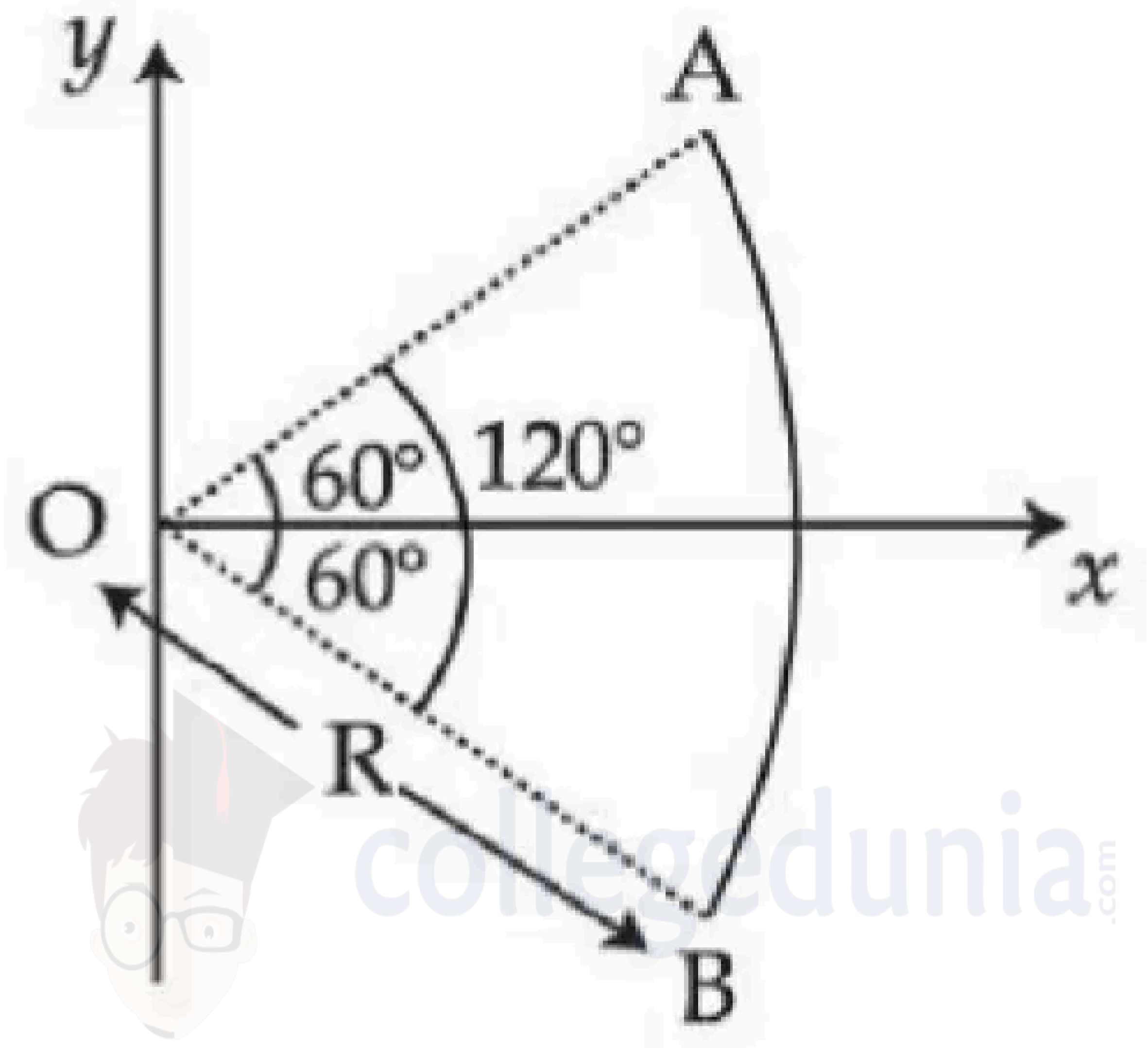
21. Figure shows a rod AB, which is bent in a 120° circular arc of radius R. A charge $(-Q)$ is uniformly distributed over rod AB. What is the electric field $\vec{E}$ at the centre of curvature O? (+4, -1)



a. $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(\hat{i})$

b. $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(-\hat{i})$

c. $\frac{3\sqrt{3}Q}{8\pi\varepsilon_0 R^2}(\hat{i})$

d. $\frac{3\sqrt{3}Q}{16\pi^2\varepsilon_0 R^2}(\hat{i})$

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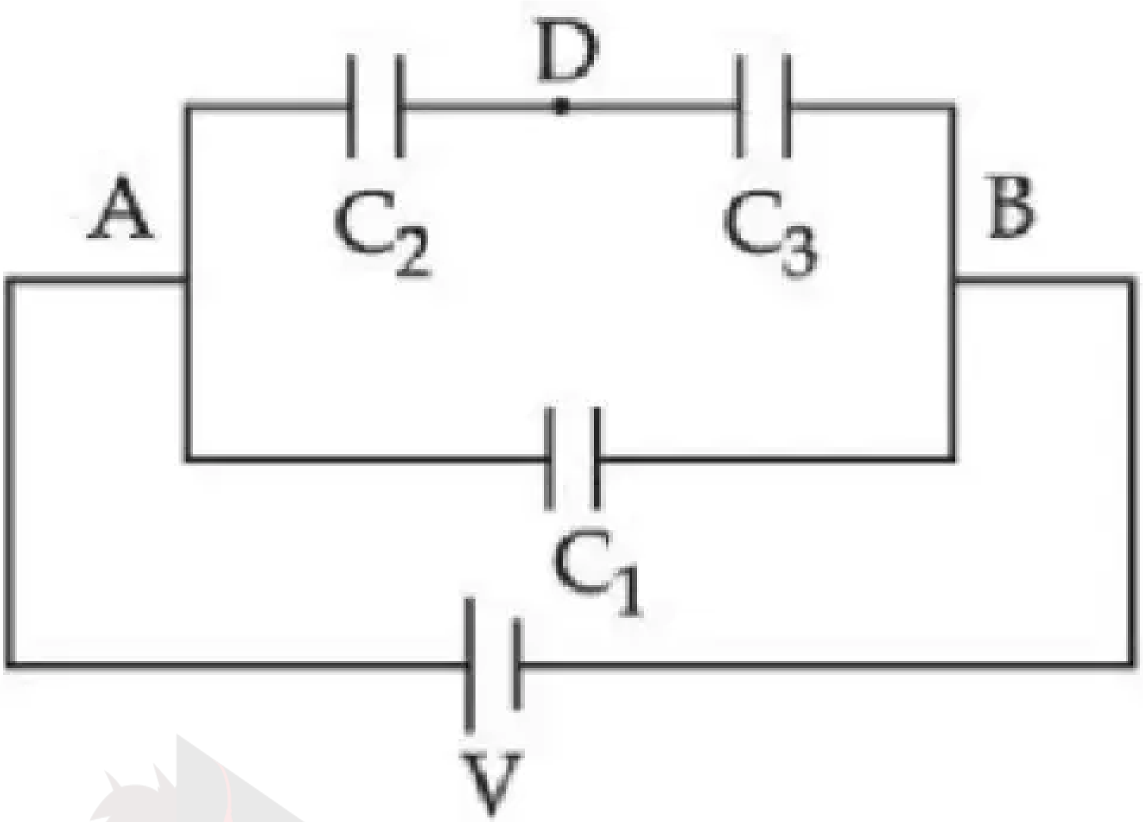
22. Three capacitors C_1 = 2 μF, C_2 = 6 μF and C_3 = 12 μF are connected as shown in figure. Find the ratio of the charges on capacitors C_1, C_2 and C_3 respectively: (+4, -1)



a. 3 : 4 : 4

b. 2 : 3 : 3

c. 2 : 1 : 1

d. 1 : 2 : 2

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23. A uniformly charged disc of radius R having surface charge density σ is placed in the xy plane with its center at the origin. Find the electric field intensity along the z-axis at a distance Z from origin : (+4, -1)

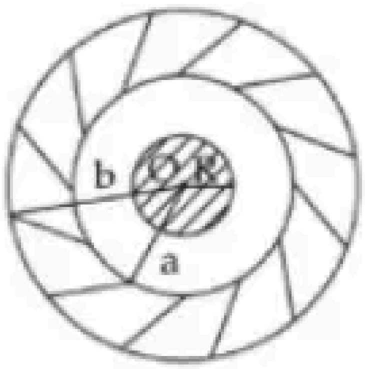
a. $E = \frac{\sigma}{2\epsilon_0}\left(1 + \frac{Z}{(Z^2+R^2)^{1/2}}\right)$

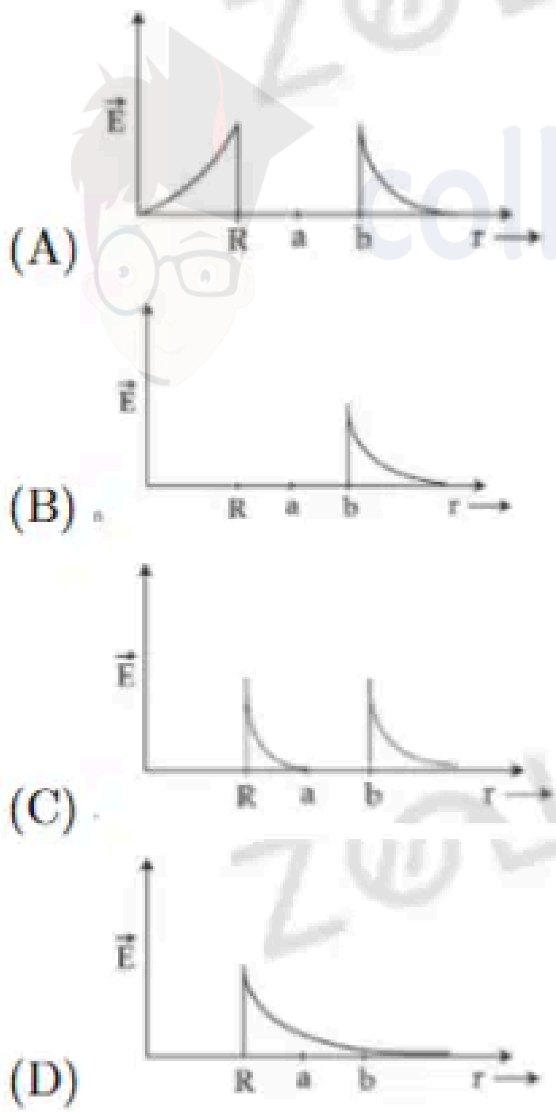
b. $E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{Z}{(Z^2+R^2)^{1/2}}\right)$

c. $E = \frac{2\epsilon_0}{\sigma}\left(\frac{1}{(Z^2+R^2)^{1/2}} + Z\right)$

d. $E = \frac{\sigma}{2\epsilon_0}\left(\frac{1}{(Z^2+R^2)} + \frac{1}{Z^2}\right)$

24. A solid metal sphere of radius R having charge q is enclosed inside the concentric spherical shell of inner radius a and outer radius b as shown in figure. The approximate variation electric field $\vec{E}$ as a function of distance r from centre O is given by : (+4, -1)





a. A

b. B

c. C

d. D

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25. A small bob of mass 100 mg and charge +10 μC is connected to an insulating string of length 1 m. It is brought near to an infinitely long non-conducting sheet of charge density σ as shown in figure. If the string subtends an angle of 45° with the sheet at equilibrium, the charge density of sheet will be : **(+4, -1)**

a. 0.885 nC/cm^2

b. 17.7 nC/cm^2

c. 885 nC/cm^2

d. 1.77 nC/cm^2

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26. The battery of a mobile phone is rated as 4.2 V, 5800 mAh. How much energy is stored in it when fully charged? **(+4, -1)**

a. 43.8 kJ

b. 48.7 kJ

c. 87.7 kJ

d. 24.4 kJ

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27. A point charge $+q$ is placed at the origin. A second point charge $+9q$ is placed at $(d, 0, 0)$ in Cartesian coordinate system. The point in between them where the electric field vanishes is: **(+4, -1)**

a. $\left(\frac{4d}{3}, 0, 0\right)$

b. $\left(\frac{d}{4}, 0, 0\right)$

c. $\left(\frac{3d}{4}, 0, 0\right)$

d. $\left(\frac{d}{3}, 0, 0\right)$

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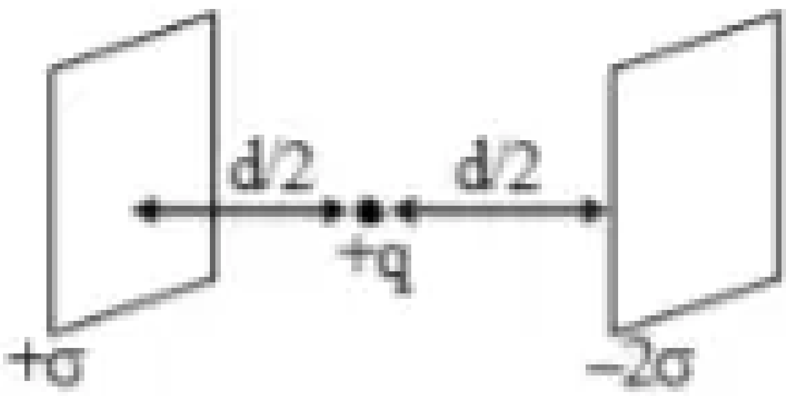
28. Consider two infinitely large plane parallel conducting plates as shown below. The plates are uniformly charged with a surface charge density $+\sigma$ and $-\sigma$. The force experienced by a point charge $+q$ placed at the mid point between the plates will be: **(+4, -1)**



a. $\frac{3q\sigma}{4\epsilon_0}$

b. $\frac{3q\sigma}{2\epsilon_0}$

c. $\frac{3q\sigma}{4\epsilon_0}$

d. $\frac{q\sigma}{2\epsilon_0}$

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29. The electric field in a region is given by $\vec{E} = (2\hat{i} + 4\hat{j} + 6\hat{k}) \times 10^3\, N/C$. The flux of the field through a rectangular surface parallel to x-z plane is $6.0\, Nm^2C^{-1}$. The area of the surface is ____ cm^2. (+4, -1)

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30. A parallel plate capacitor has charge $5 \times 10^{-6}\, C$. A dielectric slab is inserted between the plates and almost fills the space between the plates. If the induced charge on one face of the slab is $4 \times 10^{-6}\, C$ then the dielectric constant of the slab is ____. (+4, -1)

Answers

1. Answer: a

Explanation:

Step 1: Restoring force $F = 2F_e \cos\theta \approx 2(\frac{1}{4\pi\epsilon_0}\frac{q^2}{d^2})(\frac{x}{d})$.
Step 2: $F = \frac{q^2}{2\pi\epsilon_0 d^3}x$.
Step 3: In SHM, $F = m\omega^2 x$.
Step 4: $\omega^2 = \frac{q^2}{2\pi\epsilon_0 m d^3} \Rightarrow \omega = \sqrt{\frac{q^2}{2\pi\epsilon_0 m d^3}}$.

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2. Answer: 161 - 161

Explanation:

Step 1: This is a series combination of two capacitors: one with air $(d = 5)$ and one with dielectric $(d = 5)$.
Step 2: $C_{air} = \frac{\epsilon_0 A}{d/2} = \frac{8.85\times10^{-12}\times100}{5} = 177\ \mathrm{pF}$.
Step 3: $C_{dielectric} = \frac{K\epsilon_0 A}{d/2} = 10 \times 177 = 1770\ \mathrm{pF}$.
Step 4: $C_{eq} = \frac{C_1C_2}{C_1+C_2} = \frac{177\times1770}{177+1770} = \frac{177\times1770}{1947} \approx 160.9 \approx 161\ \mathrm{pF}$.

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3. Answer: b

Explanation:

Step 1: For the drop to be stationary, Electric force = Weight. $qE = mg \implies (ne)E = (\text{Volume} \times \text{Density})g$.
Step 2: $n \times (1.6 \times 10^{-19}) \times (3.55 \times 10^5) = \frac{4}{3}\pi(2 \times 10^{-3})^3 \times (3000) \times 9.81$. Note: $3\ \mathrm{g\ cm^{-3}} = 3000\ \mathrm{kg\ m^{-3}}$.
Step 3: $n \times 5.68 \times 10^{-14} \approx 9.85 \times 10^{-4}$. $n = \frac{9.85\times10^{-4}}{5.68\times10^{-14}} \approx 1.73 \times 10^{10}$.

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4. Answer: 6000 - 6000

Explanation:

Step 1: Understanding the Concept:

When a charge is placed at the midpoint between two identical charges, the net force is zero.

Displacing the middle charge along the line joining the fixed charges creates a restoring force.

For a small displacement x, this force is proportional to x, which is the condition for Simple Harmonic Motion (SHM).

Step 2: Key Formula or Approach:

The restoring force constant for a longitudinal displacement x is:

$$k_{SHM} = \frac{4kq^2}{d^3}$$

Where d is the distance from the midpoint to one of the fixed charges $(d = 1\text{ m})$.

The angular frequency is:

$$\omega = \sqrt{\frac{k_{SHM}}{m}}$$

Step 3: Detailed Explanation:

Given:

Total distance between fixed charges = $2\text{ m} \implies d = 1\text{ m}$.

Mass $m = 1\text{ mg} = 10^{-6}\text{ kg}$.

Charge parameter $q^2 = 10\text{ C}^2$.

Electrostatic constant $k = 9 \times 10^9\text{ Nm}^2/\text{C}^2$.

Calculate the restoring force constant k_{SHM}:

$$k_{SHM} = \frac{4 \times 9 \times 10^9 \times 10}{1^3} = 3.6 \times 10^{11}\text{ N/m}$$

Calculate the angular frequency ω:

$$\omega = \sqrt{\frac{3.6 \times 10^{11}}{10^{-6}}} = \sqrt{36 \times 10^{16}} = 6 \times 10^8\text{ rad/s}$$

Expressing in the form .... $\times 10^5$:

$$\omega = 6000 \times 10^5 \text{ rad/s}$$

Step 4: Final Answer:
The angular frequency is 6000 $\times 10^5$ rad/s.

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5. Answer: c

Explanation:

Let the charges be placed at the three corners of a square of side l, with point O at the fourth corner. The distance of each charge from point O is:

$$r = \sqrt{l^2 + l^2} = l\sqrt{2}$$

Hence,

$$r^2 = 2l^2$$

Electric field due to one charge q at O:

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{2l^2}$$

Two charges are placed symmetrically such that their horizontal components cancel and their vertical components add. Resultant field due to these two charges:

$$E_1 = 2E\cos 45^\circ = 2\left(\frac{1}{4\pi\epsilon_0}\frac{q}{2l^2}\right)\frac{1}{\sqrt{2}} = \frac{1}{4\pi\epsilon_0}\frac{\sqrt{2}q}{2l^2}$$

The third charge produces a field directly opposite to E_1 with magnitude:

$$E_2 = \frac{1}{4\pi\epsilon_0}\frac{q}{2l^2}$$

Therefore, net electric field at point O:

$$E = E_1 - E_2 = \frac{1}{4\pi\epsilon_0}\frac{q}{2l^2}(\sqrt{2} - 1)$$

Since two such perpendicular contributions exist, total magnitude becomes:

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{2l^2}(2\sqrt{2} - 1)$$

6. **Answer: a**

Explanation:

The system consists of two capacitors in series. One with a dielectric medium of thickness t (C_1) and another with air of thickness $(d-t)$ (C_2).
The total potential difference across the plates is $V = V_2 - (-V_1) = V_1 + V_2$.
Since the capacitors are in series, the potential difference across the air capacitor (V_{air}) where the pendulum is located is given by the potential divider rule.
$V_{air} = V \times \frac{C_1}{C_1+C_2} = (V_1+V_2)\frac{C_1}{C_1+C_2}$.
The electric field in the air gap is $E = \frac{V_{air}}{\text{thickness}} = \frac{V_{air}}{d-t}$.
Substituting the expression for V_{air}:
$E = \frac{(V_1+V_2)C_1}{(C_1+C_2)(d-t)}$.
The electric force (F_e) on the charge $+q$ is $F_e = qE$.
$F_e = \frac{qC_1(V_1+V_2)}{(C_1+C_2)(d-t)}$.
In equilibrium, let θ be the angle of deflection. The forces on the pendulum bob are tension (T), gravitational force (mg), and electric force (F_e).
Balancing forces in the horizontal and vertical directions:
$T\sin\theta = F_e$
$T\cos\theta = mg$
Dividing the two equations gives $\tan\theta = \frac{F_e}{mg}$.
$\tan\theta = \frac{1}{mg}\left[\frac{qC_1(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$.
Therefore, the deflection angle is $\theta = \tan^{-1}\left[\frac{q}{mg} \times \frac{C_1(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$.

7. **Answer: 12 - 12**

Explanation:

Step 1: Use the principle of superposition. The total force F is the sum of forces from each charge q.

$$F = \frac{kQq}{r_1^2} + \frac{kQq}{r_2^2} + \ldots\ldots = kQq\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{4^2} + \frac{1}{8^2}\ldots\ldots\right]$$

Step 2: Identify the infinite geometric progression (GP). The series is $1 + \frac{1}{4} + \frac{1}{16} + \frac{1}{64}\ldots\ldots$
First term (a) = 1, Common ratio (r) = $1/4$. Sum $S_\infty = \frac{a}{1-r} = \frac{1}{1-1/4} = \frac{4}{3}$.

Step 3: Calculate the final value.

$$F = (9 \times 10^9) \times (1) \times (1 \times 10^{-6}) \times \frac{4}{3}$$

$$F = 3 \times 10^3 \times 4 = 12 \times 10^3 \text{ N}$$

Comparing with $x \times 10^3$, we get $x = 12$.

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8. Answer: d

Explanation:

Step 1: If all vertices had $+Q$, the field at the center would be zero by symmetry.
Step 2: Having $-Q$ at the origin is equivalent to having $+Q$ there and adding a compensating charge of $-2Q$.
Step 3: Thus, the net field is that of a single $-2Q$ charge placed at the origin.
Step 4: Center $P = (a/2, a/2, a/2)$. Distance $r = \sqrt{(a/2)^2 \times 3} = \frac{\sqrt{3}a}{2}$.
Step 5: $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{(-2Q)}{r^2}(-\hat{r})$. Direction is from P to origin: $-(\frac{a}{2}\hat{i} + \frac{a}{2}\hat{j} + \frac{a}{2}\hat{k})/r$.
Step 6: Resulting field points from origin to center: $\frac{2Q}{4\pi\epsilon_0(\frac{3a^2}{4})}\frac{(\hat{i}+\hat{j}+\hat{k})}{\sqrt{3}} = \frac{2Q}{3\sqrt{3}\pi\epsilon_0 a^2}(\hat{i} + \hat{j} + \hat{k})$.

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9. Answer: d

Explanation:

Step 1: Let the capacity of each capacitor be C.
Step 2: In series: $C_s = \frac{C \cdot C}{C+C} = \frac{C}{2}$.
Step 3: In parallel: $C_p = C + C = 2C$.
Step 4: Ratio $C_s : C_p = \frac{C/2}{2C} = \frac{1}{4}$.

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10. Answer: 1 - 1

Explanation:

Step 1: Flux $\Phi = \vec{E} \cdot \vec{A}$.
Step 2: Surface 1 (parallel to y-z plane): Area vector $\vec{A}_1 = 0.2\,\hat{i}$. $\Phi_1 = (\frac{3}{5}E_0\hat{i} + \frac{4}{5}E_0\hat{j}) \cdot (0.2\hat{i}) = \frac{3}{5}E_0(0.2) = 0.12E_0$.

Step 3: Surface 2 (parallel to x-z plane): Area vector $\vec{A}_2 = 0.3\,\hat{j}$. $\Phi_2 = (\frac{3}{5}E_0\hat{i} + \frac{4}{5}E_0\hat{j}) \cdot (0.3\hat{j}) = \frac{4}{5}E_0(0.3) = 0.24E_0$.
Step 4: Ratio $\frac{\Phi_1}{\Phi_2} = \frac{0.12}{0.24} = \frac{1}{2}$.
Step 5: Ratio is $1 : 2$, so $a = 1$.

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11. Answer: 128 - 128

Explanation:

Step 1: Volume conservation: $\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3 \Rightarrow R = n^{1/3}r$.
Step 2: Charge conservation: $Q = nq$.
Step 3: Potential of small drop $v = \frac{kq}{r} = 2$ V.
Step 4: Potential of big drop $V = \frac{kQ}{R} = \frac{k(nq)}{n^{1/3}r} = n^{2/3}\frac{kq}{r} = n^{2/3}v$.
Step 5: $V = (512)^{2/3} \times 2 = (8^3)^{2/3} \times 2 = 8^2 \times 2 = 64 \times 2 = 128$ V.

---

12. Answer: b

Explanation:

Consider one of the tennis balls in equilibrium. The forces acting on it are:
1. Tension (T) along the thread.
2. Gravitational force (mg) acting vertically downwards.
3. Electrostatic repulsive force (F_e) acting horizontally.
For equilibrium, the net force is zero. Resolving the tension T into components:
$T\cos\theta = mg$ (vertical equilibrium)
$T\sin\theta = F_e$ (horizontal equilibrium)
Dividing the second equation by the first:
$\frac{T\sin\theta}{T\cos\theta} = \frac{F_e}{mg} \implies \tan\theta = \frac{F_e}{mg}$
The electrostatic force between the two charges separated by distance x is:
$F_e = \frac{1}{4\pi\epsilon_0}\frac{q^2}{x^2}$
From the geometry of the setup, if x is the separation, the distance from the center to one ball is $x/2$.
$\sin\theta = \frac{x/2}{l} = \frac{x}{2l}$
For a small angle θ, we can use the approximation $\tan\theta \approx \sin\theta$.
Therefore, $\tan\theta \approx \frac{x}{2l}$.
Now, equate the two expressions for $\tan\theta$:

$\frac{x}{2l} = \frac{F_e}{mg} = \frac{q^2}{4\pi\epsilon_0 x^2 mg}$

Rearrange the equation to solve for x:

$x^3 = \frac{2l \cdot q^2}{4\pi\epsilon_0 mg} = \frac{q^2 l}{2\pi\epsilon_0 mg}$

Taking the cube root of both sides:

$x = \left(\frac{q^2 l}{2\pi\epsilon_0 mg}\right)^{1/3}$

---

13. Answer: b

Explanation:

The arrangement shows three dielectric slabs placed between the plates of a capacitor. Since the slabs are placed one after another, this configuration is equivalent to three capacitors connected in series.

Let the three capacitors be C_1, C_2, and C_3.

For C_1: Dielectric constant = K, thickness = d, area = A.

$C_1 = \frac{K\epsilon_0 A}{d}$

For C_2: Dielectric constant = 3K, thickness = 2d, area = A.

$C_2 = \frac{3K\epsilon_0 A}{2d}$

For C_3: Dielectric constant = 5K, thickness = 3d, area = A.

$C_3 = \frac{5K\epsilon_0 A}{3d}$

For capacitors in series, the reciprocal of the equivalent capacitance (C_{eq}) is the sum of the reciprocals of individual capacitances.

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

$\frac{1}{C_{eq}} = \frac{d}{K\epsilon_0 A} + \frac{2d}{3K\epsilon_0 A} + \frac{3d}{5K\epsilon_0 A}$

Factor out the common term $\frac{d}{K\epsilon_0 A}$:

$\frac{1}{C_{eq}} = \frac{d}{K\epsilon_0 A}\left(1 + \frac{2}{3} + \frac{3}{5}\right)$

Find a common denominator for the terms in the parenthesis (which is 15):

$\frac{1}{C_{eq}} = \frac{d}{K\epsilon_0 A}\left(\frac{15}{15} + \frac{10}{15} + \frac{9}{15}\right)$

$\frac{1}{C_{eq}} = \frac{d}{K\epsilon_0 A}\left(\frac{15+10+9}{15}\right) = \frac{d}{K\epsilon_0 A}\left(\frac{34}{15}\right)$

Now, invert the expression to find C_{eq}:

$C_{eq} = \frac{15}{34}\frac{K\epsilon_0 A}{d}$

---

14. Answer: d

Explanation:

Initially, the two capacitors (2C and C) are in parallel and charged to a potential V.
The initial equivalent capacitance is $C_{initial} = 2C + C = 3C$.
The total charge stored in the system is $Q = C_{initial} \times V = (3C)V = 3CV$.
When the battery is removed, this total charge Q is conserved.
Next, the capacitor with capacitance C is filled with a dielectric of constant K. Its new capacitance becomes $C' = KC$.
The two capacitors (2C and C') are still connected in parallel.
The final equivalent capacitance is $C_{final} = 2C + C' = 2C + KC = C(2 + K)$.
The new potential difference (V') across the parallel combination is given by the total charge divided by the final equivalent capacitance.
$V' = \frac{Q}{C_{final}}$
$V' = \frac{3CV}{C(2+K)}$
$V' = \frac{3V}{K+2}$

---

15. **Answer: 36 - 36**

Explanation:

When the two identical conducting spheres are brought into contact, the total charge will be redistributed equally between them.
Total charge $Q_{total} = q_1 + q_2 = (2.1\ \text{nC}) + (-0.1\ \text{nC}) = 2.0$ nC.
Since the spheres are identical, the final charge on each sphere, q', will be half of the total charge:
$q' = \frac{Q_{total}}{2} = \frac{2.0\ \text{nC}}{2} = 1.0$ nC.
So, the charge on each sphere after separation is $q' = 1.0 \times 10^{-9}$ C.
The spheres are then separated by a distance $r = 0.5$ m.
The electrostatic force (F) between them is given by Coulomb's law:
$F = k\frac{q' \cdot q'}{r^2}$, where $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ N·m²/C².
$F = (9 \times 10^9)\frac{(1.0\times10^{-9})^2}{(0.5)^2}$.
$F = (9 \times 10^9)\frac{1.0\times10^{-18}}{0.25}$.
$F = \frac{9\times10^{-9}}{0.25} = 36 \times 10^{-9}$ N.
The question asks for the value of the force in units of 10^{-9} N.
The value is 36.

---

16. **Answer: 20 - 20**

Explanation:

Let's analyze the forces acting on one sphere in equilibrium. The forces are: Tension (T), Weight (mg), and Electrostatic Force (F_e).
Let θ be the angle the thread makes with the vertical. The distance between the spheres is $d = 0.2$ m, and the length of the thread is $L = 0.5$ m.
From the geometry, $\sin\theta = \frac{d/2}{L} = \frac{0.1}{0.5} = \frac{1}{5} = 0.2$.
Since θ is small, we can use the approximation $\tan\theta \approx \sin\theta = 0.2$.
In equilibrium, the horizontal components of forces balance: $T\sin\theta = F_e$.
The vertical components of forces balance: $T\cos\theta = mg$.
Dividing the two equations gives $\tan\theta = \frac{F_e}{mg}$.
The electrostatic force is $F_e = k\frac{q^2}{d^2}$, where $k = 9 \times 10^9$ N·m²/C².
The weight is $mg = (10 \times 10^{-6}\,\text{kg}) \times (10\,\text{m/s}^2) = 10^{-4}$ N.
Using the small angle approximation: $F_e = mg\tan\theta \approx mg\sin\theta$.
$F_e \approx 10^{-4} \times 0.2 = 2 \times 10^{-5}$ N.
Now we can find the charge q:
$q^2 = \frac{F_e d^2}{k} = \frac{(2\times10^{-5})\times(0.2)^2}{9\times10^9} = \frac{2\times10^{-5}\times0.04}{9\times10^9} = \frac{8\times10^{-7}}{9\times10^9} = \frac{8}{9} \times 10^{-16}$.
$q = \sqrt{\frac{8}{9}} \times 10^{-8} = \frac{2\sqrt{2}}{3} \times 10^{-8}$ C.
$q \approx \frac{2\times1.414}{3} \times 10^{-8} \approx 0.9428 \times 10^{-8}$ C.
We are given that $q = \frac{a}{21} \times 10^{-8}$ C.
$\frac{a}{21} = 0.9428 \implies a = 21 \times 0.9428 \approx 19.8$.
Rounding off to the nearest integer, the value of a is 20.

---

17. **Answer: c**

Explanation:

To find the flux through the cube, we imagine the charge 'q' at the corner to be at the center of a larger cube of side 2L, which is composed of 8 such smaller cubes.
By Gauss's law, the total flux through this large imaginary cube is $\Phi_{total} = \frac{q}{\epsilon_0}$.
Due to symmetry, this total flux is shared equally among the 8 smaller cubes.
The flux through a single cube due to the charge at its corner is $\Phi_{cube} = \frac{\Phi_{total}}{8} = \frac{q}{8\epsilon_0}$.
Now, consider the three faces of the cube that meet at the corner where the charge 'q' is placed. The electric field lines are parallel to the surface of these three faces. Therefore, the electric flux through these three faces is zero.
The entire flux of $\frac{q}{8\epsilon_0}$ must pass through the other three faces (the shaded faces) which do not touch the charge.

Due to the symmetry of the situation with respect to these three faces, the flux is distributed equally among them.
The shaded area in the figure appears to be a single face opposite to the corner.
Assuming the question asks for the flux through one of these faces:
$\Phi_{shaded\_face} = \frac{1}{3}\Phi_{cube} = \frac{1}{3}\left(\frac{q}{8\epsilon_0}\right) = \frac{q}{24\epsilon_0}$.

---

18. **Answer: 4 - 4**

Explanation:

Step 1: Understanding the Concept:
When a dielectric is inserted into a capacitor while the battery is still connected, the potential difference (V) remains constant, but the capacitance increases. This leads to an increase in the stored energy.
Step 2: Key Formula or Approach:
1. Initial Energy: $U_i = \frac{1}{2}CV^2$.
2. Final Energy: $U_f = \frac{1}{2}C'V^2 = \frac{1}{2}(KC)V^2$.
3. Change in Energy: $\Delta U = U_f - U_i = \frac{1}{2}(K-1)CV^2$.
Step 3: Detailed Explanation:
Given: $C = 200\mu F = 2 \times 10^{-4}$ F, $V = 200$ V, $K = 2$.

$$\Delta U = \frac{1}{2}(2-1) \times (2 \times 10^{-4}) \times (200)^2$$

$$\Delta U = \frac{1}{2} \times 1 \times 2 \times 10^{-4} \times 40000$$

$$\Delta U = 1 \times 10^{-4} \times 4 \times 10^{4} = 4 \text{ J}$$

Step 4: Final Answer:
The change in energy is 4 J.

---

19. **Answer: d**

Explanation:

Step 1: Understanding the Concept:
Electric flux (Φ) through a surface is given by the surface integral of the electric field over that surface: $\Phi = \oint \vec{E} \cdot d\vec{A}$. According to Gauss's Law, the net flux through a closed surface depends only on the net charge enclosed.
Step 2: Detailed Explanation:
(a) By convention, field lines entering a surface represent negative flux, and those leaving represent positive flux. This is **correct**.
(b) Due to symmetry, if a charge is at the center of a cube, the flux through each of the 6 faces is exactly $q/6\epsilon_0$. This is **correct**.
(c) According to Gauss's Law, if $q_{enclosed} = 0$, the net flux $\Phi = 0$, regardless of whether the external field is uniform or not. This is **correct**.
(d) If the electric field $\vec{E}$ is parallel to the surface, it is perpendicular to the area vector $d\vec{A}$ (which is always normal to the surface). Thus, $\vec{E} \cdot d\vec{A} = EdA\cos 90^\circ = 0$. The flux is zero, not a finite non-zero value. This is **incorrect**.
Step 3: Final Answer:
Only statement (d) is incorrect.

---

20. **Answer: b**

Explanation:

Step 1: Understanding the Concept:
For a third charge to experience zero net force (equilibrium) when placed near two unlike charges, it must be placed outside the segment joining them, on the side of the smaller magnitude charge.
Step 2: Key Formula or Approach:
Let the third charge q be placed at distance x from the charge $q_2 = -5\,\mu C$.
The distance from $q_1 = 20\,\mu C$ will be $(5 + x)\,\text{cm}$.
Equate the magnitudes of forces: $\frac{k|q_1||q|}{(5+x)^2} = \frac{k|q_2||q|}{x^2}$.
Step 3: Detailed Explanation:

$$\frac{20}{(5+x)^2} = \frac{5}{x^2}$$

Divide both sides by 5:

$$\frac{4}{(5+x)^2} = \frac{1}{x^2}$$

Take the square root of both sides:

$$\frac{2}{5+x} = \frac{1}{x}$$

$$2x = 5 + x$$

$$x = 5\,\text{cm}$$

The position is $5\,\text{cm}$ away from the $-5\,\mu C$ charge, on the side away from the $20\,\mu C$ charge (right side).

Step 4: Final Answer:

The third charge should be placed at $5\,\text{cm}$ from $-5\,\mu C$ on the right side.

---

21. Answer: a

Explanation:

Step 1: Understanding the Question:

We need to calculate the electric field vector at the center of a circular arc that has a uniform charge distribution. The total charge is $-Q$ and the arc subtends an angle of 120°.

Step 2: Key Formula or Approach:

The electric field at the center of a uniformly charged circular arc of radius R, subtending a total angle 2α at the center, is given by:

$$E = \frac{2k\lambda}{R}\sin(\alpha)$$

where $k = \frac{1}{4\pi\varepsilon_0}$ and λ is the linear charge density. The direction of the field is along the angle bisector.

Step 3: Detailed Explanation:

1. Setup and Symmetry:

The arc is symmetric about the x-axis, extending from $\theta = -60^\circ$ to $\theta = +60^\circ$. The total angle subtended is $2\alpha = 120^\circ$, so $\alpha = 60^\circ$.

Due to this symmetry, the y-components of the electric field from infinitesimal

charge elements will cancel out. The net electric field will be along the x-axis.
The total charge on the rod is $-Q$. The electric field due to a negative charge points towards the charge. Since the arc is in the positive x-region, the net field at the origin O will point towards the arc, i.e., in the positive x-direction $(\hat{i})$.

2. Linear Charge Density (λ):

The charge is distributed over the length of the arc.
Arc length $L = R \times (\text{angle in radians})$.
Total angle = $120^\circ = 120 \times \frac{\pi}{180} = \frac{2\pi}{3}$ radians.
$L = R\frac{2\pi}{3}$.
Linear charge density $\lambda = \frac{\text{Total Charge}}{\text{Length}} = \frac{-Q}{2\pi R/3} = -\frac{3Q}{2\pi R}$.
For calculating the magnitude of the field, we use the magnitude of the charge density, $|\lambda| = \frac{3Q}{2\pi R}$.

3. Calculate Electric Field Magnitude:

Using the formula for the field of an arc:

$$E = \frac{2k|\lambda|}{R}\sin(\alpha)$$

Substitute $k = \frac{1}{4\pi\varepsilon_0}$, $|\lambda| = \frac{3Q}{2\pi R}$, and $\alpha = 60^\circ$.

$$E = \frac{2\left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{3Q}{2\pi R}\right)}{R}\sin(60^\circ)$$

$$E = \frac{2 \cdot 3Q}{4\pi\varepsilon_0 \cdot 2\pi R^2}\sin(60^\circ)$$

$$E = \frac{6Q}{8\pi^2\varepsilon_0 R^2}\left(\frac{\sqrt{3}}{2}\right)$$

$$E = \frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}$$

4. Determine the Direction:

As established from symmetry and the negative sign of the charge, the field vector at the origin points towards the arc, along the positive x-axis.
So, $\vec{E} = E\hat{i}$.

$$\vec{E} = \frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(\hat{i})$$

Step 4: Final Answer:

The electric field at the centre of curvature O is $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(\hat{i})$.

22. Answer: d

Explanation:

Step 1: Understanding the Question:
We are given a circuit with three capacitors and need to find the ratio of the charges stored on each capacitor. To do this, we must first analyze the circuit to see how the capacitors are connected (in series or parallel).
Step 2: Key Formula or Approach:
1. **Capacitors in Series:** When capacitors are in series, the charge on each capacitor is the same. The equivalent capacitance C_{eq} is given by $\frac{1}{C_{\text{eq}}} = \frac{1}{C_a} + \frac{1}{C_b} + \dots$
2. **Capacitors in Parallel:** When capacitors are in parallel, the voltage across each capacitor is the same. The equivalent capacitance is the sum $C_{\text{eq}} = C_a + C_b + \dots$
3. **Charge on a Capacitor:** The charge Q on a capacitor is given by $Q = CV$, where V is the voltage across it.
Step 3: Detailed Explanation:
Circuit Analysis:
From the given figure, we can see that:
- Capacitors C_2 and C_3 are connected in series.
- This series combination of C_2 and C_3 is connected in parallel with capacitor C_1.
Calculate Equivalent Capacitance of the Series Combination:
Let's find the equivalent capacitance, C_{23}, for C_2 and C_3.

$$\frac{1}{C_{23}} = \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{6\,\mu\text{F}} + \frac{1}{12\,\mu\text{F}}$$

$$\frac{1}{C_{23}} = \frac{2+1}{12} = \frac{3}{12} = \frac{1}{4}$$

$$C_{23} = 4\,\mu\text{F}$$

Calculate Charges:
Let V be the total voltage applied across the entire circuit (between points A and B).
- The capacitor C_1 is in parallel with the combination C_{23}. Therefore, the voltage across C_1 is V, and the voltage across the combination C_{23} is also V.
Charge on C_1 is Q_1:

$$Q_1 = C_1 V = (2\,\mu\text{F}) \times V = 2V\,\mu\text{C}$$

- For the series combination C_2 and C_3, the total charge stored on the combination is Q_{23}.

$$Q_{23} = C_{23}V = (4\,\mu\text{F}) \times V = 4V\,\mu\text{C}$$

Since C_2 and C_3 are in series, the charge on each of them is the same and equal to the charge on their equivalent capacitor.
Therefore, $Q_2 = Q_3 = Q_{23}$.

$$Q_2 = 4V\,\mu\text{C}$$

$$Q_3 = 4V\,\mu\text{C}$$

Find the Ratio:
We need to find the ratio $Q_1 : Q_2 : Q_3$.

$$Q_1 : Q_2 : Q_3 = 2V : 4V : 4V$$

We can cancel V from all terms:

$$2 : 4 : 4$$

Dividing all terms by the greatest common divisor, which is 2:

$$1 : 2 : 2$$

Step 4: Final Answer:
The ratio of the charges on capacitors C_1, C_2, and C_3 is 1 : 2 : 2.

---

23. Answer: b

Explanation:

Step 1: Understanding the Question:
We need to find the formula for the electric field at a point on the axis of a uniformly charged circular disc. This is a standard result in electrostatics, derived using integration.
Step 2: Key Formula or Approach:
The electric field of a charged disc is found by integrating the contributions from infinitesimal charged rings that make up the disc. The electric field dE due to a ring of radius r and charge dq at a point Z on its axis is $dE = \frac{1}{4\pi\epsilon_0}\frac{Z\,dq}{(r^2+Z^2)^{3/2}}$. We express dq in terms of the surface charge density σ $\left(dq = \sigma dA = \sigma(2\pi r dr)\right)$ and integrate from $r = 0$ to $r = R$.

$$E = \int_0^R \frac{1}{4\pi\epsilon_0}\frac{Z(\sigma 2\pi r dr)}{(r^2+Z^2)^{3/2}} = \frac{\sigma Z}{2\epsilon_0}\int_0^R \frac{r dr}{(r^2+Z^2)^{3/2}}$$

Step 3: Detailed Explanation (Derivation):
Let's perform the integration. Let $u = r^2 + Z^2$, so $du = 2rdr$, or $rdr = du/2$.
The limits of integration change from $r = 0 \to u = Z^2$ and $r = R \to u = R^2 + Z^2$.

$$E = \frac{\sigma Z}{2\epsilon_0}\int_{Z^2}^{R^2+Z^2} \frac{du/2}{u^{3/2}} = \frac{\sigma Z}{4\epsilon_0}\int_{Z^2}^{R^2+Z^2} u^{-3/2} du$$

$$E = \frac{\sigma Z}{4\epsilon_0}\left[\frac{u^{-1/2}}{-1/2}\right]_{Z^2}^{R^2+Z^2} = \frac{\sigma Z}{4\epsilon_0}\left[-2u^{-1/2}\right]_{Z^2}^{R^2+Z^2}$$

$$E = -\frac{\sigma Z}{2\epsilon_0}\left[\frac{1}{\sqrt{u}}\right]_{Z^2}^{R^2+Z^2} = -\frac{\sigma Z}{2\epsilon_0}\left(\frac{1}{\sqrt{R^2+Z^2}} - \frac{1}{\sqrt{Z^2}}\right)$$

Assuming $Z > 0$, $\sqrt{Z^2} = Z$.

$$E = -\frac{\sigma Z}{2\epsilon_0}\left(\frac{1}{\sqrt{R^2+Z^2}} - \frac{1}{Z}\right) = \frac{\sigma}{2\epsilon_0}\left(-\frac{Z}{\sqrt{R^2+Z^2}} + 1\right)$$

$$E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{Z}{\sqrt{Z^2+R^2}}\right)$$

Step 4: Final Answer:
The derived formula is $E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{Z}{(Z^2+R^2)^{1/2}}\right)$. This is a standard result and matches option (B).

---

24. Answer: a

Explanation:

Step 1: Understanding the Concept:
For a metallic (conducting) sphere or shell in electrostatic equilibrium, the electric field inside the material of the conductor is always zero. Outside the conductor, the field follows the inverse square law ($E \propto 1/r^2$).
Step 2: Key Formula or Approach:
1. $E = 0$ for $r < R$ (inside solid metal sphere).
2. $E = \frac{kq}{r^2}$ for $R < r < a$ (air gap).
3. $E = 0$ for $a < r < b$ (inside the thickness of the shell).
4. $E = \frac{kq_{total}}{r^2}$ for $r > b$ (outside).

Step 3: Detailed Explanation:
The solid sphere is a conductor, so the field is zero from 0 to R.
In the region between the sphere and the shell $(R < r < a)$, the field decreases as $1/r^2$.
The shell is also metallic, so the field inside its thickness $(a < r < b)$ is zero.
Outside the entire assembly $(r > b)$, the field again decreases as $1/r^2$.
Looking at the graphs:
Graph (A) correctly shows zero field in $[0, R]$ and $[a, b]$, with $1/r^2$ decays in between.
Step 4: Final Answer:
The correct variation is represented by the graph in Option (A).

---

25. Answer: d

Explanation:

From the diagram in the solution, we have the force acting on the charge due to the electric field of the sheet:
The force is given by:

$$F_e = qE = mg$$

where q is the charge and E is the electric field due to the sheet. The electric field is related to the charge density σ as:

$$E = \frac{\sigma}{2\epsilon_0}$$

Thus, the equation becomes:

$$q\left(\frac{\sigma}{2\epsilon_0}\right) = mg$$

Rearranging to solve for σ:

$$\sigma = \frac{2gm}{q}$$

Substitute the known values:

$$\sigma = \frac{2 \times 8.85 \times 10^{-12} \times 100 \times 10^{-6} \times 10}{10 \times 10^{-6}}$$

$$\sigma = 17.7 \times 10^{-10}\ \mathrm{C/m^2}$$

$$\sigma = 1.77\ \text{nC/cm}^2$$

Thus, the charge density of the sheet is 1.77 nC/cm^2.

---

26. **Answer: c**

Explanation:

Given the voltage $V = 4.2$ volts and the battery capacity 5800 mAh, we can calculate the energy stored in the battery using the formula:

$$\text{Energy supplied by battery} = Vq$$

where q is the charge in coulombs. Converting 5800 mAh to coulombs:

$$q = 5800 \times 3600 \times 10^{-3}\,\text{C} = 5800 \times 3.6\,\text{C} = 20880\,\text{C}$$

Thus, the energy supplied by the battery is:

$$\text{Energy} = 4.2 \times 5800 \times 3600 \times 10^{-3} = 87.696\,\text{kJ}$$

Therefore, the energy stored in the battery when fully charged is approximately $87.7\,\text{kJ}$.

---

27. **Answer: b**

Explanation:

Let the electric field at point P in between the charges be zero. Let the position of P be at a distance x from the origin, where the electric field due to both charges cancels each other.
The electric field due to a point charge is given by:

$$E = \frac{kq}{r^2}$$

For the electric field to be zero at point P, the fields due to both charges must be equal and opposite. So:

$$\frac{kq}{x^2} = \frac{k(9q)}{(d-x)^2}$$

Simplifying:

$$\frac{1}{x^2} = \frac{9}{(d-x)^2}$$

Solving for x:

$$d - x = 3x \quad \Rightarrow \quad d = 4x \quad \Rightarrow \quad x = \frac{d}{4}$$

Thus, the coordinate of point P is $\left(\frac{d}{4}, 0, 0\right)$.

---

28. Answer: b

Explanation:

Let the charge distribution on the two plates be σ and $-\sigma$, with the point charge q placed at the midpoint between the plates.
The electric field due to each plate at the midpoint is as follows:
For Plate 1, the electric field is $\frac{\sigma}{2\epsilon_0}$ directed away from the plate, and for Plate 2, the electric field is $\frac{\sigma}{2\epsilon_0}$ directed towards the plate.
Thus, the net electric field experienced by the charge q is:

$$E_{\text{net}} = \frac{3\sigma}{2\epsilon_0}$$

Now, the force on the charge q is given by:

$$F = qE = q \times \frac{3\sigma}{2\epsilon_0} = \frac{3q\sigma}{2\epsilon_0}$$

---

29. Answer: 15 - 15

Explanation:

To find the area of the rectangular surface, we start with the formula for electric flux: $\Phi = \vec{E} \cdot \vec{A}$. Here, the electric field $\vec{E}$ is given by: $\vec{E} = (2\hat{i} + 4\hat{j} + 6\hat{k}) \times 10^3\, N/C$. The flux Φ is given as $6.0\, Nm^2C^{-1}$.

The surface is parallel to the x-z plane. For a surface parallel to the x-z plane, the area vector $\vec{A}$ is perpendicular to the plane in the y-direction and can be expressed as $\vec{A} = A\hat{j}$.

Since only the j-component of $\vec{E}$ contributes to the flux, we have: $\Phi = E_y \cdot A$, where $E_y = 4 \times 10^3 \, N/C$.

Substituting the values, $6.0 = 4 \times 10^3 \times A$.

Solving for A: $A = \frac{6.0}{4 \times 10^3} = 1.5 \times 10^{-3} \, m^2$.

Convert the area to cm^2: $A = 1.5 \times 10^{-3} \, m^2 \times (10^4 \, cm^2/m^2) = 15 \, cm^2$.

The area of the surface is 15 cm^2, which falls within the given range of 15,15, thus confirming the solution.

---

30. Answer: 5 - 5

Explanation:

To solve the problem of finding the dielectric constant k of a slab in a parallel plate capacitor, we start by understanding the relationship between the free charge, induced charge, and the dielectric constant. The free charge on the capacitor, Q, is given as $5 \times 10^{-6} \, \text{C}$. The induced charge on the dielectric, Q_i, is $4 \times 10^{-6} \, \text{C}$.

Step 1: Understanding the Relationship

When a dielectric is inserted, it polarizes and reduces the effective electric field between the plates of a capacitor. The induced charge Q_i is related to the induced polarization caused by the dielectric.

The relationship between the total charge Q, induced charge Q_i, and the dielectric constant k is given by the equation:

$Q = k \cdot (Q - Q_i)$

Step 2: Solving for the Dielectric Constant, k

Rearrange the equation to express k:

$k = \frac{Q}{Q - Q_i}$

Substitute the given values:

$$k = \frac{5\times10^{-6}}{5\times10^{-6}-4\times10^{-6}}$$

$$k = \frac{5\times10^{-6}}{1\times10^{-6}} = 5$$

Step 3: Validation

The calculated dielectric constant k is 5. Checking against the provided range (5,5), we confirm that the computed value fits perfectly within this range.

Thus, the dielectric constant of the slab is **5**.