Multiple choice questions. Circle the correct answer. No work need be shown and no partial credit will be given.

(5 pts) Problem 1. A very small ball containing a charge $-Q$ hangs from a light string between two vertical charged plates, as shown in the figure. When released from rest the ball will

(a) swing to the right
(b) swing to the left
(c) remain hanging vertical

(5 pts) Problem 2. A plastic rod is charged up by rubbing a wool cloth and brought to an initially neutral metallic sphere. It is allowed to touch the sphere for a few seconds and then is separated from the sphere by a small distance. After the rod is separated the rod

(a) is repelled by the sphere
(b) is attracted by the sphere
(c) feels no force due to the sphere

(5 pts) Problem 3. Two electrons are passing 21.0mm apart. What is the electric repulsive force that they exert on each other? (the value of Coulomb's constant is $k = 9.0 \times 10^9 Nm^2/C^2$)

(a) $5.2 \times 10^{-25} N$
(b) $2.0 \times 10^{10} N$
(c) $2.0 N$
(d) $5.2 \times 10^{-27} N$
(5 pts) **Problem 4.** An electron is initially moving to the right when it enters a uniform electric field directed upwards. Which trajectory shown in the figure will the electron follow?

(a) trajectory W  
(b) trajectory X  
(c) trajectory Y  
(d) trajectory Z

(5 pts) **Problem 5.** Two conductors are joined by a long copper wire. Thus (a) each conductor carries the same free charge  
(b) each conductor must be at the same potential  
(c) no free charge can be present on either conductor  
(d) the potential on the wire is the average of the potential of both conductors

**On the following problems show all your work. Partial credit will be given if earned.**

(30 pts) **Problem 6.** A small plastic ball with a mass of $6.50 \times 10^{-3} \text{kg}$ and with a charge of $+0.150 \mu \text{C}$ is suspended from an insulating threat and hangs between the plates of a capacitor (see the figure). The ball is in equilibrium with the threat making an angle of 30 degrees with respect to the vertical. The area of each plate is 0.015 m$^2$. What is the magnitude of the charge on each plate?

(25 pts) **Problem 7.** A 10.0 $\mu \text{F}$ parallel-plate capacitor is connected to a 12.0 V battery. After the capacitor is fully charged the battery is disconnected without loss of any charge on the plates.
a) A voltmeter is connected across the two plates without discharging them. What does it read? (10pts)

b) What would the voltmeter read if (i) the plate separation was doubled? (10pts) (ii) the radius of each plate was doubled but the separation between the plates was unchanged and equal to its original value? (5pts)

(15 pts) Problem 8. Three capacitors are connected in series as shown in the figure. The values of their capacitances are \(C\), \(2C\), \(3C\) and the applied voltage is \(V\). Initially all the three capacitors are completely discharged and after the battery is connected the charge on plate 1 is \(Q\).

a) What are the charges on plates 3 and 6? (5pts)

b) If the voltage across the first capacitor (the one with capacitance \(C\)) is \(V'\), then what are the voltages across the second and third capacitor? (5pts)

c) Find the voltage \(V_1\) across the first capacitor (5pts)
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Solution

Problem (1)
(b)

Problem (2)
(a)

Problem (3)
(a)

Problem (4)
(d)

Problem 5
(b)
Problem (2)

(b) Opposite charge attract. So it swings to rest.

Problem (2)

Negative charge is transferred to metallic sphere, and also rod. As it has negative charge so, they repel each other.

Problem (3)

(a) \[ F = \frac{kq_1q_2}{r^2} \]

Problem (4)

(c) The force on the negatively charged electron is opposite to the direction of the field.

Problem (5)

(b) It has to be some potential. Otherwise, charges can move from one site to another. If they are in some potential, it is not necessary they should have same sign.
\( F_E \) is the force exerted by the electric field, \( F_E = qE \).

\[ \Sigma F_y = 0 \text{ gives } T_y - mg = 0 \]

\[ T \cos \theta - mg = 0 \]

\[ \Sigma F_x = 0 \text{ gives } F_E - T \sin \theta = 0 \]

\[ F_E = \frac{mg}{\cos \theta} \sin \theta = mg \tan \theta \]

Also,

\[ F_E = |q| E \]

So,

\[ |q| E = mg \tan \theta \]

\[ E = \frac{mg \tan \theta}{|q|} \]

\[ = \frac{\left(6.6 \times 10^{-3} \text{ kg}\right) \left(9.8 \text{ m/s}^2\right) \tan 30^\circ}{0.15 \times 10^{-6} \text{ C}} \]

\[ = 245181.4 \text{ N/C} \]

Now,

\[ E = \frac{Q}{\varepsilon_0 A} \]

\[ 245181.4 \text{ N/C} = \frac{Q}{\left(8.85 \times 10^{-12}\right) \left(0.015\right)} \]

\[ Q = 3.25 \times 10^8 \text{ C} \]
Problem 7

(a) 12 V

(b) (i) When $d$ is doubled, $C$ is halved. $V_{ab} = \frac{Q}{C}$ and $Q$ is constant, so $V$ doubles. $V = 24.0 \text{ V}$

(ii) When $r$ is doubled, $A$ increases by a factor of 4. $V$ decreases by a factor of 4 and $V = 3.0 \text{ V}$

Problem 8

(a) $Q_3 = +Q$

$Q_6 = -Q$

When the plates of two adjacent capacitors are connected, the sum of the charges on the two plates must remain zero.

(b) The absolute value of charge on each plate is $Q$. It is same for all three capacitors and thus for all six plates.

So, $V = \frac{Q}{C}$

$V'_{i} = \frac{Q}{2C} = \frac{V'}{2}$

$V''_{i} = \frac{Q}{2C} = \frac{V'}{2}$
\[ V = V' + \frac{V'}{2} + \frac{V'}{3} \]
\[ V = \frac{11}{6} V' \]
\[ V' = \frac{6}{11} V \]

\[ \frac{1}{c_{tot}} = \frac{1}{c} + \frac{1}{2c} + \frac{1}{3c} \]
\[ \frac{1}{c_{tot}} = \frac{11}{6c} \]
\[ c_{tot} = \frac{6c}{11} \]

\[ Q_{tot} = c_{tot} V = \frac{6c}{11} V = Q \]
\[ V' = \frac{Q}{c} = \frac{6c^2 V}{11c} = \frac{6V}{11} \]