1. An electroscope is charged by induction using a glass rod (which has been made positive by rubbing it with silk). The electroscope leaves:

(a) lose electrons
(b) lose protons
(c) gain electrons
(d) gain protons
(e) gain an equal number of protons and electrons
(f) lose an equal number of protons and electrons
(g) none of the above

2. Two fixed particles, of charges $q_1 = +2.0 \mu C$ and $q_2 = -4 \mu C$, are 10 cm apart. How far from each should a third charge be placed so that no net electrostatic force acts on it?

(a) 5 cm from $q_1$ and 15 cm from $q_2$
(b) 15 cm from $q_1$ and 5 cm from $q_2$
(c) 24 cm from $q_1$ and 44 cm from $q_2$
(d) 5 cm from $q_1$ and 25 cm from $q_2$
(e) 25 cm from $q_1$ and 5 cm from $q_2$
(f) 10 cm from $q_1$ and 20 cm from $q_2$
(g) 44 cm from $q_1$ and 24 cm from $q_2$
(h) 24 cm from $q_1$ and 34 cm from $q_2$

3. Two protons ($p_1$ and $p_2$ each of charge $+e$) and an electron ($-e$) lie on a straight line, as shown. The directions of the force of $p_2$ on $p_1$, the force of $e$ on $p_1$, and the total force on $p_1$, respectively, are:

(a) $\rightarrow$, $\leftarrow$, $\rightarrow$
(b) $\leftarrow$, $\rightarrow$, $\rightarrow$
(c) $\rightarrow$, $\leftarrow$, $\leftarrow$
(d) $\leftarrow$, $\rightarrow$, $\leftarrow$
(e) $\leftarrow$, $\leftarrow$, $\leftarrow$
(f) $\rightarrow$, $\rightarrow$, $\rightarrow$
(g) $\rightarrow$, $\rightarrow$, $\leftarrow$
4. Charges $Q$, $-Q$, and $q$ are placed at the vertices of an equilateral triangle as shown. The total force exerted on the charge $q$ is:

(a) toward charge $Q$
(b) toward charge $-Q$
(c) away from charge $Q$
(d) at right angles to the line joining $Q$ and $-Q$ and upward
(e) parallel to the line joining $Q$ and $-Q$ and to the left
(f) at right angles to the line joining $Q$ and $-Q$ and downward
(g) parallel to the line joining $Q$ and $-Q$ and to the right
(h) none of the above

5. Two curved plastic rods, one of charge $+q$ and the other of charge $-q$, form a circle of radius $R$ in the $xy$ plane. The $x$ axis passes through their connecting points, and the charge is distributed uniformly on both rods. What is the magnitude and direction of the electric field $E$ produced at $P$, the center of the circle? ($K=1/4\pi\varepsilon_0$)

(a) $Kq/2\pi R^2$ upwards
(b) $Kq/2\pi R^2$ downwards
(c) $Kq/\pi R^2$ upwards
(d) $Kq/\pi R^2$ downwards
(e) $2Kq/\pi R^2$ upwards
(f) $4Kq/\pi R^2$ downwards
(g) $2Kq/\pi R^2$ downwards
(h) $4Kq/\pi R^2$ upwards
6. A uniform electric field exists in a region between two oppositely charged plates. An electron is released from rest at the surface of the negatively charged plate and strikes the surface of the opposite plate, 5 cm away, in time $2 \times 10^{-8}$ s. What is the speed of the electron as it strikes the second plate?

(a) $2 \times 10^7$ m/s  
(b) $1 \times 10^7$ m/s  
(c) $3 \times 10^7$ m/s  
(d) $4 \times 10^7$ m/s  
(e) $2 \times 10^6$ m/s  
(f) $3 \times 10^6$ m/s  
(g) $5 \times 10^6$ m/s  
(h) $8 \times 10^6$ m/s

7. Two spheres, one with radius $R$ and the other with radius $2R$, surround an isolated point charge. The ratio of the number of field lines through the larger sphere to the number through the smaller is:

(a) 1  
(b) 2  
(c) 4  
(d) 1/2  
(e) 1/4  
(f) 8  
(g) 1/8  
(h) 0

8. An electric dipole consists of $+6 \times 10^{-6}$ C at the origin and $-6 \times 10^{-6}$ C on the x axis at $x = 3 \times 10^{-3}$ m. Its dipole moment is:

(a) $1.8 \times 10^{-8}$ C·m, in the positive x direction  
(b) $1.8 \times 10^{-8}$ C·m, in the negative x direction  
(c) 0, because the net charge is 0  
(d) $3.6 \times 10^{-8}$ C·m, in the positive x direction  
(e) $3.6 \times 10^{-8}$ C·m, in the negative x direction  
(f) $1.2 \times 10^{-8}$ C·m, in the positive x direction  
(g) $1.2 \times 10^{-8}$ C·m, in the negative x direction  
(h) none of the above
9. A very long conducting cylindrical rod of length L with a total charge \(+2q\) is surrounded by a concentric conducting cylindrical shell (also of length L) with total charge \(-3q\), as shown. Use Gauss' law to find the electric field in the region between the shell and the rod a distance \(r\) from the center of the rod.

(a) \(2q/\pi \varepsilon_0 r L\)
(b) \(4q/\pi \varepsilon_0 r L\)
(c) \(q/\pi \varepsilon_0 r L\)
(d) \(q/4\pi \varepsilon_0 r L\)
(e) \(q/2\pi \varepsilon_0 r L\)
(f) \(8q/\pi \varepsilon_0 r L\)
(g) \(q/8\pi \varepsilon_0 r L\)
(h) \(-q/\pi \varepsilon_0 r L\)

10. A conducting sphere with positive charge \(Q\) is surrounded by a spherical conducting shell. If a charge \(2q\) is placed between the shell and the sphere, what is the charge on the inner surface of the shell?

(a) \((Q+q)\)
(b) \(-(Q+q)\)
(c) \(-Q+q\)
(d) \(-Q\)
(e) \(-q\)
(f) \(-(Q+2q)\)
(g) \(Q+2q\)
(h) \(-2q\)

11. Two infinitely large parallel plates carry positive charge of equal magnitude that is distributed uniformly over their inner surfaces. Rank the points 1 through 5 according to the magnitude of the electric field at the points, least to greatest.

(a) 1, 2, 3, 4, 5
(b) 5, 4, 3, 2, 1
(c) 1, 4, and 5 tie, then 2 and 3 tie
(d) 2 and 3 tie, then 1 and 4 tie, then 5
(e) 2 and 3 tie, then 1, 4, and 5 tie
(f) 2, 1, 4, 3, 5
(g) 5, 3, 2, 4, 1
12. Charge is distributed uniformly along a infinitely long straight wire. The electric field 2 cm from the wire is 20 N/C. The electric field 4 cm from the wire is:

(a) 120 N/C
(b) 80 N/C
(c) 40 N/C
(d) 10 N/C
(e) 20 N/C
(f) 5 N/C
(g) 2 N/C
(h) 60 N/C

13. A plastic rod having a uniformly distributed charge \(-2Q\) has been bent into a circular arc of radius R and central angle \(120^\circ\). With \(V=0\) at infinity, what is the electric potential at \(P\), the center of curvature of the rod?

(a) \(-5Q/(\pi \varepsilon_0 R)\)
(b) \(-3Q/(\pi \varepsilon_0 R)\)
(c) \(-8Q/(\pi \varepsilon_0 R)\)
(d) \(-10Q/(\pi \varepsilon_0 R)\)
(e) \(-Q/(8\pi \varepsilon_0 R)\)
(f) \(-Q/(4\pi \varepsilon_0 R)\)
(g) \(-Q/(2\pi \varepsilon_0 R)\)
(h) \(-Q/(\pi \varepsilon_0 R)\)

14. Three charged particles are located equidistant from one another as shown. Calculate the total electric potential energy of the three-particle system relative to the potential energy for infinite separation.

(a) \(3q^2/(4\pi \varepsilon_0 d)\)
(b) \(q^2/(4\pi \varepsilon_0 d)\)
(c) \(2q^2/(4\pi \varepsilon_0 d)\)
(d) \(4q^2/(4\pi \varepsilon_0 d)\)
(e) \(6q^2/(4\pi \varepsilon_0 d)\)
(f) \(7q^2/(4\pi \varepsilon_0 d)\)
(g) \(5q^2/(4\pi \varepsilon_0 d)\)
15. During a lightning discharge, 30 C of charge move through a potential difference of $1.0 \times 10^8$ V in $2.0 \times 10^{-2}$ s. The energy released by this lightning bolt is:

(a) $1.5 \times 10^{11}$ J
(b) $3.0 \times 10^9$ J
(c) $6.0 \times 10^7$ J
(d) $3.3 \times 10^6$ J
(e) $1.5 \times 10^5$ J
(f) $3.3 \times 10^3$ J
(g) $1.0 \times 10^3$ J
(h) $1.5 \times 10^2$ J

16. A conducting sphere has charge $Q$ and its electric potential is $V$, relative to the potential far away. If the charge is doubled to $2Q$, the potential is:

(a) $V$
(b) $2V$
(c) $3V$
(d) $4V$
(e) $8V$
(f) $V/2$
(g) $V/4$
(h) $V/8$

17. A capacitance $C_1 = 8.0 \ \mu$F is connected in series with a capacitance $C_2 = 2.0 \ \mu$F, and a potential difference of 400 V is applied across the pair. What is the charge on each capacitor?

(a) $5.4 \times 10^{-5}$ C
(b) $3.6 \times 10^{-5}$ C
(c) $7.0 \times 10^{-5}$ C
(d) $8.4 \times 10^{-5}$ C
(e) $1.2 \times 10^{-4}$ C
(f) $9.6 \times 10^{-4}$ C
(g) $2.4 \times 10^{-4}$ C
(h) $6.4 \times 10^{-4}$ C
18. A parallel-plate air filled capacitor having area 50 cm\(^2\) and plate spacing 1.0 mm is charged to a potential difference of 500V. Find the energy density between the plates. \((\varepsilon_0=8.85 \times 10^{-12} \text{ F/m})\)

(a) 2.2 J/m\(^3\)
(b) 6.6 J/m\(^3\)
(c) 1.1 J/m\(^3\)
(d) 9.9 J/m\(^3\)
(e) 8.8 J/m\(^3\)
(f) 4.4 J/m\(^3\)
(g) 5.5 J/m\(^3\)
(h) 7.7 J/m\(^3\)

19. Two capacitors are identical except that one is filled with air and the other with oil. Both capacitors carry the same charge. The ratio of the electric fields \(E_{\text{air}}/E_{\text{oil}}\) is:

(a) between 0 and 1
(b) 0
(c) 1
(d) between 1 and infinity
(e) infinite
(f) between -1 and 0
(g) between -infinity and -1
(h) -1

20. To charge a 1 F capacitor with 2 C requires a potential difference of:

(a) 2 V
(b) 0.2 V
(c) 5 V
(d) 0.5 V
(e) 4 V
(f) 0.4 V
(g) 1 V
(h) none of the above
electrons are attracted to the electro scope leaves from ground by the rod. Then the connection is broken before the rod is removed.

ans: gain electrons
Take square root:

\[ \sqrt{\frac{V_{ab}}{d+0.1m}} = \sqrt{\frac{1}{d}} \]

\[ d = 0.18 \text{ m} \]

Assume:

\[ d (d+0.1m) = 0.1 \text{ m} \]

\[ d = \sqrt{0.1} \text{ m} \]

\[ d = 0.3162 \text{ m} \]

\[ d = 0.31 \text{ m} \]

From \( g_1 \) and \( g_2 \):

\[ d_1 = 0.18 \text{ m} \]

\[ d_2 = 0.31 \text{ m} \]

The distance from \( g_1 \) and \( g_2 \):

\[ 0.24 \text{ cm} \]

\[ 0.34 \text{ cm} \]

The distance from \( g_2 \):

\[ 0.1 \text{ m} \]

\[ 0.3 \text{ m} \]
5 \[ E = E_x = K \frac{d\theta}{R^2} \sin \theta \]
\[ E_{\text{total}} = 2 E_{\text{top}} \]
\[ E_y = 2 K \int_0^{\pi} \sin \theta \theta d\theta \]
\[ = 2 K \left[ \frac{\theta \sin \theta}{R^2} \right]_0^{\pi} \]
\[ = \frac{2 K \theta}{R^2} \left[ 1 + 1 \right] = 0 \]
\[ = \frac{4 K \theta}{\pi R^2} \left( \text{downward} \right) \]
\[ \left( \text{upwards} \right) \]

6 \[ \sum F = ma \]
\[ |\vec{a}| = (E_x) = const = \frac{d^2 \vec{r}}{dt^2} \]
\[ \Delta \gamma = \vec{v} \cdot t \]
\[ \gamma = \left( \frac{\vec{v} - \vec{v}_0}{2} \right) \cdot t \]
\[ \vec{v} = \frac{2\vec{r}}{t} = \frac{\left( \frac{0.10 \text{ m}}{2 \times 10^{-5} \text{ s}} \right)}{2 \times 10^{-5} \text{ s}} = \left( 5 \times 10^6 \right) \frac{\text{m}}{\text{s}} \]
8 \quad P = \frac{q}{4\pi d} = \left(6 \times 10^{-6} \text{ C}\right) \left(\frac{q}{6}\right) \times 10^{-3} \text{ m} = \left(1.8 \times 10^{-8} \text{ C m}\right)

\begin{align*}
E &= \vec{E} \cdot d\vec{A} = \frac{q_0 e}{\varepsilon_0} \\
\mathcal{E} A &= \frac{q_0 e}{\varepsilon_0} \\
\mathcal{E} 2\pi r_0 L &= \frac{q_0 e}{\varepsilon_0} \\
\mathcal{E} &= \frac{q_0 e}{2\pi \varepsilon_0 r_0 L} = \frac{\left(\frac{+2q}{+4q}\right)}{2\pi \varepsilon_0 r_0 L} \\
&= \left(\frac{\frac{q}{\pi \varepsilon_0 r_0 L}}{2\pi \varepsilon_0 r_0 L}\right)
\end{align*}
10. $\Phi = \frac{\text{Q} + \frac{2\text{Q}}{6}}{\varepsilon_0}$

$\oint E \cdot dA = 0 = \text{Q} + \frac{2\text{Q}}{6} + 8\pi$ 

So

$8\pi = -\left(\text{Q} + \frac{2\text{Q}}{6}\right)$

11. $E$ between plates $= 0$

and $E = \frac{Q}{\varepsilon_0}$ outside plates

$= \text{const.}$

So

ans: 2, 3, tie; 1, 4, 5, tie

12. From ans. to 9:

$E \propto \frac{1}{N}$

So

if $E = \left(\frac{20}{40}\right) \frac{\text{N}}{\text{C}}$

at $N = 2 \text{ cm}$,

$E = \left(\frac{10}{20}\right) \frac{\text{N}}{\text{C}}$

at $N = 4 \text{ cm}$.

13. $\int dV = \frac{1}{4\pi\varepsilon_0} \int \frac{d\Phi}{R}$

$V = \frac{1}{4\pi\varepsilon_0 R} \left[ -2\Phi \right] = \left[ \frac{\Phi}{2\pi\varepsilon_0 R} \right]_{-2\Phi}^{2\Phi}$

$= \frac{\Phi}{2\pi\varepsilon_0 R} - \frac{\Phi}{2\pi\varepsilon_0 R}$

$= 0$
\[ U = V_1 g_2 + V_1 g_3 + V_2 g_3 \]
\[ = \left( \frac{q}{4\pi\varepsilon_0 d} \right) g_2 + \left( \frac{q}{4\pi\varepsilon_0 d} \right) g_3 + \left( \frac{q}{4\pi\varepsilon_0 d} \right) g_3 \]
\[ = \frac{3q^2}{4\pi\varepsilon_0 d} \]

\[ U = \sqrt{q_b} = (1 \times 10^8 V) \left( \frac{30}{10} \right) \]
\[ = \left( \frac{3}{1} \right) \times 10^9, J \]

\[ V = \frac{q_b}{4\pi\varepsilon_0 \lambda} \text{ so it charge is (doubled) tripled} \]
\[ V \Rightarrow \left( \frac{2V}{3V} \right) \]
\[ \frac{3}{10} = 1.6 \]

\[ \frac{1}{C_1} + \frac{1}{C_2} = \frac{C_2 + C_1}{C_1 C_2} \]
\[ C_0 = \frac{C_1 C_2}{C_1 + C_2} = \frac{16}{10} \text{, } 1.6 \text{ mF} \]
\[ C_0 = \frac{q}{V_{eq}} \Rightarrow q = C_0 V_{eq} = \left( 1.6 \text{ mF} \right) \left( \frac{400}{600} \right) V \]
\[ q = \left( 6.4 \right) \times 10^{-4} \text{ C} \]
\( C = \frac{\varepsilon_0 A}{d} \)

\( U = \frac{\varepsilon_0 E^2}{2} \) but \( V = E \phi \)

\[ E = \frac{V}{d} \]

\[ \phi = \frac{E_0}{2} \frac{V^2}{d^2} = \frac{E_0}{2} \frac{(500)^2}{(1000)^2} = \frac{1}{4.4} \frac{1}{m^3} \]

\( C_{oil} = k C_{air} \) where \( k > 1 \)

\[ C_{oil} = \frac{g}{V_{oil}} = \frac{g}{E_{oil} d} \] and \[ C_{air} = \frac{g}{E_{air} d} \]

\[ \frac{E_{air}}{E_{oil}} = \frac{C_{oil}}{C_{air}} = k > 1 \]

or between 1 and infinity

\( C = \frac{g}{V} \)

\[ V = \frac{g}{C} = \frac{2 \varepsilon}{(\frac{1}{2})F} = \left( \frac{2}{1} \right) V \]