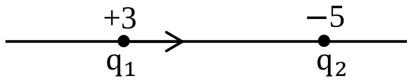
Q1.

Three point charges are arranged along the *x*-axis. Charge $q_1 = +3.00\ \mu C$ is at the origin, and charge $q_2 = -5.00\ \mu C$ is at x = 0.200 m. Where should a third charge $q_3 = -8.00\ \mu C$ be located if the net force on q_1 is 7.00 N in the negative *x*-direction?

A) – 0.144 m
B) – 0.211 m
C) + 0.412 m
D) + 0.211 m
E) – 0.520 m



Ans:

$$\vec{F}_{net} = -7\,\hat{i}$$
$$= \vec{F}_{12} + \vec{F}_{13}$$

$$\vec{F}_{12} = \frac{kq_1q_2}{r_{12}^2} = \frac{9\times10^9 \times 3\times10^{-6}\times 5\times10^{-6}}{4\times10^{-2}} = 33.75\times10^{-1}\ \mathrm{N}$$

$$\vec{F}_{12} = 3.375\,\hat{\imath}\ (\mathrm{N})$$

To the left of q_1 ↓

$$\Rightarrow \vec{F}_{13} = \vec{F}_{net} - \vec{F}_{12} = -7\,\hat{i} - 3.375\,\hat{i} = -10.375\,\hat{i}\ (\mathrm{N})$$

$$r_{13}^2 = \frac{kq_1q_2}{F_{13}} = \frac{9\times10^9\times 24\times10^{-12}}{10.375} = 0.0208m^2 \Rightarrow r_{13} = 0.144\ \mathrm{m}$$

Q2.

Two identical small conducting spheres are separated by 0.6 m center to center. The spheres carry different amounts of charge with a total charge of + 4 μC. The two spheres are now connected by a very thin conducting wire and then disconnected. The new electric force on each sphere is

A) 0.1 N, repulsive
B) 0.1 N, attractive
C) 0.4 N, attractive
D) zero
E) 0.4 N, repulsive

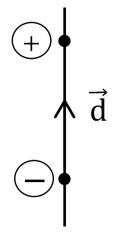
Ans:

The change of each sphere $= +2\ \mu C \Rightarrow$ Repulsive Force

$$F = \frac{kq_1q_2}{r^2} = \frac{9\times10^9\times4\times10^{-12}}{0.36} = 0.1\ \mathrm{N}$$

Q3.

An electric dipole consists of a charge of + 1.0 µC located at the point (0, 1.0) cm and a charge of – 1 µC located at the point (0, –1.0) cm. How much work must be done by an electric filed $\vec{E} = 3.0\times10^{6}\,\hat{\mathbf{i}}$ (N/C) to align the dipole with the field?



A) 0.060 J
B) 0.030 J
C) zero
D) 0.020 J
E) 0.12 J

Ans:

$$\vec{P} = qd\hat{j} = 1.0\times10^{-6}\times2.0\times10^{-2} = +2.0\times10^{-8}\hat{j}\ \mathrm{C\cdot m}$$

$$\vec{U}_i = -\vec{p}_i\cdot\vec{E} = 0$$

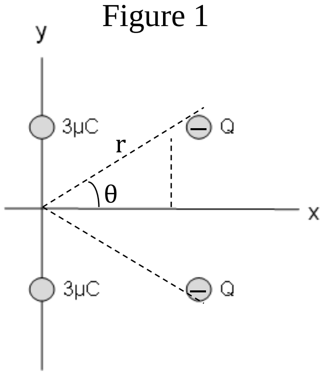
$$\vec{U}_f = -\vec{p}_f\cdot\vec{E} = -pE = -2.0\times10^{-8}\times3.0\times10^{6} = -0.06\ \mathrm{J}$$

$$W = \Delta U = U_i - U_f = 0 + 0.06 = 0.06\ \mathrm{J}$$

Q4.

Charges of 3.0 µC are located at (0, 2.0) m and at (0, – 2.0) m, as shown in **FIGURE 1**. Charges Q are located at (4.0, 2.0) m and at (4.0, – 2.0) m. The net electric field at the origin is equal to $+4.0\times10^{3}\,\hat{\mathbf{i}}$ (N/C). Determine Q.

Figure 1



A) – 5.0 µC
B) + 3.1 µC
C) – 3.1 µC
D) – 6.4 µC
E) + 5.0 µC

Ans:

$$r^2 = 16 + 4 = 20 \Rightarrow r = 4.47\ m$$

The fields due to the 3µC charges cancel

For $\vec{E}$ to be in the + x direction, Q must be (−)

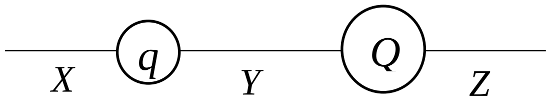
$$E_{net} = 2\frac{kQ}{r^2}\cdot\cos\theta = 2\frac{kQ}{r^2}\cdot\frac{4}{r} = 2\frac{kQ}{r^3}$$

$$Q = \frac{E\cdot r^3}{8k} = \frac{4\times10^3\times(4.47)^3}{8\times9\times10^9} = 4.969\ \mu\mathrm{C}$$

Q5.

FIGURE 2 shows two unequal point charges, *q* and *Q*, of opposite sign. Charge *Q* has greater magnitude than charge *q*. In which of the regions *X*, *Y*, *Z* will there be a point at which the net electric field due to these two charges is zero?

Figure 2



A) only region X
B) only regions X and Z
C) only region Y
D) only region Z
E) all three regions

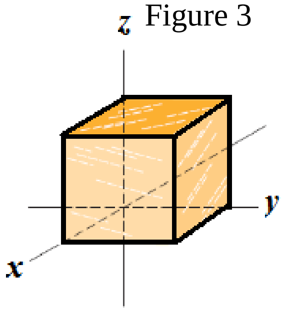
Ans:

A

Q6.

At each point on the surface of the cube shown in **FIGURE 3**, the electric field is parallel to the *z* axis. The length of each edge of the cube is 3.0 m. On the top face of the cube, the electric field is $\vec{E} = -20\,\hat{\mathbf{k}}$ (N/C), and on the bottom face $\vec{E} = +20\,\hat{\mathbf{k}}$ (N/C). Determine the net charge contained within the cube.

Figure 3



A) -3.2×10^{-9} C
B) $+3.2 \times 10^{-9}$ C
C) -1.9×10^{-10} C
D) $+1.9 \times 10^{-10}$ C
E) $+0.90 \times 10^{-9}$ C

Ans:

Top:

$$\Phi_t = \vec{E}_i \cdot \vec{A}_i = (-20\hat{k}) \cdot (9.0\,\hat{k}) = -180\ \frac{Nm^2}{C}$$

Bottom:

$$\Phi_b = \vec{E}_b \cdot \vec{A}_b = (20\hat{k}) \cdot (-9.0\,\hat{k}) = -180\ \frac{Nm^2}{C}$$

There is no electric flux through the other sides.

$$\Phi_{net} = \Phi_t + \Phi_b = -360\ \frac{Nm^2}{C}$$

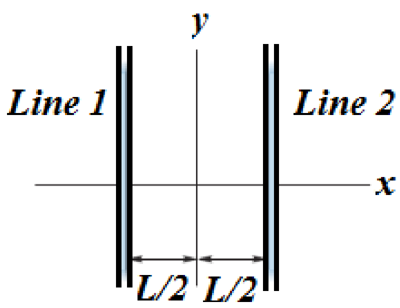
$$\Phi_{net} = \frac{q_{enc}}{\varepsilon_0}$$

$$\Rightarrow q_{enc} = \varepsilon_0\,\Phi_{net} = 8.85 \times 10^{-12} \times (-360) = -3.19 \times 10^{-9}\ C$$

Q7.

In **FIGURE 4**, short sections of two very long parallel lines of charge are shown, fixed in place, and separated by L = 8.0 cm. The uniform linear charge densities are + 6.0 μC/m for line 1 and – 2.0 μC/m for line 2. Where along the x-axis (from the origin) is the net electric field due the two lines zero?

Figure 4



A) 8.0 cm
B) 4.0 cm
C) 2.0 cm
D) 6.0 cm
E) 0.0 cm

Ans:

The point should be to the right of line z, at a distance (d) from it.

$E_1 = E_2$:

$$\frac{2k\lambda_1}{d+L} = \frac{2k\lambda_2}{d}$$

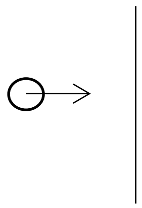
$$\frac{d+L}{d} = \frac{\lambda_1}{\lambda_2} \Rightarrow 1 + \frac{L}{d} = \frac{6}{2} = 3$$

$$\Longrightarrow \frac{L}{d} = 2 \Longrightarrow d = \frac{L}{2} = 4.0 \text{ cm}$$

$$\Longrightarrow x = \frac{L}{2} + d = 4 + 4 = 8 \text{ cm}$$

Q8.

An electron is shot directly toward the center of a large metal plate that has a surface charge density of – 2.0 μC/m^2. If the initial kinetic energy of the electron is 1.6 × 10^{-17} J and if the electron is to stop (due to electrostatic repulsion from the plate) just as it reaches the plate, how far from the plate must the launch point of the electron be?



A) 0.44 mm
B) 3.3 mm
C) 25 mm
D) 14 mm
E) 6.4 mm

Ans:

$\Delta K = \Delta U$

$$K_i = eV = eEd = e \cdot \frac{\sigma}{\varepsilon_0} \cdot d$$

$$\Rightarrow d = \frac{\varepsilon_0 K_i}{e\sigma} = \frac{8.85 \times 10^{-12} \times 1.6 \times 10^{-7}}{1.6 \times 10^{-19} \times 2 \times 10^{-6}} = 4.425 \times 10^{-4} m = 0.44\ mm$$

Q9.

Charge Q is uniformly distributed in a sphere of radius *R*. Find the ratio of the magnitude of the electric field at $r = R/2$ to that on the surface of the sphere. (r is the distance from the center of the sphere)

A) 1/2
B) 1/4
C) 2
D) 4
E) 1/3

Ans:

$$E_{in} = \frac{kq}{R^3} r \Rightarrow E_{R/2} = \frac{kq}{R^3} \cdot \frac{R}{2} = \frac{1}{2} \frac{kq}{R^2}$$

$$E_s = \frac{kq}{R^2}$$

$$\Rightarrow \frac{E_{R/2}}{E_s} = \frac{kq}{2R^2} \cdot \frac{R^2}{kq} = \frac{1}{2}$$

Q10.

An electron and a proton are accelerated from rest through the same potential difference. Which of the following statements is **CORRECT**?

A) The electron has greater speed.
B) The proton has greater speed.
C) They have the same speed.
D) The electron has greater kinetic energy.
E) The proton has greater kinetic energy.

Ans:

$K = q\,V$

(q: same; V: same)

$$\Rightarrow \frac{1}{2} m v^2 = qV \Rightarrow v^2 = \frac{2qV}{m} \Rightarrow v = \sqrt{\frac{2qV}{m}}$$

(m: different)

Q11.

The electric potential at the surface of a conducting sphere is 200 V. At a point that is 10.0 cm from the surface, the electric potential is 150 V. What is the radius of the sphere?

A) 30 cm
B) 33 cm
C) 25 cm
D) 14 cm
E) 28 cm

Ans:

$$\left.\begin{aligned} V_1 &= \frac{kq}{R} \\ V_2 &= \frac{kq}{R+d} \end{aligned}\right\} \frac{V_2}{V_1} = \frac{\cancel{kq}}{R+d} \cdot \frac{R}{\cancel{kq}} = \frac{R}{R+d}$$

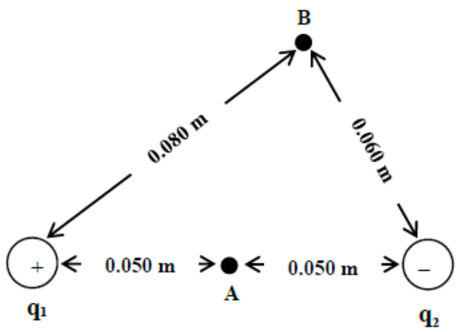
$$0.75 = \frac{R}{R+d} \Rightarrow R = 0.75\,R + 0.75\,d$$

$$0.25\,R = 0.75\,d \Rightarrow R = 3d = 30\text{ cm}$$

Q12.

Two stationary point charges $q_1 = +2.0$ nC and $q_2 = -2.0$ nC are 0.10 m apart, as shown in **FIGURE 5**. Calculate the work done by the electric field on a charge of + 2.0 nC that moves from point B to point A.

Figure 5



A) − 0.15 µJ
B) + 0.15 µJ
C) − 1.1 µJ
D) + 1.1 µJ
E) zero

Ans:

$V_A = 0$

$$V_B = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} = \frac{9 \times 10^9 \times 2 \times 10^{-9}}{0.08} - \frac{9 \times 10^9 \times 2 \times 10^{-9}}{0.06}$$

$V_B = 75$ V

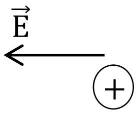
$$W = -q\Delta V = -q(V_f - V_i) = -q\,(V_A - V_B)$$

$$= qV_B = 2.00 \times 10^{-9} \times (-75) = -1.5 \times 10^{-7}\text{ J}$$

Q13.

A particle with a charge of + 5.0 nC is in a uniform electric field. It is released from rest. Its kinetic energy is found to be 1.5×10^{-6} J after it has moved 5.0 cm. What is the magnitude of the electric field?

A) 6.0 kV/m
B) 1.5 kV/m
C) 3.0 kV/m
D) 4.5 kV/m
E) 7.5 kV/m



Ans:

$$K = qV = qEd$$

$$E = \frac{K}{qd} = \frac{1.5 \times 10^{-6}}{5.0 \times 10^{-9} \times 0.05} = 6.0 \text{ kV/m}$$

Q14.

The electric potential *V* (in volts) at points in the *xyz* space is given by:
$V = -xz^2 + y^2z + 4.0$
where *x*, *y*, and *z* are in meters. Find the electric field (in V/m) at the point (2.0, 4.0, −1.0) m.

A) $+1.0\,\hat{\mathbf{i}} + 8.0\,\hat{\mathbf{j}} - 20\,\hat{\mathbf{k}}$

B) $+2.0\,\hat{\mathbf{i}} + 3.0\,\hat{\mathbf{j}} - 1.0\,\hat{\mathbf{k}}$

C) $+1.0\,\hat{\mathbf{i}} + 4.0\,\hat{\mathbf{j}} + 2.0\,\hat{\mathbf{k}}$

D) $+4.0\,\hat{\mathbf{i}} - 14\,\hat{\mathbf{j}} + 2.0\,\hat{\mathbf{k}}$

E) $+5.0\,\hat{\mathbf{i}} + 3.0\,\hat{\mathbf{j}} + 6.0\,\hat{\mathbf{k}}$

Ans:

$$V = -xz^2 + y^2z + 4$$

$$E_x = -\frac{\partial V}{\partial x} = -(-z^2) = z^2 = 1.0 \text{ V/m}$$

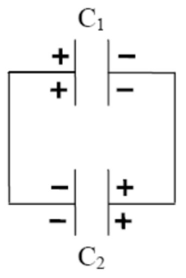
$$E_y = -\frac{\partial V}{\partial y} = -(2yz) = -2yz = (-2)(4)(-1) = 8.0 \text{ V/m}$$

$$E_z = -\frac{\partial V}{\partial z} = -(-2xz + y^2) = 2xz - y^2 = (2)(2)(-1) - 16 = -20 \text{ V/m}$$

Q15.

Two capacitors C_1 and C_2 are each charged to 60 V, and then disconnected from the battery. They store charges of 100 μC and 300 μC. The two capacitors are then connected with opposite polarity as shown in **FIGURE 7**. What then is the potential difference across the capacitors?

Figure 7



A) 30 V
B) 120 V
C) 40 V
D) 20 V
E) 50 V

Ans:

$$C_1 = \frac{100}{60} = \frac{5}{3}\mu F;\ C_2 = \frac{300}{60} = 5\mu F \Rightarrow C_1 + C_2 = \frac{5}{3} + 5 = \frac{20}{3}$$

Series ⟶ charge cancellation ⟹ Redistribution ⟹ Parallel

$$Q_{net} = 200\mu C$$

Same P.D.

$$\left.\begin{matrix} q_1 = C_1 V \\ q_2 = C_2 V \end{matrix}\right\} \quad Q_{net} = (C_1 + C_2)V \Rightarrow V = \frac{Q_{net}}{C_1+C_2} = \frac{200}{20} \times 3 = 30\ V$$

Q16.

A charged isolated capacitor stores an energy of U. It is connected in parallel to an identical uncharged capacitor. After the combination, the total energy stored in the two capacitors is

A) U/2
B) U
C) U/4
D) 2U
E) 4U

Ans:

$$U_i = \frac{q^2}{2C} = U \Rightarrow q = \sqrt{2CU}$$

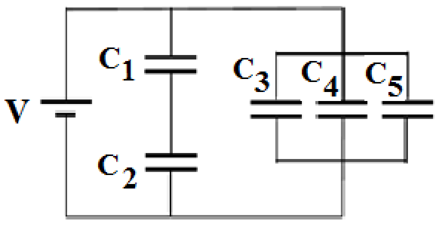
<u>After:</u>

$$\left.\begin{matrix} q_1 = CV \\ q_2 = CV \end{matrix}\right. \quad \Rightarrow \left.\begin{matrix} q_f \\ C_{eq=2C} \end{matrix}\right\} \quad U_f = \frac{q_f^2}{2C_{eq}} = \frac{1}{2} \cdot q^2 \cdot \frac{1}{2C} = \frac{1}{4\not{C}} \cdot 2\not{C}U = \frac{U}{2}$$

Q17.

In the capacitor circuit shown in **FIGURE 6**, the capacitance of each capacitor is **C**. Find the ratio of Q_3/Q_2.

Figure 6



A) 2
B) 1/2
C) 3
D) 1/3
E) 2/3

Ans:

$$V_3 = V \implies Q_3 = CV$$

$$\frac{Q_1}{C} + \frac{Q_2}{C} = V$$

$$2\frac{Q_2}{C} = V \Rightarrow Q_2 = \frac{CV}{2}$$

$$\Rightarrow \frac{Q_3}{Q_2} = CV \cdot \frac{2}{CV} = 2$$

Q18.

A 500-pF capacitor consists of two circular plates 15 cm in radius, separated by a sheet of polystyrene ($\kappa = 2.6$). What is the thickness of the sheet?

A) 3.3 mm
B) 3.7 mm
C) 4.5 mm
D) 5.1 mm
E) 4.2 mm

Ans:

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

$$d = \frac{k\varepsilon_0 A}{C} = \frac{k\varepsilon_0 \pi r^2}{C} = \frac{2.6 \times 8.85 \times \cancel{10^{-12}} \times \pi \times 225 \times 10^{-4}}{500 \times \cancel{10^{-12}}} = 3.25 \times 10^{-3} m$$

Q19.

A light bulb has a tungsten filament and is powered by a battery. When the bulb is turned ON, its temperature is 20.0 °C and the current passing through it is 0.850 A. After 60.0 s, the current is 0.220 A. What then is the temperature of the filament? Tungsten has a temperature coefficient of resistivity of 4.50 × 10^{-3} $(^{o}C)^{-1}$. Assume the filament's dimensions did not change.

A) 656 °C
B) 561 °C
C) 415 °C
D) 280 °C
E) 300 °C

Ans:

$$R_i = \frac{V}{0.85};\ R_f = \frac{V}{0.22} \quad R = \frac{V}{I}$$

$$\frac{\not{V}}{0.22} = \frac{\not{V}}{0.85}(1 + 4.5 \times 10^{-3} \times \Delta T)$$

$$\Rightarrow \frac{0.85}{0.22} = 1 + 4.5 \times 10^{-3}\Delta T \ \Rightarrow \Delta T = 636°C$$

$$\Rightarrow T_f = 656°C$$

Q20.

Two points in a conducting wire are 75 cm apart and the potential difference between them is 0.95 V. If the current density is 4.5 × 10^{7} A/m^2, what is the resistivity of the wire?

A) 2.8 × 10^{-8} Ω.m
B) 1.5 × 10^{-8} Ω.m
C) 1.7 × 10^{-8} Ω.m
D) 2.4 × 10^{-8} Ω.m
E) 5.3 × 10^{-8} Ω.m

Ans:

$$\left.\begin{matrix} E = \rho J \\ \frac{V}{d} = \rho J \end{matrix}\right\} \rho = \frac{V}{dJ} = \frac{0.95}{0.75 \times 4.5 \times 10^{7}} = 2.8 \times 10^{-8}\Omega \cdot m$$
