2. (a) i. Since copper is a conductor, all of the charge is located at the surface ($R_1 = 0.12$ m). Therefore, the electric field everywhere inside the copper sphere is zero. So, the potential inside this sphere is a constant (everywhere the same) and equal to the potential at a point just outside the surface of the sphere. Assume zero potential at infinity.

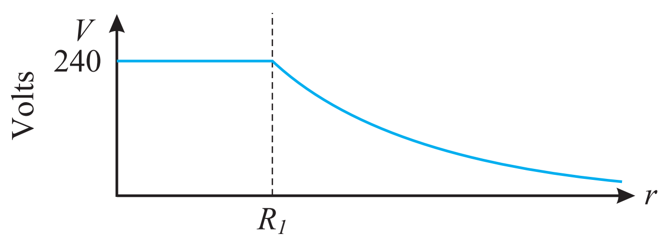
$$V = k\frac{Q}{r} = \left(9 \text{ x } 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\frac{6.4 \text{ x } 10^{-9} \text{ C}}{0.12 \text{ m}}$$

$$\boxed{V = 480 \text{ V}}$$

ii. $$V = k\frac{Q}{r} = \left(9 \text{ x } 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\frac{6.4 \text{ x } 10^{-9} \text{ C}}{0.24 \text{ m}}$$

$$\boxed{V = 240 \text{ V}}$$

(b)

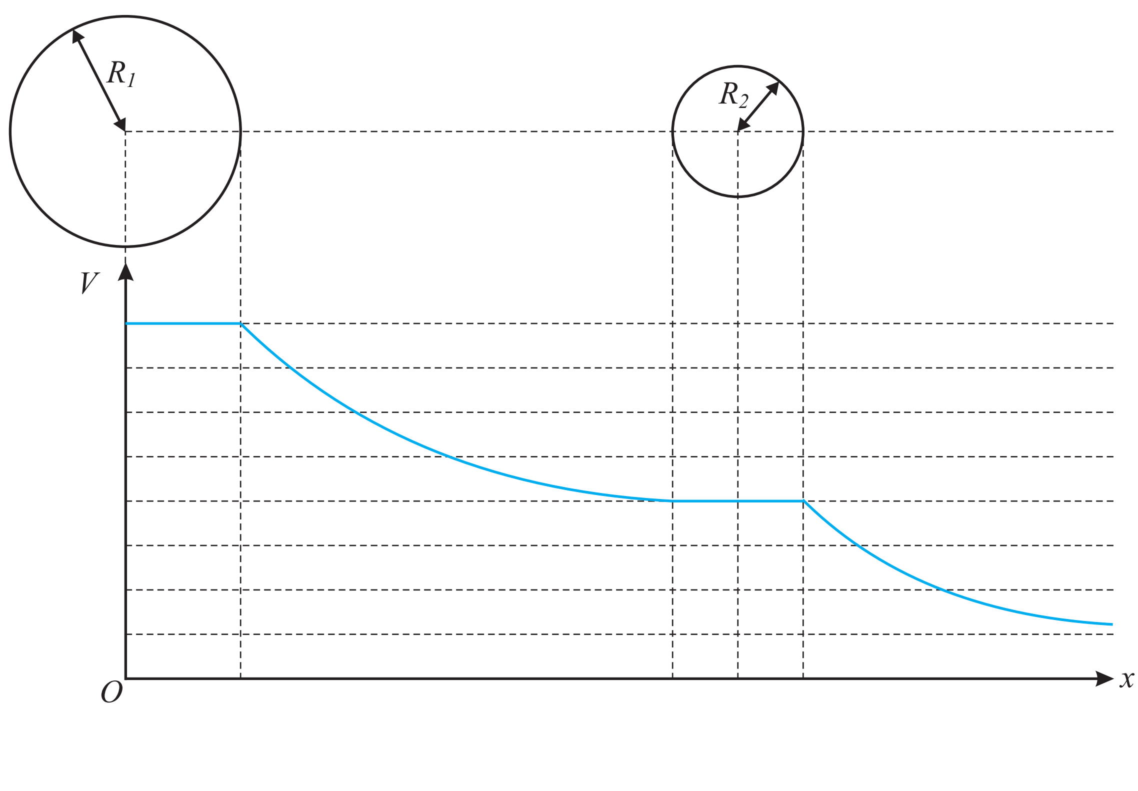


(c) i. Zero as described above

ii. $$E = k\frac{Q}{r^2} = \left(9 \text{ x } 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\frac{6.4 \text{ x } 10^{-9} \text{ C}}{(0.24 \text{ m})^2}$$

$$\boxed{E = 240 \text{ N/C}}$$

(d)



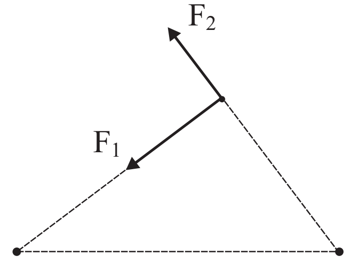
2010 B

3. (a)

q_1 __X__ Negative
____ Positive

q_2 ____ Negative
__X__ Positive

(b)



(c) $\mathbf{F} = \sum F_x = -F_{1x} - F_{2x} = -k\dfrac{q_1 q_3}{r_{1-3}^{\;2}} - k\dfrac{q_2 q_3}{r_{2-3}^{\;2}}$

$$= -\left(9.0 \text{ x } 10^{9} \text{ N}\cdot\text{m}^2/\text{C}^2\right)\left[\frac{\left(4.0 \text{ x } 10^{-6} \text{ C}\right)\left(1.0 \text{ x } 10^{-6} \text{ C}\right)}{(4.0 \text{ m})^2}\cos 37 + \frac{\left(1.7. \text{ x } 10^{-6} \text{ C}\right)\left(1.0 \text{ x } 10^{-6} \text{ C}\right)}{(3.0 \text{ m})^2}\cos 53\right]$$

$$\boxed{\mathbf{F} = -2.8 \text{ x } 10^{-3} \text{ N}}$$

(d) $\mathbf{F} = -2.8 \text{ x } 10^{-3} \text{ N}$

$-2.8 \text{ x } 10^{-3} \text{ N} = \left(1.0 \text{ x } 10^{-6} \text{ C}\right)E$

$$\boxed{E = -2.8 \text{ x } 10^{3} \text{ N/C}}$$

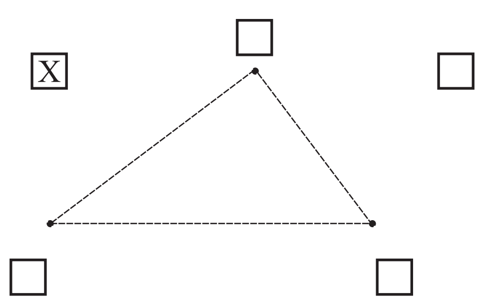
OR (The long method)

$\mathbf{E} = \sum E_x = -E_{1x} - E_{2x} = -k\dfrac{q_1}{r_{1-3}^{\;2}} - k\dfrac{q_2}{r_{2-3}^{\;2}}$

$$= -\left(9.0 \text{ x } 10^{9} \text{ N}\cdot\text{m}^2/\text{C}^2\right)\left[\frac{\left(4.0 \text{ x } 10^{-6} \text{ C}\right)}{(4.0 \text{ m})^2}\cos 37 + \frac{\left(1.7. \text{ x } 10^{-6} \text{ C}\right)}{(3.0 \text{ m})^2}\cos 53\right]$$

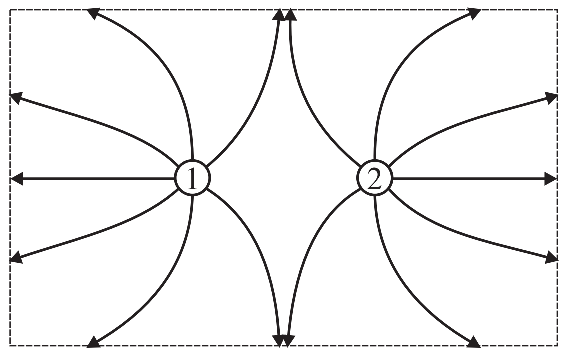
$$\boxed{E = -2.8 \text{ x } 10^{3} \text{ N/C}}$$

(e)



The net force on charge q_3 is currently to the left, so this additional charge would have to create a force equal and opposite to the current net force to produce a new net force of zero. Therefore, this additional force would have to be to the right. Since, q_3 and this new charge are both positively charged, and like charges repel, placing this new charge to the left of charge q_3 would create a force to the right.

2. (a)

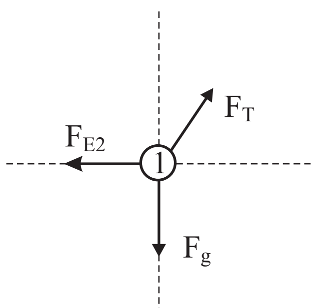


(b) $V_A = V_{1A} + V_{2A} = k\dfrac{Q}{r_A} + k\dfrac{Q}{r_B}$ Note: $r_A = r_B = L\sin\theta$

$$V_A = \frac{kQ}{L\sin\theta} + \frac{kQ}{L\sin\theta}$$

$$\boxed{V_A = \frac{2kQ}{L\sin\theta}}$$

(c)



(d) $\Sigma F_x = F_{Tx} - F_{E2} = 0$
$\Sigma F_y = F_{Ty} - F_g = 0$

3. (a)

__X__ Positive ____ Negative

Since q_1 is negative, the electric field due to this charge at point P is to the right. If the net electric field is to be zero at point P, then the field from charge q_2 must be equal but **OPPOSITE**. A positive charge for q_2 would produce an electric field that is to the left at point P.

(b) $\Sigma E = E_1 - E_2 = 0$

$$k\frac{q_1}{r_1} = k\frac{q_2}{r_2}$$

$$\frac{3.0 \text{ x } 10^{-9}\text{ C}}{0.10\text{ m}} = \frac{q_2}{0.30\text{ m}}$$

$$\boxed{q_2 = 9 \text{ x } 10^{-9}\text{ C}}$$

(c) $E_{21} = k\frac{q_1}{r_1} = \left(9.0 \text{ x } 10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2\right)\frac{-3.0 \text{ x } 10^{-9}\text{ C}}{0.30\text{ m}}$

$$\boxed{E_{21} = -90\text{ N/C}}$$

(d) $V_{\text{NET}} = V_2 - V_1 = 0$ Note: $r_1 + r_2 = 0.30\text{ m}$, so $r_1 = 0.30\text{ m} - r_2$

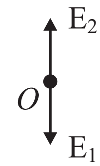
$$k\frac{q_2}{r_2} = k\frac{q_1}{r_1}$$

$$\frac{9.0 \text{ x } 10^{-9}\text{ C}}{r_2} = \frac{3.0 \text{ x } 10^{-9}\text{ C}}{0.30\text{ m} - r_2}$$

$r_2 = -0.225$ m. So, zero potential would occur 0.225 m to the left of q_2 which would be at position $\boxed{-0.05\text{ m}}$ on the x-axis.

(e) Zero work because $W = q\Delta V$ and the potential at an infinite distance away is zero, so $\Delta V = 0$. Therefore, the work done in bringing an electron from infinity to this zero-potential point would be zero.

3. (a) $E_{NET} = E_2 - E_1 = k\frac{Q_2}{r^2} - k\frac{Q_1}{r^2} = k\frac{+2q}{a^2} - k\frac{+q}{a^2}$



$$\boxed{E_{NET} = k\frac{q^2}{a^2}}$$

(b) $V_{NET} = V_1 + V_2 = k\frac{Q_1}{r_1} + k\frac{Q_2}{r_2} = k\frac{+q}{a} + k\frac{+2q}{a}$

$$\boxed{V_{NET} = k\frac{3q^2}{a}}$$

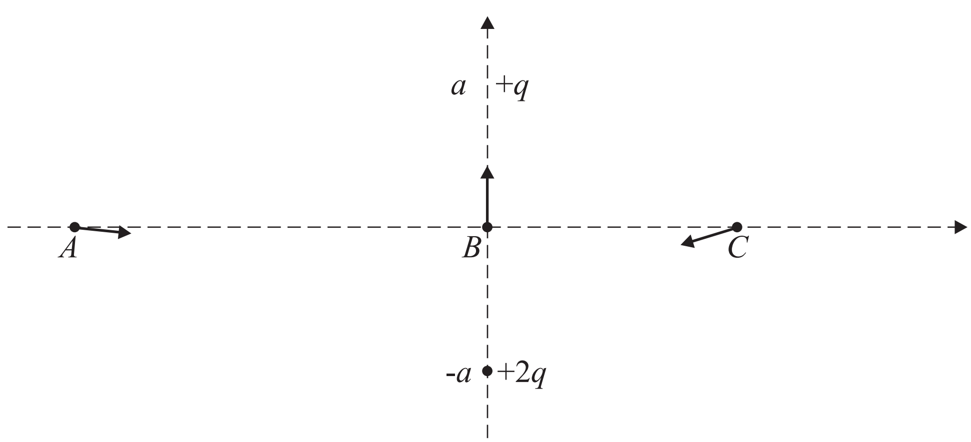
(c) i. $F_{31} = k\frac{Q_1Q_3}{r_{31}^{\ 2}} = k\frac{(+q)(-q)}{\left(\sqrt{a^2 + x_0^{\ 2}}\right)^2}$

$$\boxed{F_{31} = -k\frac{q^2}{a^2 + x_0^{\ 2}}}$$

ii. $F_{32} = k\frac{Q_2Q_3}{r_{32}^{\ 2}} = k\frac{(+2q)(-q)}{\left(\sqrt{a^2 + x_0^{\ 2}}\right)^2}$

$$\boxed{F_{32} = -k\frac{2q^2}{a^2 + x_0^{\ 2}}}$$

(d)



3. (a) i. Let d be the length of the diagonal of this square.

$s^2 + s^2 = d^2$

$2s^2 = d^2$

$d = \sqrt{2}\, s$

let r = the distance from any of the corners of the square to the center (these are equidistance).

$r = ½d = \frac{\sqrt{2}}{2} s$

$$V_{total} = V_1 + V_2 + V_3 + V_4 = k\frac{q_1}{r} + k\frac{q_2}{r} + k\frac{q_3}{r} + k\frac{q_4}{r} = k\frac{+Q}{r} + k\frac{-Q}{r} + k\frac{+Q}{r} + k\frac{-Q}{r}$$

$$\boxed{V_{total} = 0\ \text{V}}$$

ii. E_{total} = 0 N/C since the x-components will add to zero and the y-components will add to zero due to the symmetrical arrangement of the charges.

(b) i. $V_{total} = V_1 + V_2 + V_3 + V_4\ \ k\frac{q_1}{r} + k\frac{q_2}{r} + k\frac{q_3}{r} + k\frac{q_4}{r} = k\frac{+Q}{r} + k\frac{+Q}{r} + k\frac{-Q}{r} + k\frac{-Q}{r}$

$$\boxed{V_{total} = 0\ \text{V}}$$

ii. The y-components of the total electric field will add to zero due to the symmetrical arrangement of the charges. However, all of the x-components will be equal in magnitude and have direction to the right. The electric field is always away from a positive charge and toward the negative charges.

$E_{total} = E_{totalx} = E_{1x} + E_{2x} + E_{3x} + E_{4x} = E_{1x} + E_{1x} + E_{1x} + E_{1x} = 4E_{1x}$, since $E_{1x} = E_{2x} = E_{3x} = E_{4x}$

$$E_{total} = 4k\frac{Q}{r^2} = 4k\frac{Q}{\left(\frac{\sqrt{2}}{2}s\right)^2} = 4k\frac{Q}{\frac{2}{4}s^2}$$

$$\boxed{E_{total} = 8k\frac{Q}{s^2}}$$

(c) __**X**__ Arrangement 1

Calculations for the total potential difference for Arrangement 1:

$$\Delta V_1 = V_{total1} - 0 = V_1 + V_2 + V_3 = k\frac{q_1}{s} + k\frac{q_2}{s} + k\frac{q_3}{s} = k\frac{+Q}{s} + k\frac{-Q}{\sqrt{2}s} + k\frac{+Q}{s} = k\frac{\sqrt{2}Q}{\sqrt{2}s} - k\frac{Q}{\sqrt{2}s} + k\frac{\sqrt{2}Q}{\sqrt{2}s}$$

$$\Delta V_1 = k\frac{(2\sqrt{2}-1)Q}{\sqrt{2}s} = 1.29k\frac{Q}{s}$$

$$\Delta V_2 = V_{total2} - 0 = k\frac{q_1}{s} + k\frac{q_2}{s} + k\frac{q_3}{s} = k\frac{+Q}{s} + k\frac{-Q}{s} + k\frac{+Q}{\sqrt{2}s}$$

$$\Delta V_2 = k\frac{Q}{\sqrt{2}s}$$

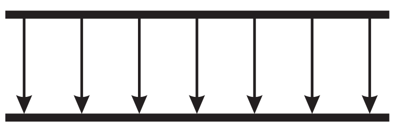
This shows that $\Delta V_1 > \Delta V_2$. Since $W = q\Delta V$, arrangement 1 will require more work to remove the particle at the upper right corner from its present position to a distance a long way away from the arrangement.

7. (a)

__ Positive **X** Negative __ Neutral __ It cannot be dtermined from this information.

The right-hand rule (put your fingers in the direction of the moving charged particles, rotate your wrist until your fingers can curl in the direction of the magnetic field, and your thumb will indicate the direction of the magnetic force on the moving charges, thus, the direction of the center of the circular path followed by these moving charges) is for positive charges. Applying the right-hand rule to these charges gives a direction toward the center of the circular path that is toward the top of the page which is opposite that shown in the diagram. [or the left-hand rule would give the results in the diagram].

(b)



(c) In the region between the plates both a magnetic force and electrostatic force are acting on the moving charges.

$\Sigma F = F_m - F_e = ma = 0$

$qvB = qE$

$E = vB = (1.96 \times 10^6 \text{ m/s})(0.20 \text{ T})$

$E = 3.8 \times 10^5 \text{ V/m}$

$V = Ed = (3.8 \times 10^5 \text{ V/m})(6.0 \times 10^{-3} \text{ m})$

$\boxed{V = 2.28 \times 10^3 \text{ V} = 2280 \text{ V}}$

(d) In the region outside the plates only a magnetic force is acting on the moving charges resulting in circular motion.

$\Sigma F = F_m = F_c$

$qvB = m\frac{v^2}{R}$

$\frac{q}{m} = \frac{v}{BR} = \frac{1.9x10^6\, m/s}{(0.20T)(0.10m)}$

$\boxed{\frac{q}{m} = 9.5 \times 10^7 \text{ C/kg}}$

Units Analysis:

$$\frac{1}{Ts} = \frac{1}{(N/A \bullet M) \bullet s} = \frac{A \bullet m}{N \bullet s} = \frac{\frac{C}{s}m}{(kg\frac{m}{s^2})s} = \frac{C}{kg}$$