SHOW ALL WORK!

A. Four charges are placed at the corners of a square with sides of length 2a that is centered at the origin, as shown. Let a = 2.00 m and q = 3.00 μC.

1. [7 pts.] What is the magnitude of the electric field at point A (at the origin)?
2. [7 pts.] What is the direction of the electric field at point B, (x,y) = (a,0)?

B. A configuration of four charges is shown in the figure. Let \( Q_1 = +9 \mu C \), \( Q_2 = -11 \mu C \), \( Q_3 = +6 \mu C \), and \( Q_4 = +2 \mu C \). The distance \( a = 2.00 \text{ cm} \), and the distance \( d = 5.00 \text{ cm} \).

1. [12 pts.] What is the y-component of the electric force acting on charge \( Q_4 \)?
2. [12 pts.] What is the magnitude of the electric field at a point halfway between charge \( Q_2 \) and \( Q_3 \)?
Problem 1

B 2. Find \( E \) at midpoint of \( q_2, q_4 \).

\[
E = \frac{kq_1}{r^2} \hat{r}
\]

\[
E_{1x} = \frac{kq_1}{r_1^2} \cos \Theta = \frac{(8.99 \times 10^9)(9 \times 10^{-6}) \cos 38.7^\circ}{0.02^2} \approx 6.16 \times 10^7 \text{ N/C}
\]

\[
E_{1y} = \frac{kq_1}{r_1^2} \sin \Theta = -4.43 \times 10^7 \text{ N/C} \hat{y}
\]

\[
E_{3x} = \frac{kq_3}{r_3^2} \cos \Theta = \frac{(8.99 \times 10^9)(6 \times 10^{-6}) \cos 38.7^\circ}{0.02^2} \approx 4.11 \times 10^7 \text{ N/C} \hat{x}
\]

\[
E_{3y} = \frac{kq_3}{r_3^2} \sin \Theta = 3.29 \times 10^7 \text{ N/C} \hat{y}
\]

\[
E_z = E_{2x} = \frac{kq_2}{(d/2)^2} = \frac{(8.99 \times 10^9)(-11 \times 10^{-6})}{0.025^2} \approx -1.58 \times 10^7 \text{ N/C} \hat{z}
\]

\[
E_y = E_{4x} = \frac{-kq_4}{(d/2)^2} = \frac{(8.99 \times 10^9)(2 \times 10^{-6})}{0.025^2} = -2.88 \times 10^7 \text{ N/C} \hat{z}
\]

\[
E_x = E_{1x} - E_{3x} - E_{4x} = 6.16 \times 10^7 - 1.58 \times 10^7 + 4.11 \times 10^7 - 2.88 \times 10^7
\]

\[
E_x = -8.43 \times 10^7 \text{ N/C}
\]

\[
E_y = E_{1y} + E_{3y} = -4.43 \times 10^7 + 3.29 \times 10^7
\]

\[
E_y = -1.64 \times 10^7 \text{ N/C}
\]

\[
|E| = \sqrt{E_x^2 + E_y^2} = 8.58 \times 10^7 \text{ N/C}
\]
SHOW ALL WORK!

A. The figure shows electric field lines for a system of two point charges, A and B. Three positions, labeled 1, 2, and 3, are also marked.

1. [7 pts.] What are the signs of the charges? How do you know?
2. [7 pts.] Which charge has the greater magnitude, or do the charges have the same magnitude? How do you know?

B. Three charges, \( Q_A = +3 \mu C, Q_B = -2 \mu C, \) and \( Q_C = +2 \mu C, \) are placed in the configuration as shown. The separation \( s_1 = 7 \text{ cm} \), and the separation \( s_2 = 3.5 \text{ cm} \).

1. [12 pts.] Calculate the work done by the electrostatic force when this charge configuration is assembled from infinity.
2. [12 pts.] Calculate the electric potential at the point halfway between \( Q_A \) and \( Q_B \).

\[
1) W = -\Delta U; \quad \Delta U = \frac{Kq_A q_B}{s_1} + \frac{Kq_A q_C}{s_{1/2}} + \frac{Kq_B q_C}{s_2} \\
= K \left( \frac{(3)(-2)(\mu C)^2}{7 \times 10^{-2} \text{ m}} + \frac{(3)(2)(\mu C)^2}{10.5 \times 10^{-2} \text{ m}} + \frac{(-2)(2)(\mu C)^2}{3.5 \times 10^{-2} \text{ m}} \right) \\
= (9 \times 10^9) \frac{10^{-2}}{10^{-1}} \left( \frac{6}{7} + \frac{6}{10.5} - \frac{4}{3.5} \right) = -1.284 \text{ mJ} \\
\text{and} \quad W = -\Delta U = 1.284 \text{ mJ} \\

2) V = \frac{Kq_A}{s_{1/2}} + \frac{Kq_B}{s_{1/2}} + \frac{Kq_C}{s_{1/2} + s_2} = 4K \left( \frac{3\mu C}{3.5 \times 10^{-2} \text{ m}} + \frac{-2\mu C}{3.5 \times 10^{-2} \text{ m}} + \frac{2\mu C}{7 \times 10^{-2} \text{ m}} \right) \\
= 8.5 \times 10^5 \text{ V} \]
SHOW ALL WORK!

A point charge \( Q = -5.00 \mu C \) is located at the origin of an x,y coordinate plane. Concentric with the point charge is a thick conducting spherical shell with inner radius \( a_1 = 3 \text{ cm} \) and outer radius \( a_2 = 4 \text{ cm} \). The conducting shell has zero net charge (\( Q_c = 0 \)). Concentric with these is a thin insulating spherical shell with radius \( a_3 = 9 \text{ cm} \). The insulating shell has a uniform surface charge density. The net charge on the conducting shell is \( Q_{nc} = +17 \mu C \).

A. [12 pts.] What is the electric field at point \( P \) (10 cm from the origin)?

B. [12 pts.] What is the surface charge density on the outer surface of the conducting shell?

\[ A. \quad \mathbf{E} \cdot dA = \frac{Q_{\text{enclosed}}}{\varepsilon_0} \]

\[ E = \frac{Q + Q_c}{4\pi \varepsilon_0 r^2} = \frac{-5 \mu C + 17 \mu C}{4\pi \varepsilon_0 (0.1 \text{ m})^2} = 1.08 \times 10^7 \text{ N/C} \]

\[ B. \quad \text{In the conductor } \mathbf{E} = 0 \Rightarrow Q_{\text{enclosed inside the conductor}} = 0 \Rightarrow Q_{\text{point}} + Q_{\text{inner } c} = 0 \]

\[ \text{For the conductor } Q_{\text{net}} = 0 = Q_{\text{inner } c} + Q_{\text{outer } c} \Rightarrow Q_{\text{outer}} = Q_{\text{point}} \]

\[ \sigma = \frac{Q_{\text{surface}}}{4\pi a_2^2} = \frac{Q_{\text{point}}}{4\pi (0.09 \text{ m})^2} = 2.49 \times 10^4 \text{ C/m}^2 \]