Quiz 1

Problem 1

(a) Possible positions for charge 3 are on the left side of the two charges.

\[ \vec{F} = 0 \]

\[ \frac{Q_0 Q_2}{(X_2 - X_0)^2} + \frac{Q_0 Q_3}{(X_3 - X_0)^2} = 0 \]

\[ \frac{\sqrt{Q_2}}{X_2 - X_0} = \frac{\pm \sqrt{Q_1}}{X_3 - X_0} \]

\[ X_2 = \pm \frac{\sqrt{Q_2}}{\sqrt{Q_1}} (X_3 - X_0) + X_0 \]

\[ X_0 = 0 \]

\[ \Rightarrow X_2 = \pm \frac{\sqrt{Q_2}}{\sqrt{Q_1}} X_0 \]

Since \( X_2 < 0 \), \( X_0 = -\frac{\sqrt{Q_2}}{\sqrt{Q_1}} X_0 \)
So \( X_2 = -X_1 \), when \( Q_2 = Q_1 \),
\[ X_2 = \frac{-Q_1}{x_1} \], \( Q_2 = 2Q_1 \),

(b)

Using the superposition principle

For \( Q_2 = Q_1 \),

\[ U(x) = \frac{Q_0 Q_1}{|x_2 - x_1|} + \frac{Q_0 Q_1}{|x_2 + x_1|} \]

\[ = \frac{Q_0 Q_1}{|x_1 + x_1|} + \frac{Q_0 Q_1}{|x_1 - x_1|} \]

\[ U(0) = \frac{2Q_1 Q_0}{|x_1|} \]

\[ U(x) - U(0) = Q_0 Q_1 \left( \frac{1}{|x_1 + x_1|} + \frac{1}{|x_1 - x_1|} \right) - \frac{2Q_1 Q_0}{|x_1|} \]

\[ U(x) - U(0) \frac{2Q_1 Q_0}{|x_1|} \]
(c) In this case, the total force will point to the right, so the \( Q \) will move toward the positive \( x \) direction.
Problem 2.
If the object doesn't carry a third type of charge, only positive or negative, then if I measure the forces between it and a positive charge, and the force between it and a negative charge, the two forces will be in the different direction. Otherwise, if the forces are both repulsive or attractive, then there must be something new on the charges.
(a) If $-Q$ was made more negative, the net force may be reversed. Then, if you rotate it again, it will move away from the original orientation.
Problem 4

(a) According to Gaussian theorem,
\[ E(r) = 0 \quad \text{for} \quad r < r_0 \]
when \( r > r_0 \).
\[ E = \frac{\psi}{\varepsilon_0 r} \]

(b)\[ V(r) = \int_{-\infty}^{r} \mathcal{E} \, dr = \mathcal{E} \int_{-\infty}^{r} \, dr \]
if \( r < r_0 \), \( V(r) = V(r_0) \)
if \( r > r_0 \), \( V(r) = V(0) - \frac{\psi}{\varepsilon_0 r} \log \frac{r}{r_0} \)
if \( r < r_0 \), \( V(r) = V(0) \)