12. (a) The distance between q_1 and q_2 is

$$r_{12} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} = \sqrt{(-0.020 - 0.035)^2 + (0.015 - 0.005)^2} = 0.0559 \text{ m} .$$

The magnitude of the force exerted by q_1 on q_2 is

$$F_{21} = k\frac{|q_1 q_2|}{r_{12}^2} = \frac{\left(8.99 \times 10^9\right)\left(3.0 \times 10^{-6}\right)\left(4.0 \times 10^{-6}\right)}{0.0559^2} = 34.5 \text{ N} .$$

The vector $\vec{F}_{21}$ is directed towards q_1 and makes an angle θ with the $+x$ axis, where

$$\theta = \tan^{-1}\left(\frac{y_2 - y_1}{x_2 - x_1}\right) = \tan^{-1}\left(\frac{1.5 - 0.5}{-2.0 - 3.5}\right) = -10.3^\circ .$$

(b) Let the third charge be located at (x_3, y_3), a distance r from q_2. We note that q_1, q_2 and q_3 must be colinear; otherwise, an equilibrium position for any one of them would be impossible to find. Furthermore, we cannot place q_3 on the same side of q_2 where we also find q_1, since in that region both forces (exerted on q_2 by q_3 and q_1) would be in the same direction (since q_2 is attracted to both of them). Thus, in terms of the angle found in part (a), we have $x_3 = x_2 - r\cos\theta$ and $y_3 = y_2 - r\sin\theta$ (which means $y_3 > y_2$ since θ is negative). The magnitude of force exerted on q_2 by q_3 is $F_{23} = k|q_2 q_3|/r^2$, which must equal that of the force exerted on it by q_1 (found in part (a)). Therefore,

$$k\frac{|q_2 q_3|}{r^2} = k\frac{|q_1 q_2|}{r_{12}^2} \implies r = r_{12}\sqrt{\frac{q_3}{q_1}} = 0.0645 \text{ cm} .$$

Consequently, $x_3 = x_2 - r\cos\theta = -2.0\,\text{cm} - (6.45\,\text{cm})\cos(-10.3^\circ) = -8.4\,\text{cm}$ and $y_3 = y_2 - r\sin\theta = 1.5\,\text{cm} - (6.45\,\text{cm})\sin(-10.3^\circ) = 2.7\,\text{cm}$.