Solutions to Exercise Problems — Class-1 — Summer-2025

Incepting Ideas (3-Top question)

Steps to follow:

- Draw the vector diagram. Label the source charges and the force vectors on the observer charge accurately. This is done for you in the slides. Refer to page-11 of Class-1.
- Find the individual force vectors on q_3 in unit vector notation applied by source charges q_1 and q_2:

$$
\begin{aligned}
\vec{F}_{31} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1 q_3|}{r_{13}^2}\right)\hat{i}\right]\,\mathrm{N} \\
\vec{F}_{32} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2 q_3|}{r_{23}^2}\right)\{-\hat{i}\}\right]\,\mathrm{N}, \\
\text{where }\; q_1 &= +2\times10^{-9}\,\mathrm{C},\; q_2 = -2\times10^{-9}\,\mathrm{C}, \\
q_3 &= +3\times10^{-9}\,\mathrm{C},\; r_{13} = 40\times10^{-2}\,\mathrm{m} \\
r_{23} &= 20\times10^{-2}\,\mathrm{m},\;\; \&\; C = \frac{1}{4\pi\epsilon_0} = 8.988\times10^{9}\,\mathrm{N\,m^2\,C^{-2}}.
\end{aligned}
$$

- Superpose the vectors to get the net force on q_3 as $\vec{F}_3$:

$$
\begin{aligned}
\vec{F}_3 &= \vec{F}_{31} + \vec{F}_{32} \\
&= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1 q_3|}{r_{13}^2}\right)\hat{i} - \left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2 q_3|}{r_{23}^2}\right)\hat{i}\right]\,\mathrm{N} \\
&= \left[3.3705\times10^{-7}\hat{i} - 1.3482\times10^{-6}\hat{i}\right]\,\mathrm{N} \\
&= \underbrace{\left(1.01115\times10^{-6}\,\mathrm{N}\right)}_{\text{magnitude}}\;\underbrace{\{-\hat{i}\}}_{\text{direction}}.
\end{aligned}
$$

Incepting Ideas (6-Top question)

Steps to follow:

- Draw the vector diagram. Label the source charges and the force vectors on the observer charge accurately. This is done for you in the slides. Refer to page-14 of Class-1.
- Find the individual force vectors on q_3 in unit vector notation applied by source charges q_1 and q_2:

$$
\begin{aligned}
\vec{E}_{31} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{13}^2}\right)\hat{i}\right]\,\mathrm{N\,C^{-1}} \\
\vec{E}_{32} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2|}{r_{23}^2}\right)\{-\hat{i}\}\right]\,\mathrm{N\,C^{-1}}, \\
\text{where }\; q_1 &= +2\times10^{-9}\,\mathrm{C},\; q_2 = -2\times10^{-9}\,\mathrm{C}, \\
r_{13} &= 40\times10^{-2}\,\mathrm{m},\; r_{23} = 20\times10^{-2}\,\mathrm{m},\;\; \&\; C = \frac{1}{4\pi\epsilon_0} = 8.988\times10^{9}\,\mathrm{N\,m^2\,C^{-2}}.
\end{aligned}
$$

- Superpose the vectors to get the net electric field $\vec{E}$:

$$
\begin{aligned}
\vec{E} &= \vec{E}_{31} + \vec{E}_{32} \\
&= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{13}^2}\right)\hat{i} - \left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2|}{r_{23}^2}\right)\hat{i}\right]\,\mathrm{N\,C^{-1}} \\
&= \left[112.35\hat{i} - 449.4\hat{i}\right]\,\mathrm{N\,C^{-1}} \\
&= \underbrace{\left(337.05\,\mathrm{N\,C^{-1}}\right)}_{\text{magnitude}}\;\underbrace{\{-\hat{i}\}}_{\text{direction}}.
\end{aligned}
$$

Incepting Ideas (3-Bottom question)

Steps to follow:

- Draw the vector diagram. Label the source charges and the force vectors on the observer charge accurately. This is done for you in the slides. Refer to page-11 of Class-1.
- Find the individual force vectors on q_4 in unit vector notation applied by source charges q_1, q_2 and q_3:

$$\begin{aligned}
\vec{F}_{41} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1q_4|}{r_{14}^2}\right)\hat{j}\right]\text{ N}\\
\vec{F}_{42} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1q_4|}{r_{43}^2}\right)\hat{r}\right]\text{ N}\\
&= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1q_4|}{r_{43}^2}\right)\left(\cos 315^\circ\hat{\imath}+\sin 315^\circ\hat{\jmath}\right)\right]\text{ N}\\
\vec{F}_{43} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2q_4|}{r_{24}^2}\right)\{-\hat{\imath}\}\right]\text{ N},\\
\text{where }\ q_1 &= +2\times10^{-9}\,\text{C},\ q_2=-2\times10^{-9}\,\text{C},\\
q_3 &= +3\times10^{-9}\,\text{C},\ q_4=+1\times10^{-9}\,\text{C}\\
r_{13} &= 40\times10^{-2}\,\text{m},\ r_{23}=20\times10^{-2}\,\text{m},\\
\&\ C &= \frac{1}{4\pi\epsilon_0}=8.988\times10^{9}\,\text{N}\,\text{m}^2\,\text{C}^{-2}
\end{aligned}$$

Note: 315° angle is made by $\vec{F}_{43}$ counterclockwise with the $+x$-axis

You can also use -90° clockwise with the $+x$-axis.

Use either with the correct sign and your calculator with take care of the rest.

- Superpose the vectors to get the net force on q_4 in unit vector notation as $\vec{F}_4$:

$$\begin{aligned}
\vec{F}_4 &= \vec{F}_{41}+\vec{F}_{42}+\vec{F}_{43}\\
&= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1q_4|}{r_{13}^2}\right)\hat{j}+\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1q_4|}{r_{43}^2}\right)\cdot\left(\cos 315^\circ\hat{\imath}+\sin 315^\circ\hat{\jmath}\right)-\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2q_4|}{r_{23}^2}\right)\hat{\imath}\right]\text{ N}\\
&= \left[449.4\hat{\jmath}+158.887\hat{\imath}-158.887\hat{\jmath}-674.1\hat{\imath}\right]\text{ N}\\
&= \underbrace{\left(-515.213\hat{\imath}+290.513\hat{\jmath}\right)}_{\text{magnitude and direction}}\text{ N};\ \text{ this points in the 2}^{\text{nd}}\text{ quadrant since }\left(F_x,F_y\right)\to(-,+).
\end{aligned}$$

$$\begin{aligned}
|\vec{F}_4| &= \sqrt{(-515.213\,\text{N})^2+(290.513\,\text{N})^2}\\
&= \underbrace{591.475\,\text{N}}_{\text{magnitude only}}\ .\\
\theta &= 180^\circ-\tan^{-1}\left|\frac{290.513\,\text{N}}{-515.213\,\text{N}}\right|\\
&= 180^\circ-29.42^\circ\\
&= \underbrace{150.583^\circ}_{\text{direction only}}\ ;\text{ measured counterclockwise with }+x\text{-axis.}
\end{aligned}$$

Incepting Ideas (6-Bottom question)

Steps to follow:

- Draw the vector diagram. Label the source charges and the force vectors on the observer charge accurately. This is done for you in the slides. Refer to page-11 of Class-1.

- Find the individual electric field vectors at q_4 due to source charges q_1 and q_2:

$$
\begin{aligned}
\vec{E}_{41} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{14}^2}\right)\hat{j}\right]\,\mathrm{N\,C^{-1}}\\
\vec{E}_{42} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{43}^2}\right)\hat{r}\right]\,\mathrm{N\,C^{-1}}\\
&= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{43}^2}\right)\left(\cos 315^\circ\hat{\imath}+\sin 315^\circ\hat{\jmath}\right)\right]\,\mathrm{N\,C^{-1}}\\
\vec{E}_{43} &= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2|}{r_{24}^2}\right)\{-\hat{\imath}\}\right]\,\mathrm{N\,C^{-1}},
\end{aligned}
$$

$$
\begin{aligned}
\text{where }\; q_1 &= +2\times10^{-9}\,\mathrm{C},\; q_2 = -2\times10^{-9}\,\mathrm{C},\\
q_4 &= +1\times10^{-9}\,\mathrm{C},\\
r_{13} &= 40\times10^{-2}\,\mathrm{m},\; r_{23} = 20\times10^{-2}\,\mathrm{m},\\
\&\; C &= \frac{1}{4\pi\epsilon_0} = 8.988\times10^{9}\,\mathrm{N\,m^2\,C^{-2}}
\end{aligned}
$$

Note: 315° angle is made by $\vec{E}_{42}$ counterclockwise with the $+x$-axis

You can also use -90° clockwise with the $+x$-axis.

Use either with the correct sign and your calculator will take care of the rest.

- Superpose the vectors to get the net electric field at q_4 as $\vec{E}_4$:

$$
\begin{aligned}
\vec{E}_4 &= \vec{E}_{41}+\vec{E}_{42}+\vec{E}_{43}\\
&= \left[\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{13}^2}\right)\hat{j}+\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_1|}{r_{43}^2}\right)\cdot\left(\cos 315^\circ\hat{\imath}+\sin 315^\circ\hat{\jmath}\right)-\left(\frac{1}{4\pi\epsilon_0}\cdot\frac{|q_2|}{r_{23}^2}\right)\hat{\imath}\right]\,\mathrm{N\,C^{-1}}\\
&= \left[449.4\hat{\jmath}+158.887\hat{\imath}-158.887\hat{\jmath}-674.1\hat{\imath}\right]\,\mathrm{N\,C^{-1}}\\
&= \underbrace{\left(-515.213\hat{\imath}+290.513\hat{\jmath}\right)}_{\text{magnitude and direction}}\,\mathrm{N\,C^{-1}};\;\text{ this points in the 2}^{\text{nd}}\text{ quadrant since }\left(E_x,\,E_y\right)\to(-,+).
\end{aligned}
$$

$$
\begin{aligned}
|\vec{E}_4| &= \sqrt{(-515.213\,\mathrm{N\,C^{-1}})^2+(290.513\,\mathrm{N\,C^{-1}})^2}\\
&= \underbrace{591.475\,\mathrm{N\,C^{-1}}}_{\text{magnitude only}}.
\end{aligned}
$$

$$
\begin{aligned}
\theta &= 180^\circ-\tan^{-1}\left|\frac{290.513\,\mathrm{N\,C^{-1}}}{-515.213\,\mathrm{N\,C^{-1}}}\right|\\
&= 180^\circ-29.42^\circ\\
&= \underbrace{150.583^\circ}_{\text{direction only}}\;;\;\text{measured counterclockwise with }+x\text{-axis.}
\end{aligned}
$$