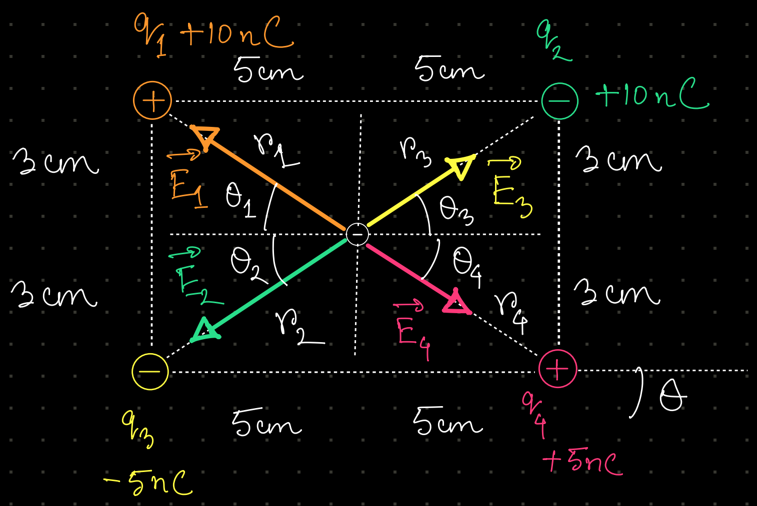
S8 Assignment #1.

1/ (a) Field lines are visual representations of how it behaves in 3D space. $\vec{E}$ is also vector field and is observer independent. $\vec{F_E}$ is not. It depends on the observer charge. It does not a physical existence.

(b)



$$\theta = \theta_1 = \theta_2 = \theta_3 = \theta_4$$
$$= \tan^{-1}\left(\frac{3}{5}\right)$$
$$= 30.96^\circ.$$

$$r_1 = r_2 = r_3 = r_4$$
$$= 5.83 \times 10^{-2}\, m.$$

$$E_1 = \left(\frac{c q_1}{r_1^2}\right) = 26442.608\ NC^{-1}.$$

$$E_2 = \left(\frac{c q_2}{r_2^2}\right) = 13221.304\ NC^{-1}.$$

$$E_3 = \left(\frac{c q_3}{r_3^2}\right) = 26442.608\ NC^{-1}.$$

$$E_4 = \left(\frac{c q_4}{r_4^2}\right) = 13221.304\ NC^{-1}.$$

$$\vec{E}_{net} = \vec{E_1} + \vec{E_2} + \vec{E_3} + \vec{E_4}$$
$$= E_1 \cos(\pi - \theta)\,\hat{i} + E_1 \sin(\pi - \theta)\,\hat{j}$$
$$+ E_2 \cos(\pi + \theta)\,\hat{i} + E_2 \sin(\pi + \theta)\,\hat{j}$$
$$+ E_3 \cos(\theta)\,\hat{i} + E_3 \sin(\theta)\,\hat{j}$$
$$+ E_4 \cos(2\pi - \theta)\,\hat{i} + E_4 \sin(2\pi - \theta)\,\hat{j}$$

$$= \{ -\cancel{22675.24}\,\hat{i} + 13603.12\,\hat{j} - \cancel{11337.62}\,\hat{i} - 6801.56\,\hat{j}$$

$$+ \cancel{22675.24}\,\hat{i} + 13603.12\,\hat{j} + \cancel{11337.62}\,\hat{i} - 6801.56\,\hat{j} \} \; NC^{-1}$$

$$= (27.21 \times 10^{3}\,\hat{j} - 13.60 \times 10^{3}\,\hat{j})\; NC^{-1}$$

$$\vec{E}_{net} = (\underbrace{13.67 \times 10^{3}}_{\text{magnitude}}\,\underbrace{\hat{j}}_{\text{direction}})\; NC^{-1}$$

$$\vec{F}_{net} = Q\,\vec{E}_{net} = (-3.0 \times 10^{-9}\,C) \times (13.67 \times 10^{3}\,\hat{j})\; NC^{-1}$$

$$= (\underbrace{-4.101 \times 10^{-5}}_{\text{magnitude}}\,\underbrace{\hat{j}}_{\text{direction}})\; N.$$

Note: If anybody calculated using the Coulomb force formula, it is acceptable as long as the answer matches.

2/ (a) A neutron in a uniform $\vec{E}$-field will not be deflected because it is chargeless.

(b) Say, the electron just misses the plates. Thus, it needs to clear $x - x_0 = 3 \times 10^{-2}\, m$ and $y - y_0 = \frac{3}{4} \times 10^{-2}\, m$.

Find the time it takes the electron to cross the $x - x_0$, horizontal distance. $t = \frac{x - x_0}{v_{x_0}} = \frac{3 \times 10^{-2}\,m}{2 \times 10^{6}\,ms^{-1}} = 15\ ns.$

Find the acceleration in that same time to cross the $y - y_0$, vertical distance.

$$y - y_0 = \cancel{v_{y_0}}^{0} t + \frac{1}{2} a_y t^2$$

$$\Rightarrow a_y = \frac{2(y - y_0)}{t^2} = 6.67 \times 10^{13}\ ms^{-2}.$$

This acceleration is caused by the uniform $\vec{E}$-field between the plates.

$$E = \frac{F}{q_e} = \frac{m_e a_y}{q_e} = 379.231\ NC^{-1}.$$

(c) $E_{new} = 5E = 1896.16\ NC^{-1}$.

Now lets imagine the proton hits the plate,

$$y - y_0 = \cancel{v_{y_0}}^{0} t + \frac{1}{2} a_y t^2$$

$$\Rightarrow t = \sqrt{\frac{2(y - y_0)}{a_y}}$$

$$\Rightarrow t = \sqrt{\frac{2(y - y_0)\,m_p}{q_p E_{new}}} \quad ; \quad a_y^{proton} = \frac{q_p E_{new}}{m_p}$$

$$= 2.87 \times 10^{-7}\,s.$$

At the same amount of time, find how much the proton horizontally travel.

$$x - x_0 = v_{x_0} t = 57.48\ cm.$$

The proton has far crossed the plates.

(d) Since proton and electrons are oppositely charged, their deflection direction is also opposite. The proton deflects downward (toward $\vec{E}$) and the electron deflects upward (opposite to $\vec{E}$).

Compare the electric forces involved:

$$F_E^{proton} = m_p a_p = 3.04 \times 10^{-16} N.$$

$$F_E^{electron} = m_e a_e = 3.04 \times 10^{-16} N.$$

Compare the gravitational forces involved:

$$F_g^{proton} = m_p g = 1.64 \times 10^{-26} N.$$

$$F_g^{electron} = m_e g = 8.94 \times 10^{-30} N.$$

In both cases, $F_g \ll F_E$. This is why it is reasonable to ignore the effects of gravity in our problem.