A proton enters a region of uniform electric field with an initial velocity of 80 km/s in the opposite direction as the electric field, which has magnitude E = 100 N/C.

(a) What is the acceleration of the proton?

\[ a = \frac{eE}{m} = \frac{(1.6 \times 10^{-9}) (100)}{1.67 \times 10^{-27}} = 9.6 \times 10^7 \text{ m/s}^2 \]

(b) What is the speed of the proton 1.5 ns after entering this region?

\[ v = v_0 - at = 80 \times 10^3 - 9.6 \times (10^9 \times 1.5 \times 10^{-9}) = 7.99 \times 10^4 \text{ m/s} \]

(c) How far does the proton travel during the 1.5 ns interval?

\[ x = x_0 + v_0 t - \frac{1}{2} at^2 = 80 \times 10^3 \times 1.5 \times 10^9 - \frac{1}{2} (9.6 \times 10^9) (1.5 \times 10^{-9})^2 = 1.2 \times 10^{-4} \text{ m} \]
An electric dipole with dipole moment \( \mathbf{p} = (3.00 \mathbf{i} + 4.00 \mathbf{j}) \times 10^{-30} \text{ C.m} \) is in an electric field \( \mathbf{E} = 4000 \mathbf{i} \text{ N/C} \).

(a) Calculate the potential energy of the electric dipole?

\[
U = -\mathbf{p} \cdot \mathbf{E} = - \left( (3 \mathbf{i} + 4 \mathbf{j}) \times 10^{-30} \right) \cdot (4000 \mathbf{i})
\]

\[
= -1.2 \times 10^{-26} \text{ J}
\]

(b) Calculate magnitude and direction of the torque acting on the dipole?

\[
\mathbf{T} = \mathbf{p} \times \mathbf{E}
\]

\[
\begin{vmatrix}
\hat{i} & \hat{j} & \hat{k} \\
3 \times 10^{-30} & 4 \times 10^{-30} & 0 \\
4000 & 0 & 0
\end{vmatrix}
= 0 \hat{i} + 0 \hat{j} - 1.6 \times 10^{-26} \hat{k}
\]

\[
\mathbf{T} = -1.6 \times 10^{-26} \hat{k} \text{ N.m}
\]

(c) If an external agent turns the dipole until its electric dipole moment is \((-3.00 \mathbf{i} + 4.00 \mathbf{j}) \times 10^{-30} \text{ C.m} \), how much work is done by the agent?

\[
W_{\text{app}} = \Delta U = U_f - U_i
\]

\[
U_f = -\mathbf{p}_f \cdot \mathbf{E} = 1.2 \times 10^{-26} \text{ J}
\]

\[
U_i = -1.2 \times 10^{-26} \text{ J}
\]

\[
W_{\text{app}} = 2.4 \times 10^{-26} \text{ J}
\]
In the figure, the two particles are fixed in place and have charges \( q_1 = +10 \, \text{nC} \) and \( q_2 = -15 \, \text{nC} \). The distance \( d = 10 \, \mu\text{m} \) and \( D = 20 \, \mu\text{m} \). What is the magnitude and direction of the net electric field at point P due to these particles?

\[
E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times (10 \times 10^{-9})}{(5 \times 10^{-6})^2 + (20 \times 10^{-6})^2} = 2.12 \times 10^7 \, \text{N/C}
\]

\[
E_2 = \frac{kq_2}{r^2} = \frac{9 \times 10^9 \times (15 \times 10^{-9})}{(5 \times 10^{-6})^2 + (20 \times 10^{-6})^2} = 3.18 \times 10^7 \, \text{N/C}
\]

\[
\theta = \tan^{-1} \left( \frac{20}{5} \right) = 76^\circ
\]

\[
E_{x, \text{net}} = E_1 \cos 76^\circ + E_2 \cos 76^\circ = 1.3 \times 10^7 \, \text{N/C}
\]

\[
E_{y, \text{net}} = E_1 \sin 76^\circ - E_2 \sin 76^\circ = -1.0 \times 10^7 \, \text{N/C}
\]

\[
\vec{E}_{\text{net}} = 1.3 \times 10^7 \hat{\jmath} - 1.0 \times 10^7 \hat{\imath} \, \text{N/C}
\]

Magnitude \( |\vec{E}_{\text{net}}| = 1.64 \times 10^7 \, \text{N/C} \)

\[
\theta = \tan^{-1} \left( \frac{1}{1.3} \right) = -37.6^\circ
\]
An electric dipole with dipole moment \( \mathbf{p} = (3.00 \hat{i} + 4.00 \hat{j}) \times 10^{-30} \) C.m is in an electric field \( \mathbf{E} = 4000 \) N/C.

(a) Calculate the potential energy of the electric dipole?

\[
U = -\mathbf{p} \cdot \mathbf{E} = - (3 \hat{i} + 4 \hat{j}) \times 10^{-30} \cdot (4000 \hat{k}) = -1.2 \times 10^{-26} \text{ J}
\]

(b) Calculate magnitude and direction of the torque acting on the dipole?

\[
\mathbf{\tau} = \mathbf{p} \times \mathbf{E} = \begin{vmatrix}
\hat{i} & \hat{j} & \hat{k} \\
3 \times 10^{-30} & 4 \times 10^{-30} & 0 \\
0 & 0 & 4000 \\
\end{vmatrix} = 0 \hat{i} + 0 \hat{j} - 1.6 \times 10^{-26} \hat{k} \text{ N.m}
\]

(c) If an external agent turns the dipole until its electric dipole moment is \((-3.00 \hat{i} + 4.00 \hat{j}) \times 10^{-30} \) C.m, how much work is done by the agent?

\[
\mathbf{\Delta W}_{\text{app}} = \Delta U = U_f - U_i
\]

\[
U_i = -\mathbf{p} \cdot \mathbf{E} = 1.2 \times 10^{-26} \text{ J}
\]

\[
U_f = -1.2 \times 10^{-26} \text{ J}
\]

\[
\mathbf{\Delta W}_{\text{app}} = 2.4 \times 10^{-26} \text{ J}
\]
In the figure, the two particles are fixed in place and have charges $q_1 = +10 \text{ nC}$ and $q_2 = -15 \text{ nC}$. The distance $d = 10 \mu\text{m}$ and $D = 20 \mu\text{m}$. What is the magnitude and direction of the net electric field at point P due to these particles?

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E_1 = \frac{k|q_1|}{r^2} = \frac{9 \times 10^9 \times (10 \times 10^{-9})}{(5 \times 10^{-6})^2 + (20 \times 10^{-6})^2} = 2.12 \times 10^7 \text{ N/C}
\]

\[
E_2 = \frac{k|q_2|}{r^2} = \frac{9 \times 10^9 \times (15 \times 10^{-9})}{(5 \times 10^{-6})^2 + (20 \times 10^{-6})^2} = 3.18 \times 10^7 \text{ N/C}
\]

\[
\theta = \tan^{-1}\left(\frac{20}{5}\right) = 76^\circ
\]

\[
E_{x,\text{net}} = E_1 \cos 76^\circ + E_2 \cos 76^\circ = 1.3 \times 10^7 \text{ N/C}
\]

\[
E_{y,\text{net}} = E_1 \sin 76^\circ - E_2 \sin 76^\circ = -1.0 \times 10^7 \text{ N/C}
\]

\[
\mathbf{E}_{\text{net}} = 1.3 \times 10^7 \hat{\mathbf{c}} - 1.0 \times 10^7 \hat{\mathbf{d}} \text{ N/C}
\]

Magnitude \( |\mathbf{E}_{\text{net}}| = 1.64 \times 10^7 \text{ N/C} \)

\[
\theta = \tan^{-1}\left(\frac{-1}{1.3}\right) = -37.6^\circ
\]