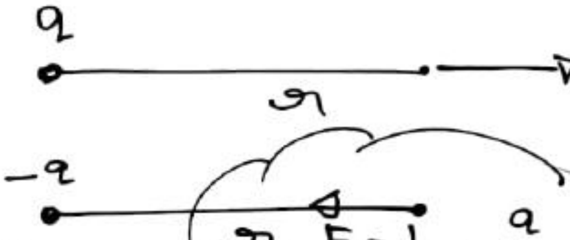
Electric field strength:-



$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

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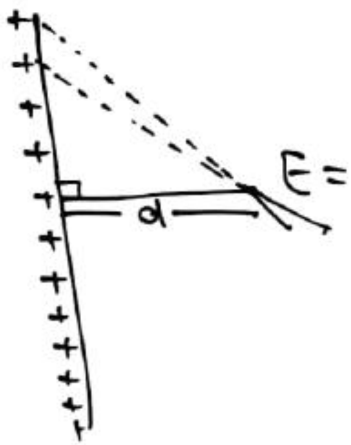
⟹ electric field is a vector quantity

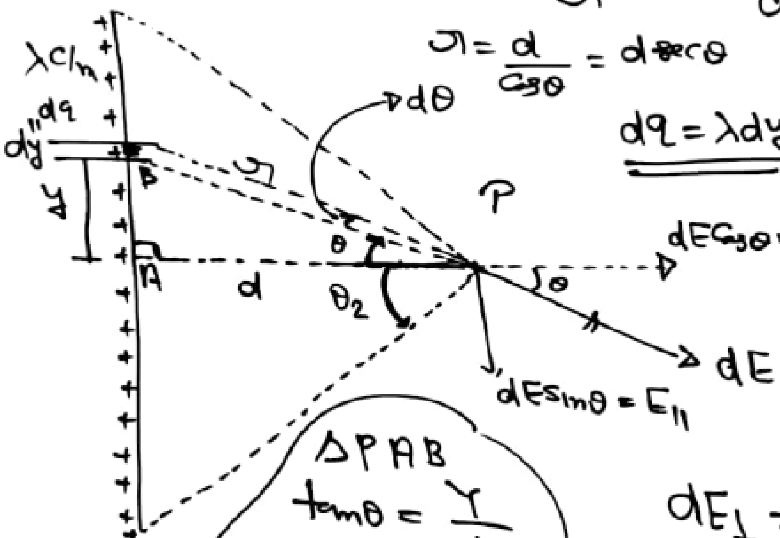
⟹ SI Unit $= \vec{E} = \frac{\vec{F}}{q_0} = N/C$

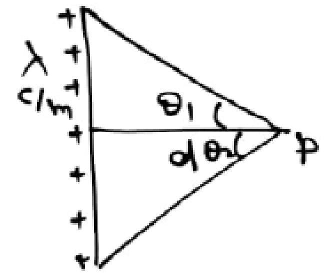
$$[E] = \frac{[MLT^{-2}]}{[AT]} = [MLT^{-3}A^{-1}]$$

Article 1:- Find Electric field due to ~~in~~ finite charged wire.



⇒ Electric field due to a finite wire at distance d from wire. Charge density of wire is λ.





$$\cos\theta = \frac{d}{r}$$

$$r = \frac{d}{\cos\theta} = d\sec\theta$$

$$dE = \frac{K\,dq}{r^2}$$

$$dE = K\frac{dq}{(d^2\sec^2\theta)}$$

$$K = \frac{1}{4\pi\varepsilon_0}$$

$$dq = \lambda dy$$

$$dE = \frac{K\lambda dy}{d^2\sec^2\theta}$$

$$dE_\perp = \frac{K\lambda dy\cos\theta}{d^2\sec^2\theta}$$

$$[dy = d\sec^2\theta\, d\theta]$$

$$dE_\perp = \frac{(K\lambda\cos\theta)\,d\sec^2\theta\, d\theta}{d^2\sec^2\theta}$$

$$dE_\perp = \frac{K\lambda}{d}\cos\theta\, d\theta$$

$$\int dE_\perp = \frac{K\lambda}{d}\int_{-\theta_2}^{\theta_1}\cos\theta\, d\theta \Rightarrow E_\perp = \frac{K\lambda}{d}\left[\sin\theta\right]_{-\theta_2}^{\theta_1}$$

$$E_\perp = \frac{K\lambda}{d}\left[\sin\theta_1 - (\sin(-\theta_2))\right]$$

$$E_\perp = \frac{K\lambda}{d}\left[\sin\theta_1 + \sin\theta_2\right]$$

ΔPAB

$$\tan\theta = \frac{y}{d}$$

$$y = d\tan\theta$$

$$dy = d\sec^2\theta \cdot d\theta$$

$$\sin(-\theta) = -\sin\theta$$

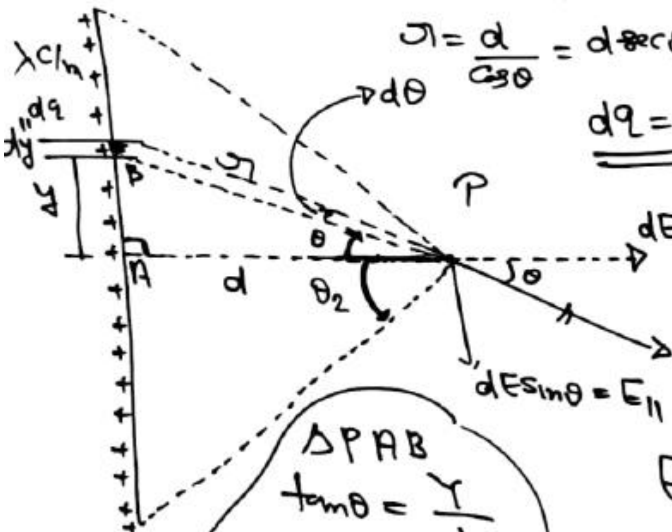
$$\frac{d}{d\theta}\sin\theta = \cos\theta$$

$$\frac{d}{d\theta}\cos\theta = -\sin\theta$$

$$\int \sin\theta\, d\theta = -\cos\theta$$

$$\int \cos\theta\, d\theta = \sin\theta$$

⇒ Electric field due to a finite wire at distance d from wire. Charge density of wire is λ. ③



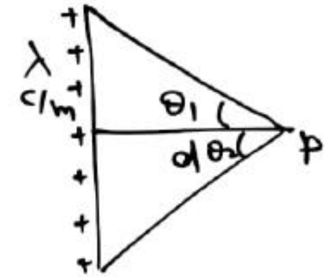
$\cos\theta = \frac{d}{r}$

$r = \frac{d}{\cos\theta} = d\sec\theta$

$dE = \frac{K\,dq}{r^2}$

$dE = K\frac{dq}{(d^2\sec^2\theta)}$

$K = \frac{1}{4\pi\varepsilon_0}$



$dq = \lambda\,dy$

$$dE = \frac{K\lambda\,dy}{d^2\sec^2\theta}$$

$$E_{\parallel} = dE\sin\theta = \frac{K\lambda\,dy}{d^2\sec^2\theta}\sin\theta = \frac{K\lambda\,d\sec^2\theta\,d\theta\,\sin\theta}{d^2\sec^2\theta}$$

$$\int E_{\parallel} = \frac{K\lambda}{d}\int_{-\theta_2}^{\theta_1}\sin\theta\,d\theta$$

$$E_{\parallel} = \frac{K\lambda}{d}\left[-\cos\theta\right]_{-\theta_2}^{\theta_1} = \frac{K\lambda}{d}\left[-\cos\theta_1 - (\cos(-\theta_2))\right]$$

$$E_{\parallel} = \frac{K\lambda}{d}\left[\cos\theta_2 - \cos\theta_1\right]$$

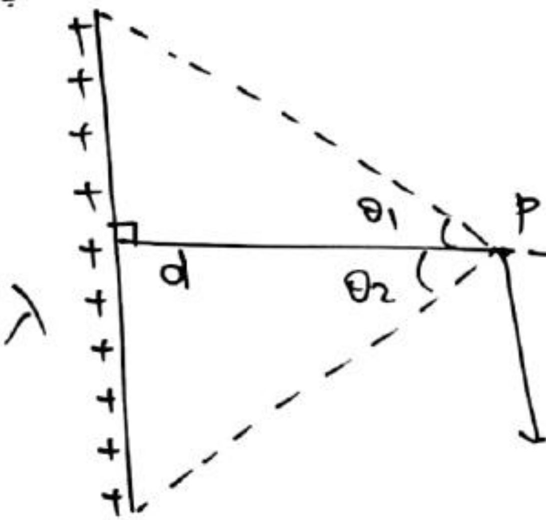
ΔPAB

$\tan\theta = \frac{Y}{d}$

$Y = d\tan\theta$

$dY = d\sec^2\theta\cdot d\theta$

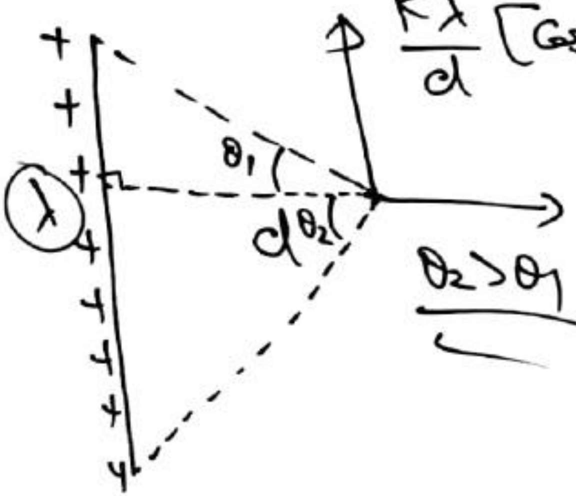
$\sin(-\theta) = -\sin\theta$



$$E_{\perp} = \frac{K\lambda}{d}\left(\sin\theta_1 + \sin\theta_2\right)$$

$$E_{\parallel} = \frac{K\lambda}{d}\left[\cos\theta_2 - \cos\theta_1\right]$$

$\equiv)$

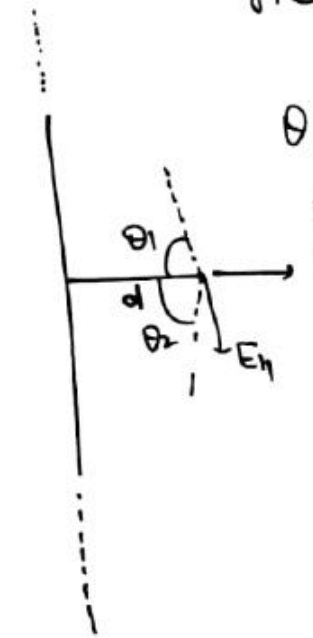


$$\frac{K\lambda}{d}\left[\cos\theta_2 - \cos\theta_1\right]$$

$$E_{\perp} = \frac{K\lambda}{d}\left(\sin\theta_1 + \sin\theta_2\right)$$

$\theta_2 > \theta_1$

Electoric field due to infinite charge wire:-



$\theta_1 = 90^\circ$

$\theta_2 = 90^\circ$

$$E_\perp = \frac{K\lambda}{d}\left[\sin\theta_1 + \sin\theta_2\right]$$

$$E_\perp = \frac{K\lambda}{d}\left[\sin 90 + \sin 90\right]$$

$$= \frac{\lambda}{4\pi\varepsilon_0 d}\left[1+1\right]$$

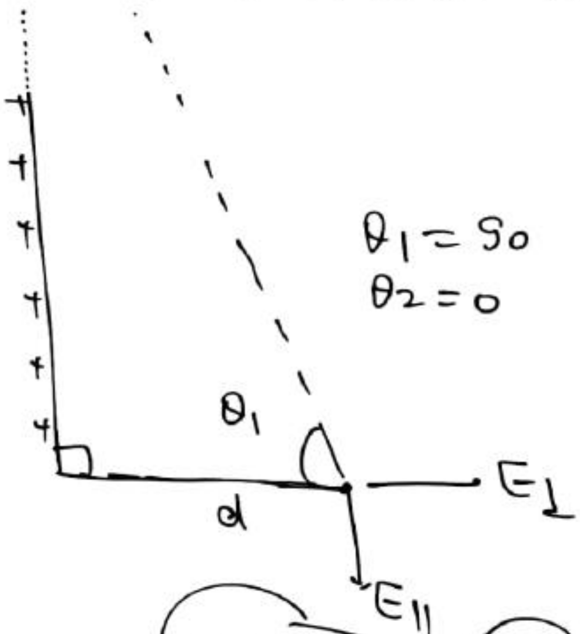
$$E_\perp = \frac{\lambda}{2\pi\varepsilon_0 d} = \frac{2K\lambda}{d}$$

$$E_{\parallel} = \frac{K\lambda}{d}\left[\cos\theta_2 - \cos\theta_1\right]$$

$$= \frac{K\lambda}{d}\left(\cos 90^\circ - \cos 90^\circ\right)$$

$$E_{\parallel} = 0$$

Electric field due to semi-infinite wire :-



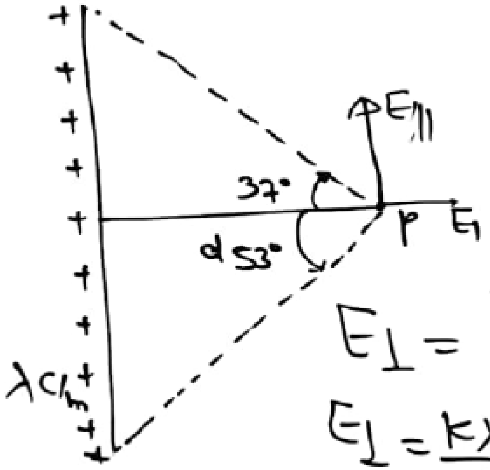
$\theta_1 = 90$
$\theta_2 = 0$

$$E_\perp = \frac{K\lambda}{d}\left[\sin\theta_1 + \sin\theta_2\right]$$
$$= \frac{K\lambda}{d}\left[\sin 90 + \sin 0^\circ\right]$$
$$= \frac{K\lambda}{d}\left[1 + 0\right] = \frac{K\lambda}{d} = \frac{\lambda}{4\pi\varepsilon_0 d}$$

$$E_\parallel = \frac{K\lambda}{d}\left[\cos\theta_2 - \cos\theta_1\right]$$
$$= \frac{K\lambda}{d}\left[\cos 0 - \cos 90^\circ\right]$$
$$E_\parallel = \frac{K\lambda}{d}\left[1 - 0\right] = \frac{K\lambda}{d} = \frac{\lambda}{4\pi\varepsilon_0 d}$$

$$|E_\perp| = |E_\parallel| = \frac{K\lambda}{d}$$

Q11 Find Electric field at point P. If $\lambda = 5\ C/m$ & $d = 2.5\ m$.



$\vec{E}_p = ?$

$\theta_1 = 37°$

$\theta_2 = 53°$

$E_{\perp} = \frac{K\lambda}{d}(\sin 37 + \sin 53)$

$E_{\perp} = \frac{K\lambda}{d}\left[\frac{3}{5} + \frac{4}{5}\right]$

$E_{\perp} = \frac{9\times10^9 \times 5}{2.5}\left[\frac{7}{5}\right]$

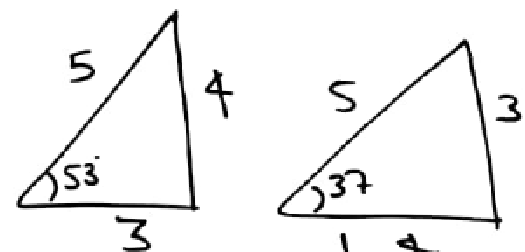
$E_{\perp} = 18\times10^9 \times \frac{7}{5}\ \hat{i}$

$E_{||} = \frac{K\lambda}{d}[\cos 53 - \cos 37]$

$= \frac{9\times10^9\times 5}{2.5}\left[\frac{3}{5} - \frac{4}{5}\right]$

$= 18\times10^9 \times \frac{1}{5}$

$= \frac{18}{5}\times10^9\ N/C$ ↑



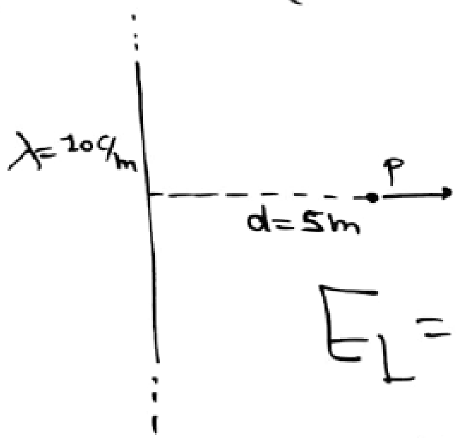
$\sin 53 = \frac{4}{5}$

$\cos 53 = \frac{3}{5}$

$\sin 37$

$\cos 37$

Q1: Infinite wire



$E_p = ?$

$\theta_1 = 90^\circ$

$\theta_2 = 90^\circ$

$$E_\perp = \frac{K\lambda}{d}\left[\sin\theta_1 + \sin\theta_2\right]$$

$$E_\parallel = \frac{K\lambda}{d}\left[\cos\theta_2 - \cos\theta_1\right]$$

$$E_\perp = \frac{K\lambda}{d}\left[\sin\theta_1 + \sin\theta_2\right]$$

$$= \frac{K\lambda}{d}\left[\sin 90^\circ + \sin 90^\circ\right]$$

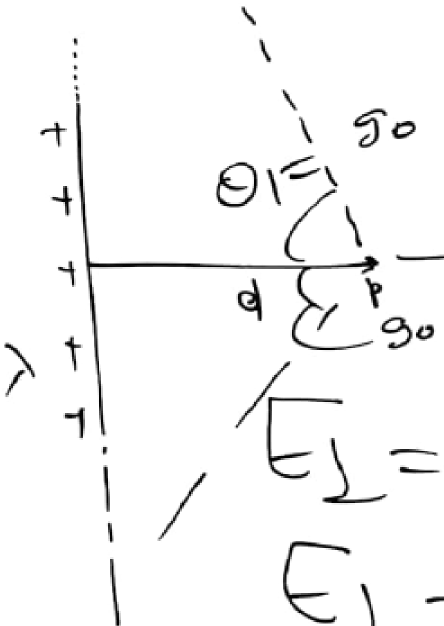
$$= \frac{K\lambda}{d}\left[1+1\right] = \frac{2K\lambda}{d}$$

$$= \frac{2 \times 9 \times 10^9 \times 10}{5} = 4 \times 9 \times 10^9$$

$$= 36 \times 10^9 \, N/C$$

$$E_\parallel = \frac{K\lambda}{d}\left[\cos 90^\circ - \cos 90^\circ\right]$$

$$E_\parallel = 0$$

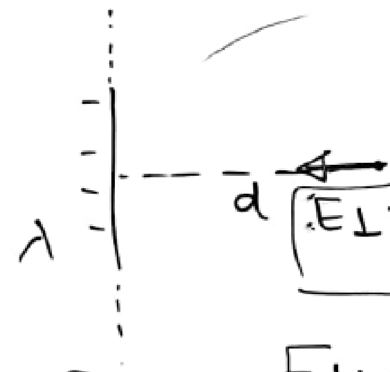


$\rightarrow E_\perp = \frac{2K\lambda}{d}$

$$E_\perp = \frac{K\lambda}{d}[\sin\theta_1 + \sin\theta_2]$$

$$E_\perp = \frac{K\lambda}{d}[\sin 90 + \sin 90]$$

$$E_\perp = \frac{2K\lambda}{d} \qquad E_{\parallel} = 0$$



$E_\perp = \frac{2K\lambda}{d}$

$E_{\parallel} = 0$

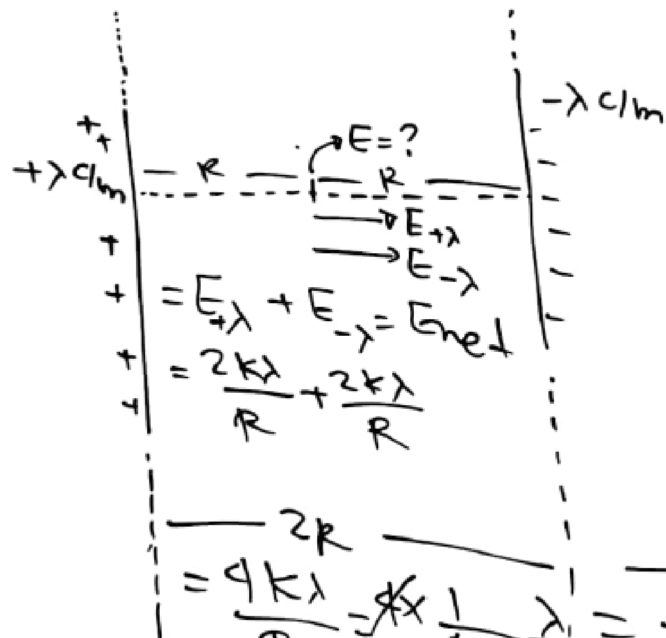
NEET 2019) Two parallel infinite line charges with linear charge density $+\lambda$ C/m & $-\lambda$ C/m are placed at a distance $2R$ in free space. What is the electric field mid-way b/w the two line charge.

(a) zero

(b) $\frac{2\lambda}{\pi \varepsilon R}$ N/C

(c) $\frac{\lambda}{\pi \varepsilon_0 R}$ N/C

(d) $\frac{\lambda}{2\pi \varepsilon_0 R}$ N/C



$= E_{+\lambda} + E_{-\lambda} = E_{net}$

$= \frac{2k\lambda}{R} + \frac{2k\lambda}{R}$

$= \frac{4k\lambda}{R} = 4 \times \frac{1}{4\pi\varepsilon_0} \frac{\lambda}{R} = \frac{\lambda}{\pi \varepsilon_0 R}$