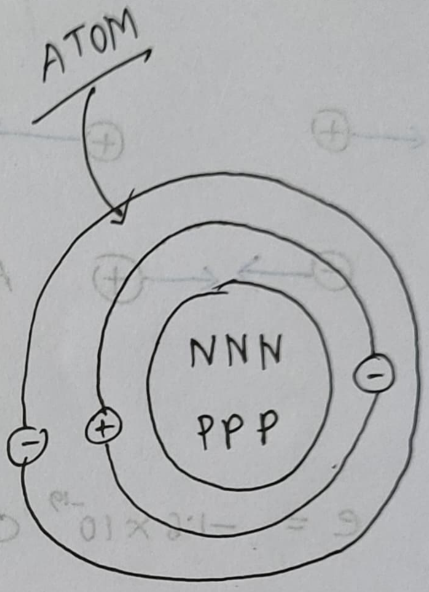
L-1 / 25.01.2023 /

⊛ Electricity & Magnetism

Electro- magnetism

ENM



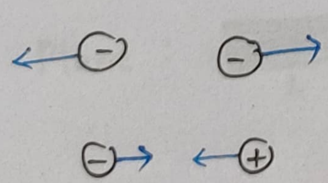
⊛ Charge → ?

Property of
electron
proton
newton

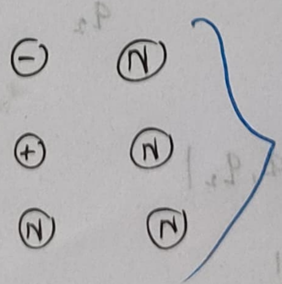
electron : '–' ⇒ e ⇒ -1.6×10^{-19} C

proton : '+' ⇒ p ⇒ $+1.6 \times 10^{-19}$ C

newton : '0' ⇒ N ⇒



electrical force



No Force

L-2 /30.01.2023/

Charge

(i) ← ⊖   ⊖ → reverse reaction

(ii) ← ⊕   ⊕ → reverse reaction

(iii) ⊖ → ← ⊕ Attraction

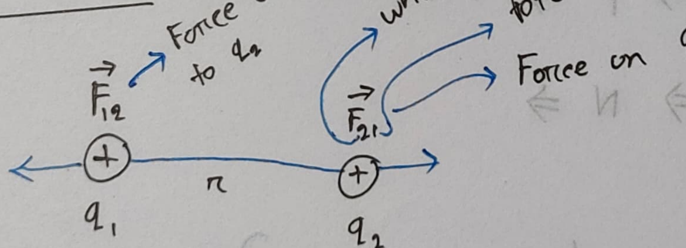
$e = -1.6 \times 10^{-19}$ C → Coulomb

Symbol

q, Q

$p = +1.6 \times 10^{-19}$ C

⊛ Coulomb's Law:



$\Rightarrow$ Force $\propto |q_1 q_2|$

$\Rightarrow$ Force $\propto \dfrac{1}{r^2}$

$\therefore$ Force $\propto \dfrac{|q_1 q_2|}{r^2}$

$\therefore$ Force $= k \dfrac{|q_1 q_2|}{r^2}$

$$\therefore F = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_2|}{r^2}$$

⇒ Coulomb's Law

$k = \dfrac{1}{4\pi\epsilon_0} = 9 \times 10^9$

ϵ = epsilon

$\epsilon_0 = 8.85 \times 10^{-12}$ F/m

$$|F_{21}| = \frac{1}{4\pi\epsilon_0} \left| \frac{q_2 q_1}{r^2} \right|$$

$$|F_{12}| = \frac{1}{4\pi\epsilon_0} \left| \frac{q_1 q_2}{r^2} \right|$$

$$\therefore |F_{12}| = |F_{21}|$$

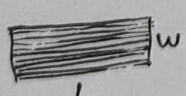
Point Charge: Point like charges

Points: .

Line: ------------

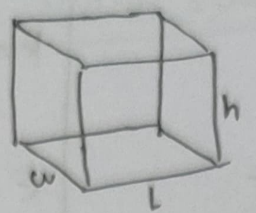
length : m

Plane :

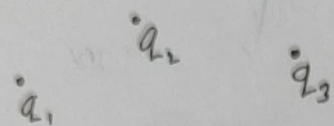


$A = L \cdot W$: m^2

* Volume :



* Coulomb's Law is only valid for point charge.



$\vec{F}_{12} + \vec{F}_{13} = \vec{F}_{1\,Net}$

$\vec{F}_{2net} = \vec{F}_{21} + \vec{F}_{23}$

$\vec{F}_{3Net} = \vec{F}_{31} + \vec{F}_{32}$

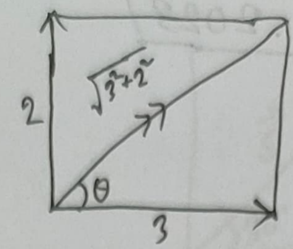
* $(\text{Dist})^n$ of point charges.

$q_1 \quad q_2 \quad q_3 \quad \cdots\cdots \quad q_N$

Net Force on q_1 :

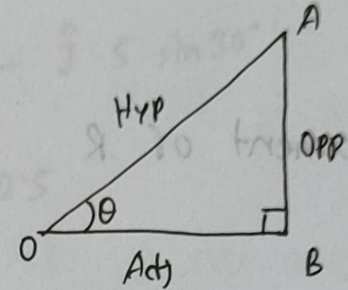
$\vec{F}_{12} + \vec{F}_{13} + \cdots\cdots + \vec{F}_{1(n-1)} + \vec{F}_{1N}$

Super position



Review:

1. Integration
2. Differentiation
3. Trig. Identity



Soh

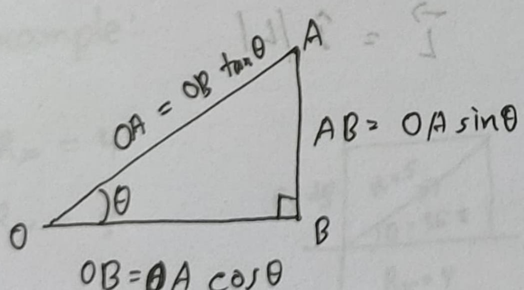
Cah

Toa

$$\sin\theta = Soh = \frac{o}{h} = \frac{Opp}{Hyp} = \frac{AB}{OA}$$

$$\cos\theta = Cah = \frac{a}{h} = \frac{Adj}{Hyp} = \frac{OB}{OA}$$

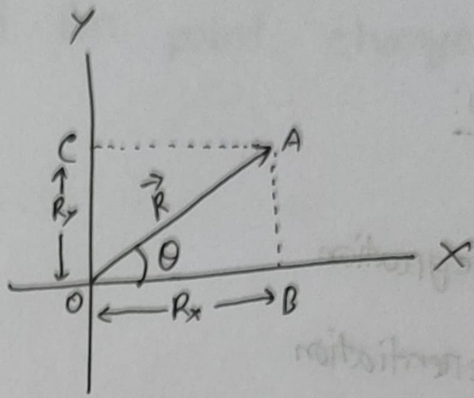
$$\tan\theta = Toa = \frac{o}{a} = \frac{Opp}{Adj} = \frac{AB}{OB}$$



L-3/01.02.2023/

Components:

① Given $(\vec{R}, \theta)$



R_x = x component of R

$= OB$

$= OA\cos\theta$

$\therefore R_x = R\cos\theta$

R_y = y component of R

$= OC = AB$

$= OA\sin\theta$

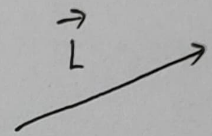
$\therefore R_y = R\sin\theta$

$\tan\theta = \frac{AB}{OB} = \frac{R_y}{R_x}$

$\therefore \theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$

$\vec{R} = \hat{i}R\cos\theta + \hat{j}R\sin\theta$

(*)

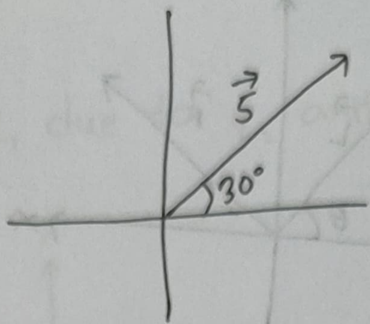


unit vector : $\frac{\vec{L}}{|L|} = \hat{L}$

$= 1$

$\vec{L} = \hat{L}|L|$

Example:

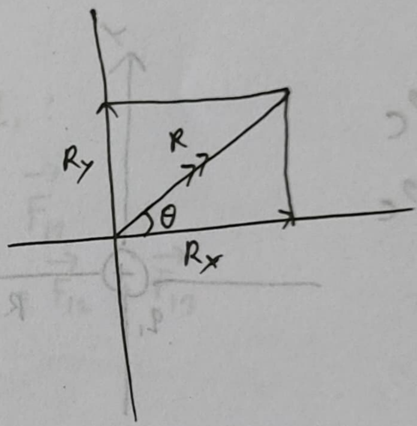


$$\vec{5} = \hat{i}\cdot 5\cos 30^\circ + \hat{j}\cdot 5\sin 30^\circ$$

$$\vec{5} = \hat{i}\,4.33 + \hat{j}\,2.5$$

(ii)

Given (R_x, R_y)

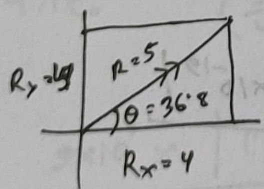


Example:

$$R = \sqrt{R_x^2 + R_y^2}$$

$R_x = 4$

$R_y = 3$

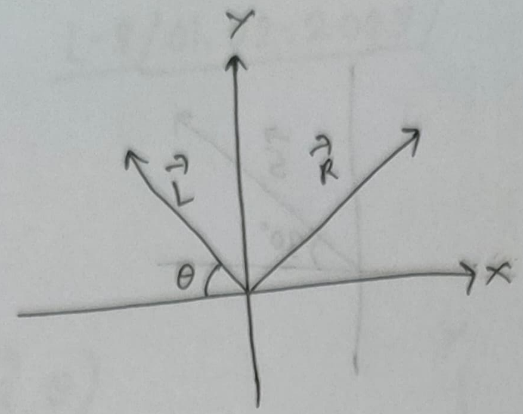


$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

$$R = \sqrt{4^2+3^2} = \sqrt{12+9} = 5$$

$$\theta = \tan^{-1}\frac{3}{4} = 36.8^\circ$$

⊛



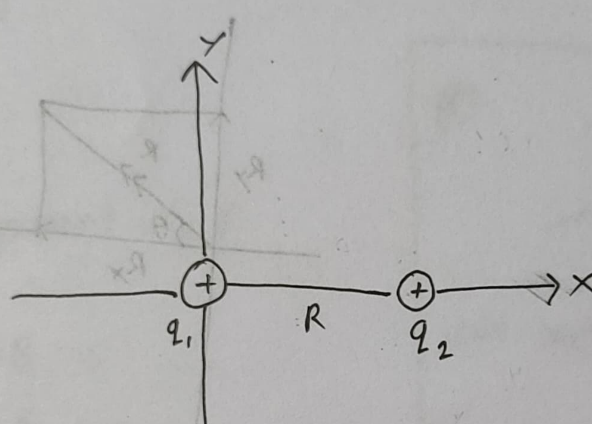
⊛ Mid and Quiz Must :

Find the force on q_1 due to q_2 : $F_{12} = ?$

$q_1 = 1.6 \times 10^{-19} C$

$q_2 = 3.2 \times 10^{-19} C$

$R = 0.02 m$



$$F_{12} = \frac{1}{4\pi\epsilon_0} \cdot \frac{|q_1 q_2|}{R^2}$$

$$= \frac{9 \times 10^9 \times |1.6 \times 10^{-19} \times 3.2 \times 10^{-19}|}{(0.02)^2}$$

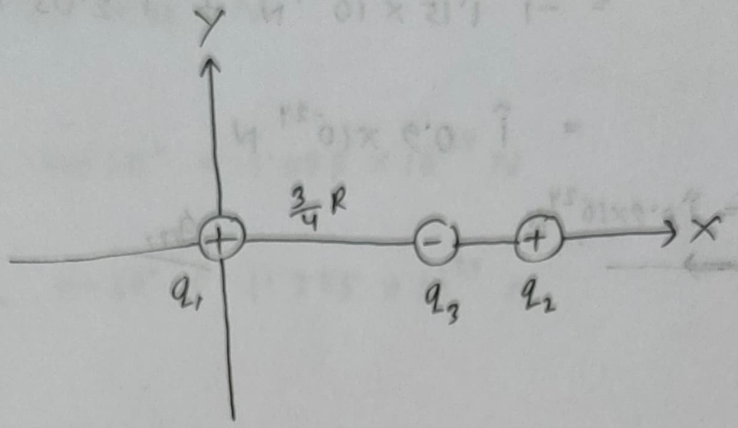
$$= 1.15 \times 10^{-24} N \; (-x\text{-axis})$$

$$\therefore \vec{F}_{12} = -\hat{i} \; 1.15 \times 10^{-24} N$$

Ans

Example:

Find net force on q_1 due to q_2 and q_3



$q_1 = 1.6 \times 10^{-19}\,C$

$q_2 = 3.2 \times 10^{-19}\,C$

$q_3 = -3.2 \times 10^{-19}\,C$

$R = 0.02\,m$

$r = \frac{3}{4}R$

Force on q_1 :

$\vec{F}_{12}$ & $\vec{F}_{13}$

$\vec{F}_{1Net} = \vec{F}_{12} + \vec{F}_{13}$

$\vec{F}_{12} = -\hat{i}\ 1.15 \times 10^{-24}\,N$

$$\vec{F}_{13} = \frac{1}{4\pi\epsilon_0} \cdot \frac{|q_1 q_3|}{(\frac{3}{4}R)^2}$$

$$= \frac{9\times10^{9} \times |1.6\times10^{-19} \times 3.2\times10^{-19}|}{(\frac{3\times0.02}{4})^2}$$

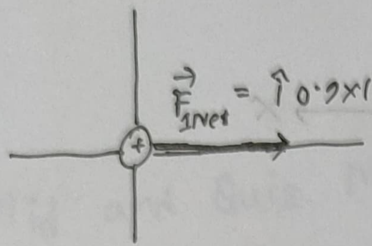
$$= 2.048 \times 10^{-24}\,N \quad (x\text{-axis})$$

$\therefore \vec{F}_{13} = \hat{i}\ 2.05 \times 10^{-24}\,N$

$$\therefore \vec{F}_{1Net} = \vec{F}_{12} + \vec{F}_{13}$$

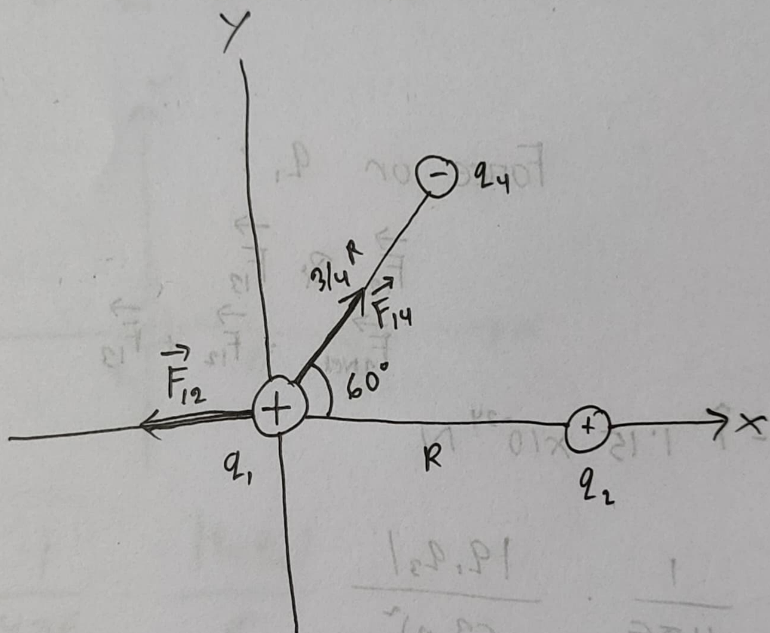
$$= -\hat{i}\ 1.15 \times 10^{-24}\ N + \hat{i}\ 2.05 \times 10^{-24}\ N$$

$$= \hat{i}\ 0.9 \times 10^{-24}\ N$$



Ans

Example:



$q_1 = 1.6 \times 10^{-19}\ C$

$q_2 = 3.2 \times 10^{-19}\ C$

$q_4 = -3.2 \times 10^{-19}\ C$

$R = 0.02\ m$

Find the net force on q_1 due to q_2 and q_4

$\Rightarrow$

Forces on q_1 : $\vec{F}_{12}$ & $\vec{F}_{14}$

Net force on q_1 :

$$\vec{F}_{1Net} = \vec{F}_{12} + \vec{F}_{14}$$

$$\vec{F}_{12} = -\hat{i}\, 1.15 \times 10^{-24}\ N$$

$$F_{14} = 2.05 \times 10^{-24}\ N$$

$$F_{14x} = F_{14} \cos 60^\circ = 1.025 \times 10^{-24}\ N$$

$$F_{14y} = F_{14} \sin 60^\circ = 1.775 \times 10^{-24}\ N$$

$$\vec{F}_{14} = \hat{i}\, F_{14x} + \hat{j}\, F_{14y}$$

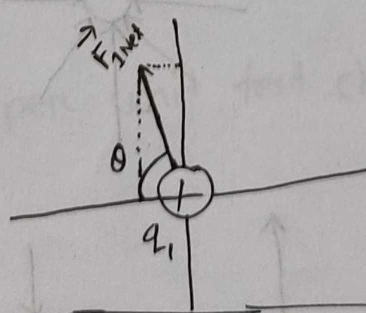
$$= \hat{i}\, 1.025 \times 10^{-24}\ N + \hat{j}\, 1.775 \times 10^{-24}\ N$$

$$\therefore \vec{F}_{1Net} = \hat{i}\, 1.025 \times 10^{-24}\ N + \hat{j}\, 1.775 \times 10^{-24}\ N - \hat{i}\, 1.15 \times 10^{-24}\ N$$

$$\cancel{= \hat{i}\, 1.025 \times 10^{-24} + \hat{j}\, 1.775 \times 10^{-24}\ N}$$

$$\cancel{= -\hat{i}\, 0.125 \times}$$

$$= -\hat{i}\, 1.25 \times 10^{-25}\ N + \hat{j}\, 1.775 \times 10^{-24}\ N$$



$$\therefore \theta = \tan^{-1}\left(\frac{(F_{1Net,y})}{(F_{1Net,x})}\right)$$

$$=$$

$$\therefore |\vec{F}_{1Net}| = \sqrt{(1.25 \times 10^{-25})^2 + (1.775 \times 10^{-24})}$$

$$=$$

⊛ Charge is conserved:

⊛ Charge is quantized. → counting number cannot be fraction

$Q = -Ne$

$Q = +Ne$

→ integer number

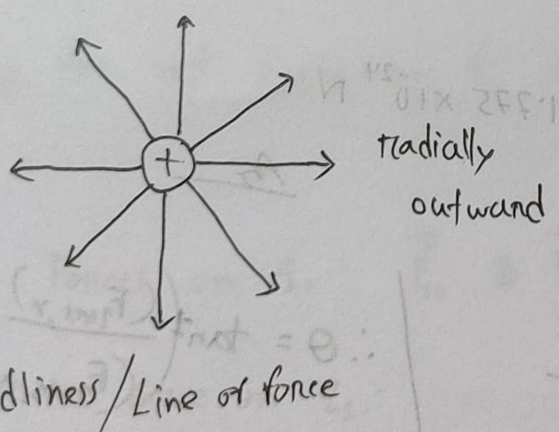
$|e|$ = electronic charge = $1.6 \times 10^{-19}\,C$

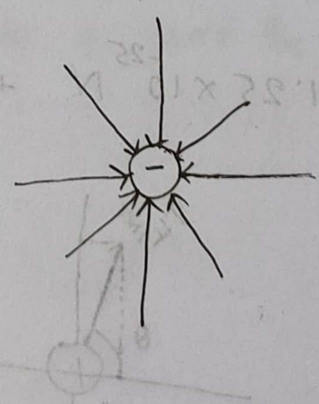
$\therefore Q = \pm Ne$ → integer number

⊛ Electric Field ($\vec{E}$):

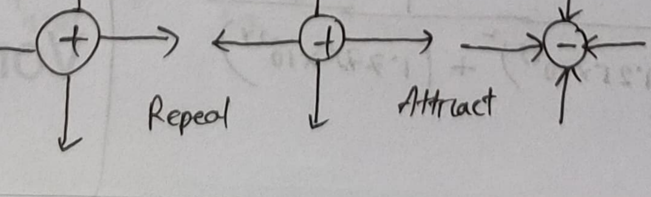
Spatial Co-ordinate (x, y, z)

temporal Co-ordinate (t) → (x, y, z, t)





Fieldliness / Line of force



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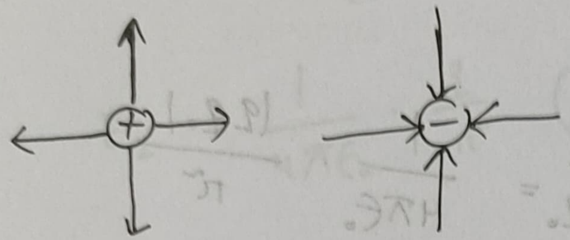
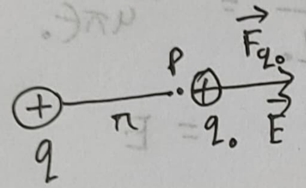
⊛ Electric Field ($\vec{E}$)





⊛ Electric Field due to a point charge q at point P, at distance r from q.

⇒ Place a test charge q_0 at point P

⇒ Test charge is a positive point charge.

$\therefore F_{q_0}$ = Force on q_0 due to q $= \frac{1}{4\pi\epsilon_0} \frac{|qq_0|}{r^2}$

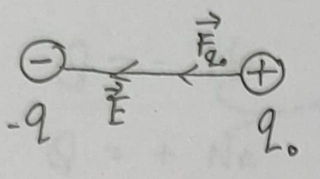
$\therefore \frac{F_{q_0}}{q_0}$ = Force per unit test charge $= \frac{1}{4\pi\epsilon_0} \cdot \frac{|qq_0|}{r^2 q_0}$

$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} = E$

$\therefore \vec{E} = \frac{\vec{F}_{q_0}}{q_0}$

⊛ $$\boxed{E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}}$$

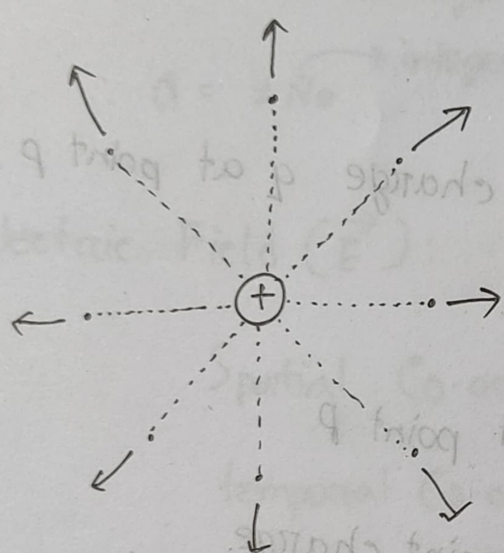
⊛

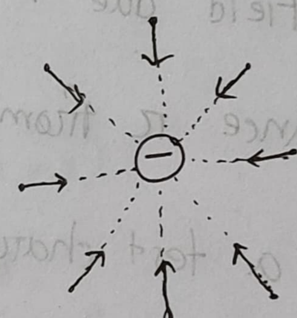


$$F_{q_0} = \frac{1}{4\pi\epsilon_0} \cdot \frac{|q q_0|}{r^2}$$

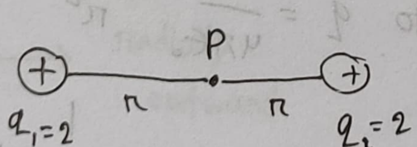
$$\frac{F_{q_0}}{q_0} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} = E$$

⊛





⊛ Example:



$E_{net} = E_1 + E_2$

$q_1 \; q_2 \; q_3 \; \ldots\ldots \; q_N$

Dist^n of N point changes

$$\vec{E}_{net} = E_1 + E_2 + E_3 + \ldots + E_N$$

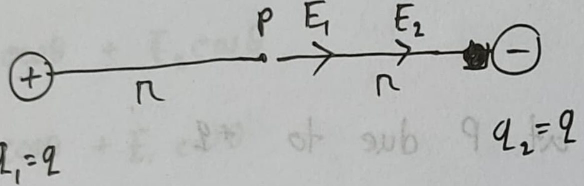
E_{net} at P:

$$E_1 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \text{ (Right)}$$

$$E_2 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \text{ (Left)}$$

$$E_{net} = E_1 - E_2 = 0$$

Example:

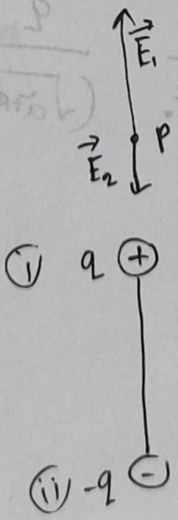


$$E_1 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

$$E_2 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

$$E_{net} = E_1 + E_2$$
$$= 2E_1$$
$$= 2E_2$$

Electric Dipole:



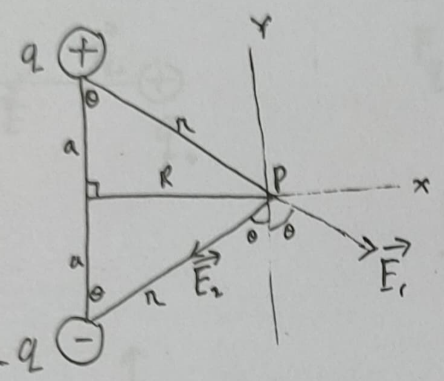
$$E_1 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r_+^2} \text{ (Up)}$$

$$E_2 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r_-^2} \text{ (Down)}$$

$$\therefore E_{net} = E_1 - E_2 \text{ (Up)}$$

Midterm 2nd Question Must!

Find Electric Field at Point P along the perpendicular bisector of the dipole axis.



$$r = \sqrt{a^2+R^2}$$

+q

E_1 = Electric Field at P due to +q

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(\sqrt{a^2+R^2})^2}$$

-q

E_2 = Electric Field at P due to -q

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(\sqrt{a^2+R^2})^2}$$

$$= E_1$$

E_{1x} = x component of E_1

$= E_1 \sin\theta$ (Right)

E_{1y} = y component of E_1

$= E_1 \cos\theta$ (Down)

$E_{2x} = E_2 \sin\theta$ (Left)

$E_{2y} = E_2 \cos\theta$ (Down)

$\therefore E_1 = \hat{i} E_1 \sin\theta - \hat{j} E_1 \cos\theta$

$\therefore E_2 = -\hat{i} E_2 \sin\theta - \hat{j} E_2 \cos\theta$

E_{1x} and E_{2x} will cancel each other.

$E_{net} = E_1 \cos\theta + E_2 \cos\theta$

$= E_1 \cos\theta + E_1 \cos\theta$

$= 2 E_1 \cos\theta$

$= 2 E_2 \cos\theta$

$= 2 \cdot \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(a^2+R^2)} \cdot \frac{a}{\sqrt{a^2+R^2}}$

$\cos\theta = \frac{a}{r} = \frac{a}{\sqrt{a^2+R^2}}$

$\therefore \vec{E}_{net} = (-\hat{j}) E_{net}$

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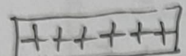
$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

$$\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \cdots + \vec{E}_n$$

⊛ Continuous charge distⁿ:



(i) Line charge:

length = $L = 3m$

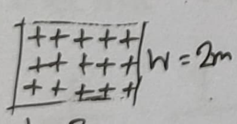
charge = $q = 9$ coul.

Per unit Length

$\lambda = \frac{q}{L}$ = Line charge density

$$\lambda = \frac{9c}{3m} = 3\ c/m$$

(ii) Surface charge:



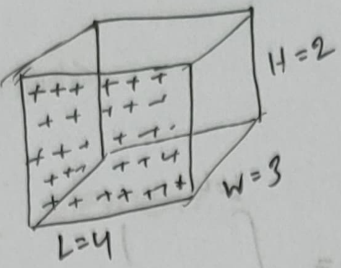
Area = $A = LW = 3 \cdot 2\ m^2$
$= 6\ m^2$

q = charge = 60 coul.

$\sigma = \frac{q}{A}$ = Surface charge density

$$= \frac{60\,coul}{6\,m^2} = 6\ c/m^2$$

(iii) Volume charge:

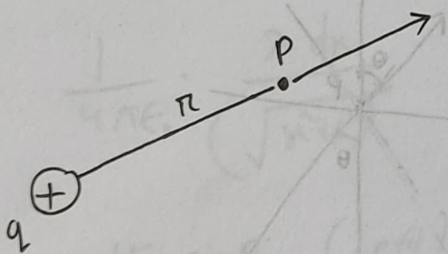


$$\text{Volume} = V = LWH = 4\cdot 3\cdot 2 = 24\,m^3$$

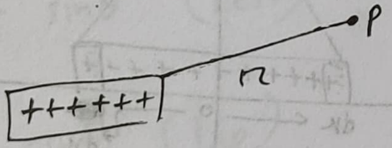
$$\text{charge} = q = 72 \text{ coul.}$$

$$\text{Volume charge density} = \rho = \frac{q}{V} = \frac{72}{24} = 3\ c/m^3$$

(i) Line Charge



$$\frac{1}{4\pi\epsilon_0}\cdot\frac{q}{r^2} = E$$



$$\lambda = \frac{q}{L}$$

dL = diff^n Line element

dq = diff^n charge element

dE = Diff electric field at P due dq.

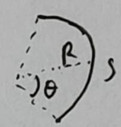
$$\underset{dq}{\boxed{+}} = \frac{1}{4\pi\epsilon_0} \cdot \frac{d^2}{r^2} = dE$$

$dq > dL$

$$\int dE = E = \int \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r^2} = \int_{L=0}^{L=L} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda dL}{r^2}$$

⊛ Circular charge:

$$\int ds = s = 2\pi R$$

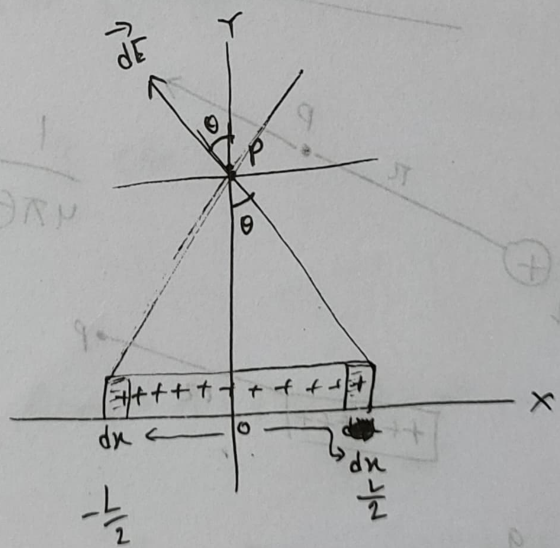


$s = R\theta$

⊛ Line charge

Length = L

Charge = q



Find the electric field at p due to this line charge.

$\Rightarrow$

⊗ Right Side:

differentiation

dx = line element

dq = diff charge element = charge in 'dx'

$dq = \lambda dx$

r = is the distance of point P from dq

$= \sqrt{x^2+d^2}$

$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r^2}$ = Differentiate electric field at P due to dq

$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda dx}{(\sqrt{x^2+d^2})^2}$

$dE_x = dE \sin\theta$ (Left)

$dE_y = dE \cos\theta$ (Up)

* Left Side

$dx =$

$dq = \lambda dx$

$r = \sqrt{x^2+d^2}$

$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda dx}{(\sqrt{x^2+d^2})^2}$

$dE_x = dE \sin\theta$ (Right) : will cancel each other

$dE_y = dE \cos\theta$ (Up)

$$\therefore E = \int dE_y + \int dE_x$$

$$= \int dE_y$$

$$E = \int dE \cos\theta = \int_{x=-\frac{L}{2}}^{x=+\frac{L}{2}} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda dx}{(x^2+d^2)} \cdot \cos\theta$$

$$= \text{H.W.}$$

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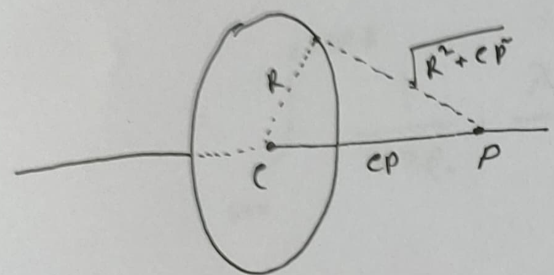
(*) Ring Charge:

$$\int ds = s = 2\pi R = L$$

$$dq = \lambda\, ds$$



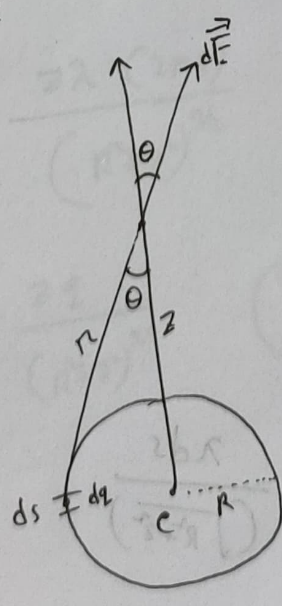
(2) Ring Charge:

R = radius

q = charge

λ = line charge density $= \frac{q}{L} = \frac{q}{2\pi R}$

$q = \lambda 2\pi R$



(*) Find electric field $\vec{E}$ at P due to ring?

$\Rightarrow$

Left Side element:

ds = differentiate line element

dq = differentiate change element

$dq = \lambda ds$

dE = differentiate electric field at p due to dq

r = distance from p to dq

$$= \sqrt{R^2 + z^2}$$

$$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r^2}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{(\sqrt{R^2+z^2})^2}$$

$dE_x = dE \sin\theta$ (Right)

$dE_y = dE \cos\theta$ (up)

Right side element:

$ds =$

$dq =$

$dq =$

$r = \ldots$

$$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{(\sqrt{R^2+z^2})^2}$$

$\therefore dE_x = dE \sin\theta$ (Left) : will cancel each other

$\therefore dE_y = dE \cos\theta$ (Up)

$$\therefore E = \int dE \cos\theta + \cancel{\int dE \sin\theta} \rightarrow 0$$

$$= \int dE \cos\theta$$

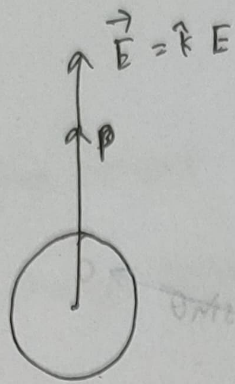
$$= \int_{s=0}^{s=2\pi R} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{R^2+z^2} \cdot \frac{z}{\sqrt{R^2+z^2}} \quad \frac{z}{\sqrt{R^2+z^2}} \rightarrow \cos\theta$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda}{R^2+z^2} \cdot \frac{z}{\sqrt{R^2+z^2}} \int_0^{s=2\pi R} ds$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{z\lambda}{(R^2+z^2)^{3/2}} \cdot s \Big]_0^{2\pi R}$$

$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{z\lambda(2\pi R)}{(R^2+z^2)^{3/2}}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{zq}{(R^2+z^2)^{3/2}} \quad \text{(Up - positive z)}$$



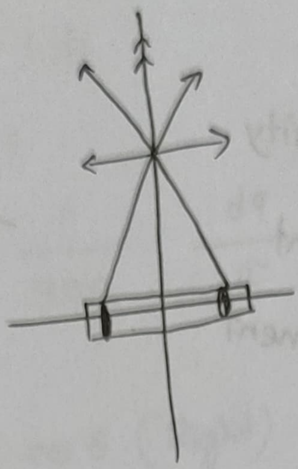
$\therefore \vec{E} = \hat{k}\,(E)$

Ans

⊛ if $z \ggg R$

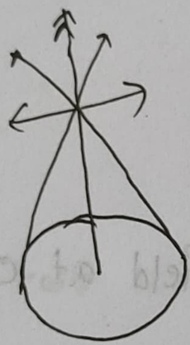
$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{z^2} = \frac{1}{4\pi\epsilon_0} \cdot$$

① Line charge:



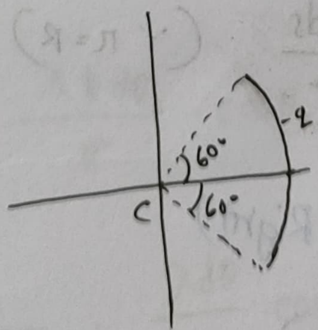
$$E = \int dE_y$$

② Ring charge:



$$E = \int dE \cos\theta$$

③ Arc charge:



Find electric field at c due to this arc charge.

$\Rightarrow$

R = radius

$-q$ = charge

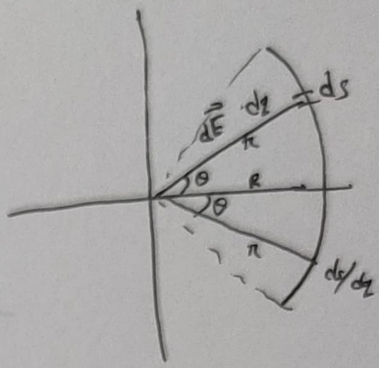
λ = line charge density

ds = Diff. Line element

dq = Diff. charge element

$= \lambda ds$

r = distance of point c from dq



Here,

$r = R$

dE = Diff. electric field at c due to $-dq$

$$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r^2}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{R^2} \quad (\because r = R)$$

$dE_x = dE \cos\theta$ (Right)

$dE_y = dE \sin\theta$ (Up)

~~ds~~

2nd part

$$ds =$$

$$dq = \lambda ds$$

$$r = R$$

$$dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{R^2}$$

$dE_x = dE \cos\theta$ (Right)

$dE_y = dE \sin\theta$ (Down) : will cancel each other.

$$E = \int dE_x + \int dE_y$$

$$= \int dE_x = \int dE \cos\theta$$

$$E = \int \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{R^2} \cos\theta$$

$$= \int \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda R d\theta}{R^2} \cdot \cos\theta$$

$$= \int_{\theta=-60^\circ}^{\theta=+60^\circ} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda d\theta}{R} \cdot \cos\theta$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda}{R} \int_{\theta=-60^\circ}^{\theta=+60^\circ} \cos d\theta$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda}{R} \cdot \sin\theta \Big]_{\theta=-60^\circ}^{\theta=+60^\circ}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda}{R} \left[\sin 60^\circ - \sin(-60^\circ)\right]$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda}{R} \; 2\sin 60^\circ$$

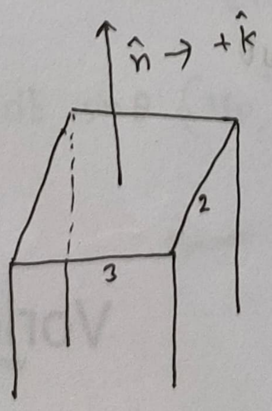
$$= \frac{1.73\lambda}{4\pi\epsilon_0 R} \quad (\text{Right})$$

$$\therefore \vec{E} = +\hat{i}\left(\frac{1.73\lambda}{4\pi\epsilon_0 R}\right)$$

⊛ Electric Flux (ϕ_E):

is basically number of lines passing through a surface in an electric field.

Direction of a Surface:



$A = 3 \cdot 2 = 6\ m^2$

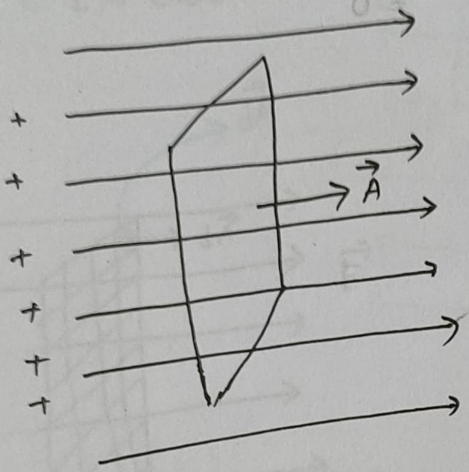
$\vec{A} = \hat{k}\,(6\ m^2)$

$\phi_E = \vec{E} \cdot \vec{A}$

$= EA \cos\theta$

Angle between $\vec{E}$ and surface area.

①



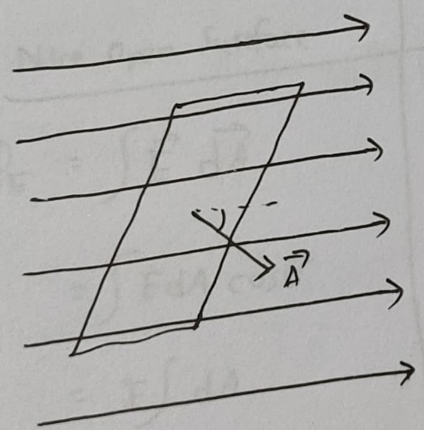
5 lines cross

$\theta = 0°$

$\phi_E = EA \cos\theta$

$= EA \cos 0 = EA$

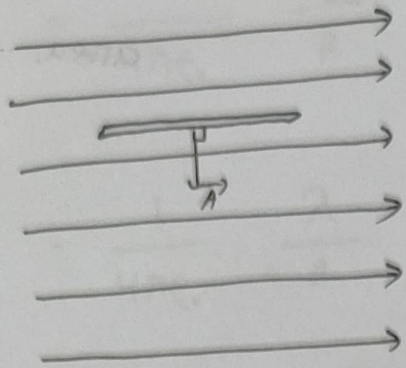
②



$\theta = 30°$

$\phi_E = EA \cos 30°$

(3)



$\vec{E}$

$\theta = 90^\circ$

$\phi_E = EA \cos 90^\circ$

$= 0$

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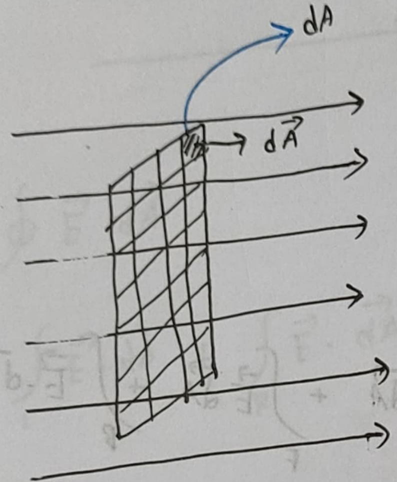
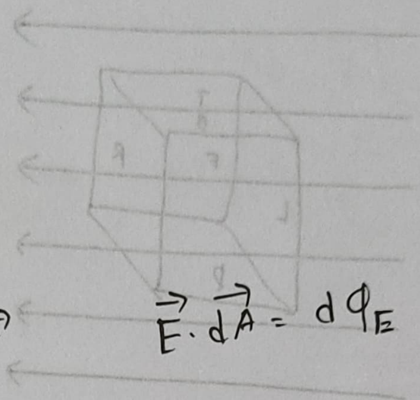
⊛ Electric Flux (ϕ_E)

$$\phi_E = \vec{E} \cdot \vec{A}$$

$$= EA\cos\theta$$

⊛





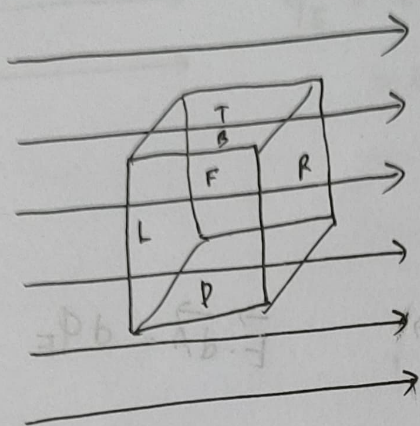
$$\vec{E} \cdot \vec{dA} = d\phi_E$$

Nice Open Surface	Crazy Surface
$\phi_E = \int \vec{E}\,\vec{dA}$	$d\phi_E = \vec{E} \cdot \vec{dA}$
$= \int E\,dA \cos 0^\circ$	$\phi_E = \Sigma\, \vec{E} \cdot \vec{dA}$
$= E \int dA$	
$= EA$	

⊛ Closed Surface :

⊛ Find ϕ_E through closed box ?

$$\phi_E = \oint \vec{E} \cdot d\vec{A}$$



$$\cancel{\oint_R \vec{E} \cdot d\vec{A}}$$

$$= \int_R \vec{E} \cdot d\vec{A} + \int_L \vec{E} \cdot d\vec{A} + \int_T \vec{E} \cdot d\vec{A} + \int_D \vec{E} \cdot d\vec{A} + \int_F \vec{E}\, d\vec{A} + \int_B \vec{E} \cdot d\vec{A}$$

$$= \int_R E\,dA \cos 0^\circ + \int_L E\,dA \cos 180^\circ + \int_T \vec{E}\,dA \cos 90^\circ + 0 + 0 + 0$$

$$= \int_R E\,dA - \int_L E\,dA + 0 + 0 + 0 + 0$$

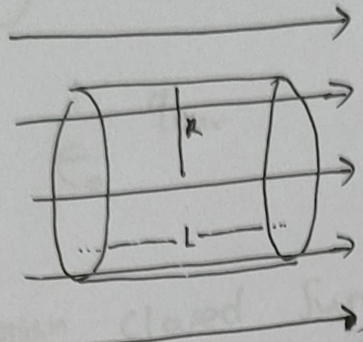
$$= E \int_R dA - E \int_L dA + 0$$

$$= EA - EA$$

$$= 0$$

⊛ if line entered and goes out are same then Net flux = 0.

⊛ ϕ_E through closed Cylinder?



$\boxed{A = \pi r^2}$

$$\phi_E = \oint \vec{E}\, d\vec{A}$$

$$= \int_L \vec{E} \cdot d\vec{A} + \int_R \vec{E} \cdot d\vec{A} + \int_{Cyl} \vec{E} \cdot d\vec{A}$$

$$= \int_L E\, dA \cos 180^\circ + \int_R E\, dA \cos 0^\circ + \int_{cyl} E\, dA \cos 90^\circ$$

$$= -\int_L E\, dA + \int_R E\, dA + 0$$

$$= -E \int_L dA + E \int_R dA$$

$$= -EA + EA = 0$$