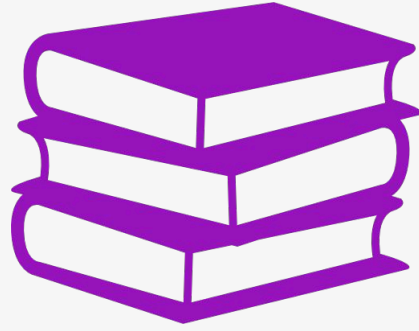




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دفتر :

فيزياء عامة 2

Physics 2

للدكتور : زياد

إعداد : ميس محمد

اللجنة الأكاديمية لقسم الهندسة الصناعية

2024



Coulomb's law:-

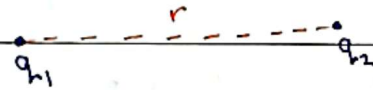
q is charge

$$[q] = C$$

$$mC = 10^{-3} C, \mu C = 10^{-6} C, nC = 10^{-9} C, KC = 10^3 C$$

r is the distance between the charges.

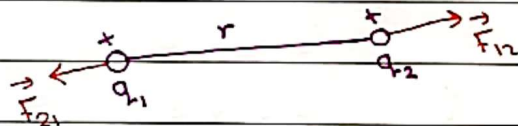
$$F \propto \frac{q_1 q_2}{r^2} = F = K_c \frac{q_1 q_2}{r^2}$$



$$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}; \quad \epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}$$

ϵ_0 is Free space permittivity, $K_c = 9 \times 10^9 N \cdot m^2 / C^2$
($\vec{F}$ is a vector).

$$\vec{F}_{21} = \vec{F}_{12}$$



e.g) which of the following is correct :-

a) $F_{12} = -F_{21}$

موجهة لهما في سالب

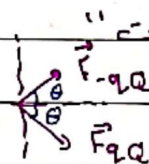
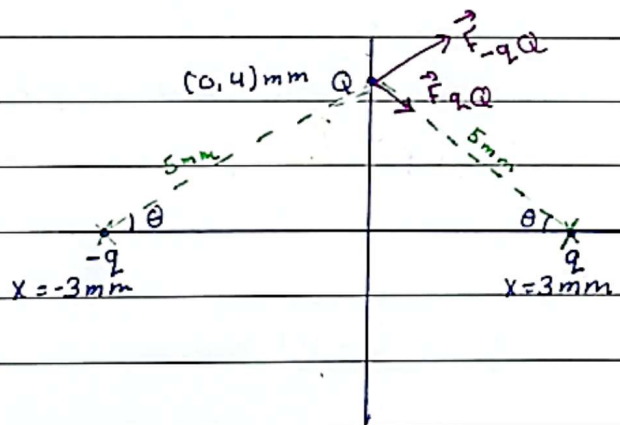
(d)

b) $\vec{F}_{12} = \vec{F}_{21}$

c) $\vec{F}_{12} = 2\vec{F}_{21}$

d) $\vec{F}_{12} = -\vec{F}_{21}$

e.g) $q = 5 \mu C$, $Q = -10 \mu C$, what is the Force exerted on Q?



"يعني Q يتجذب q والباقى ثابت"

$$\vec{F}_{qQ} = \frac{9 \times 10^9 \times 5 \times 10^{-9} \times 10 \times 10^{-6}}{(5 \times 10^{-3})^2} * \left(\frac{3}{5} \hat{i} - \frac{4}{5} \hat{j} \right)$$

$$\vec{F} = \frac{90}{25} (3\hat{i} - 4\hat{j}) \text{ K N.}$$

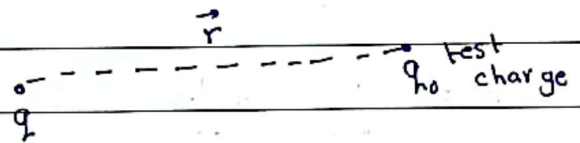
[attractive]

$$\vec{F}_{-qQ} = \frac{9 \times 10^9 \times 5 \times 10^{-6} \times 10 \times 10^{-6}}{(5 \times 10^{-3})^2} \left(\frac{3}{5} \hat{i} + \frac{4}{5} \hat{j} \right)$$

$$\vec{F} = \frac{q_0}{25} (3\hat{i} + 4\hat{j}) \text{ K.N} \quad [\text{Repulsive}]$$

$$\vec{F}_T = \vec{F}_q + \vec{F}_{-q} = \frac{90 \times 6}{25} \hat{i} \text{ K.N}$$

Electric Field : المجال الكهربائي



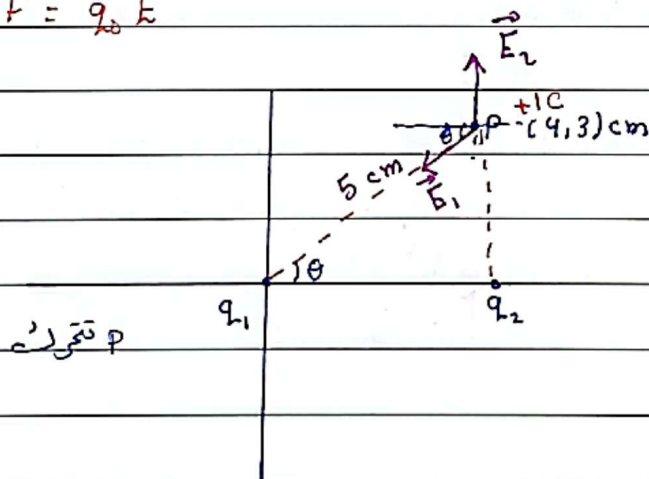
We define the electric field as :-

$$\vec{E} = \frac{\vec{F}}{q_0}, \quad \vec{E} = \frac{k_e q_0}{r^2}$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

$$\vec{F} = q_0 \vec{E}$$

e.g)



$$q_1 = -25 \text{ nC}$$

$$q_2 = 18 \text{ nC}$$

Find the electric field at P?

"دائماً يفرض عند P +1C" "P ثابتة"

$$\vec{E}_1 = \frac{9 \times 10^9 \times 25 \times 10^{-9}}{(5 \times 10^{-2})^2} \left(-\frac{4}{5} \hat{i} - \frac{3}{5} \hat{j} \right) = \frac{90}{5} (-4\hat{i} - 3\hat{j}) \frac{\text{K.N}}{\text{C}}$$

$$\vec{E}_2 = \frac{9 \times 10^9 \times 18 \times 10^{-9}}{(3 \times 10^{-2})^2} \hat{j} = 180 \frac{\text{K.N}}{\text{C}} \hat{j}$$

$$\vec{E}_p = \vec{E}_1 + \vec{E}_2$$

$$= -72\hat{i} + 126\hat{j} \text{ K N/C}$$

* Calculate the electric Force on a point charge $q = -10 \text{ mC}$ located at the point p?

$$\vec{F} = q_0 \vec{E} = -10 \times 10^{-3} (-72\hat{i} + 126\hat{j}) \times 10^3 = 720\hat{i} - 1260\hat{j} \text{ N.}$$

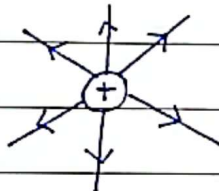
The electric Field lines:-

1] The EF line dont intersects.

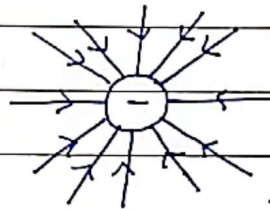
2] The EF lines emerge from +ve charge and terminated (ends) in -ve charges

3] The number of EF lines proportional to the charge. $N \propto Q$

e.g)



q

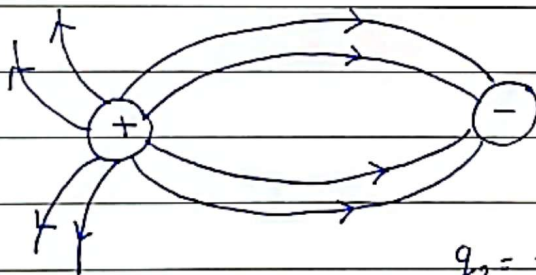


2q

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} = \frac{6}{12} = \frac{1}{2}$$

$$\therefore Q_2 = 2Q_1 \text{ و } N_2 = 2N_1$$

e.g)



$q_1 = 10 \mu\text{C}$

$q_2 = -5 \mu\text{C}$

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} = \frac{8}{4} = 2$$

"كلما كبرت الشحنة زادت خطوط المجال الخارجة منها"

*

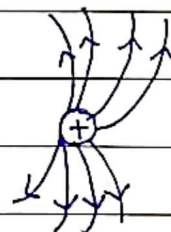


$E_p = 0$

p

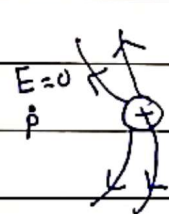


q



$q_1 = 2q$

$q_1 = 10 \mu\text{C}$



$E = 0$

p

$q_2 = q$

$q_2 = 5 \mu\text{C}$

* اين يقدم المجال ؟

- إذا كانت السحنتين متشابهتين في الإشارة ينفرد المجال بينهما وأقرب إلى الصغرى (دون إشارة).

١١ " " مختلفين " " " " خارجهما " " " (بوزن اشارة).

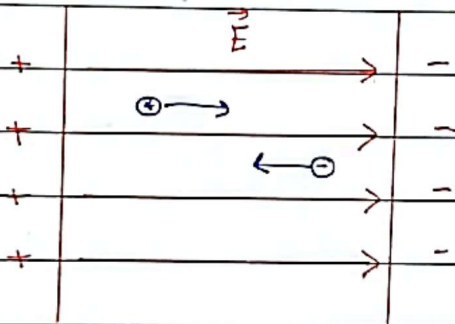
e.g) $E=0$

$\ominus$	$\oplus$
$-q$	$2q$
$-5\mu C$	$10\mu C$

Diagram showing a horizontal line with two points marked: $-10 \mu s$ (labeled with a minus sign) and $5 \mu s$ (labeled with a plus sign). The text $E = 0$ is written to the right of the line.

The motion of a charge particle in a uniform $\vec{E}$ -field.

$$F = ma = q_0 E$$



$$a = \frac{q_0 E_0}{m}$$

$$v_f = v_i + at$$

$$\Delta x = v_i t + \frac{1}{2} a t^2$$

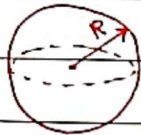
$$v_f^2 = v_i^2 + 2a\Delta x$$

The Electric Field of continuous charge distribution

"charge density"

1. 3D $\Rightarrow \rho: \rho = \frac{\text{charge}}{\text{Volume}} = \frac{Q}{V} = \frac{C}{m^3}$

Ex: Sphere (كرة)



R is radius نصف القطر

$2R = D$ is Diameter القطر

$$\rho = \frac{Q}{\frac{4}{3}\pi R^3}$$

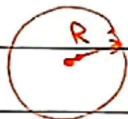
Ex: Cylinder (أسطوانة)



$$\rho = \frac{Q}{\pi R^2 L}$$

2. 2D $\Rightarrow \sigma: \sigma = \frac{\text{charge}}{\text{Area}} = \frac{Q}{A} = \frac{C}{m^2}$

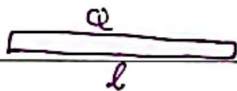
Ex: charged disk (قرص)



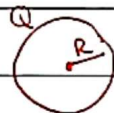
$$\sigma = \frac{Q}{\pi R^2}$$

3. 1D $\Rightarrow \lambda: \lambda = \frac{\text{charge}}{\text{length}} = \frac{Q}{l} = \frac{C}{m}$

Ex: charge Rod $\Rightarrow \lambda = \frac{Q}{l}$



Ex: charge ring:



$$\Rightarrow \lambda = \frac{Q}{2\pi R}$$

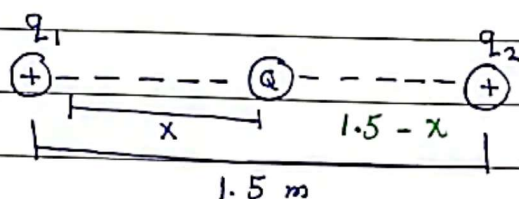


$$dE = k_e \frac{dq}{r^2}$$

$$E = k_e \int_{\text{charge}} \frac{dq}{r^2}$$

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$$q_1 = 3q, \quad q_2 = q, \quad d = 1.5 \text{ m}$$



- where to put third charged q such that q is in equilibrium?

$$\frac{k_e q_1}{(1.5-x)^2} = \frac{k_e q_2}{x^2} \Rightarrow \frac{3q}{(1.5-x)^2} = \frac{q}{x^2}$$

$$3x^2 = (1.5-x)^2$$

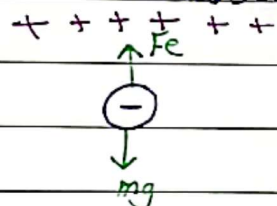
$$x = 0.4$$

بجرب كل الخيارات الي بتزبد نجتاها

24 / 718

$$m = 38 \text{ g}, \quad q = -18 \text{ } \mu\text{C}$$

لا تتحرك : motion less : محالقة : Suspended : مخفوسة : immersed :



$$\Sigma F = 0 \Rightarrow q_0 E_0 = mg$$

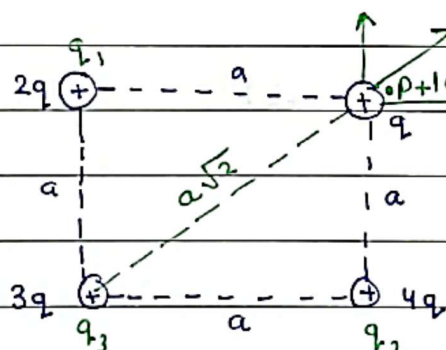
$$E_0 = \frac{mg}{q_0} = \frac{38 \times 10^{-3} \times 10}{18 \times 10^{-6}} \text{ N/C}$$

$$\text{Note : } m = 5 \text{ mg} = 5 \times 10^{-6} \text{ kg}$$

25 / 718

$$q = 10 \text{ nC}$$

$$a = 3 \text{ cm}$$



$$\vec{E}_1 = \frac{q \times 10^9 \times 20 \times 10^{-9}}{9 \times 10^{-4}} (\hat{i})$$

$$= 0.2 \frac{\text{M N}}{\text{C}} \hat{i}$$

$$M = 10^6$$

$$\vec{E}_2 = \frac{q \times 10^9 \times 40 \times 10^{-9}}{9 \times 10^{-4}} (\hat{j})$$

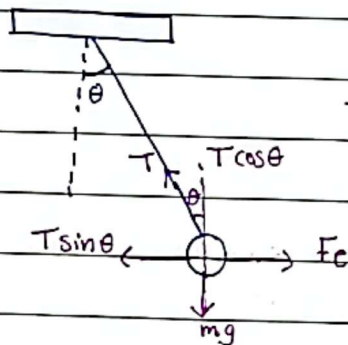
$$= 0.4 \frac{\text{M N}}{\text{C}} \hat{j}$$

$$\vec{E}_3 = \frac{q \times 10^9 \times 30 \times 10^{-9}}{2 \times 9 \times 10^{-4}} \left(\frac{1}{\sqrt{2}} \hat{i} + \frac{1}{\sqrt{2}} \hat{j} \right) \Rightarrow E_p = \sqrt{E_x^2 + E_y^2}$$

$$b) F_q = q E_p$$

33/719

$$m = 2g, \quad l = 20 \text{ cm}, \quad \theta = 15^\circ, \quad q = ??$$



$$E = 1 \times 10^3 \text{ N/C}$$

$$\sum F_x = 0$$

$$T \sin \theta = F_e = q_0 E_0$$

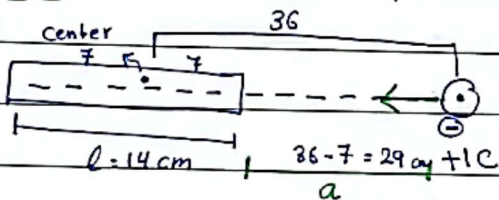
$$\sum F_y = 0$$

$$T \cos \theta = mg$$

$$\tan \theta = \frac{q_0 E_0}{mg} \Rightarrow q_0 = \frac{mg \tan \theta}{E} = 5.25 \mu\text{C} \text{ [positive]}$$

37/719

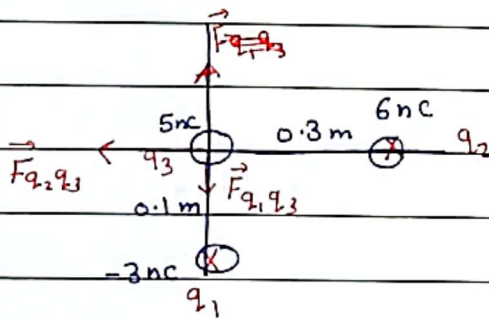
$$q = -22 \mu\text{C}, \quad l = 14 \text{ cm}, \quad a = 36 \text{ cm}$$



$$E = \frac{k_e q Q}{a(a+l)} = \frac{9 \times 10^9 \times 22 \times 10^{-6}}{0.29(0.29+0.14)} \text{ N/C} = 1.59 \times 10^6 \text{ N/C}$$

$$b) \text{ if } q_0 = -5 \mu\text{C} \Rightarrow F = ?? = F = q_0 E = (+i)$$

11/717



$$\vec{F}_{q_1 q_2} = \frac{9 \times 10^9 \times 3 \times 10^{-9} \times 5 \times 10^{-9}}{(1 \times 10^{-2})^2} = 135 \times 10^{-5} \text{ N} (-\hat{j})$$

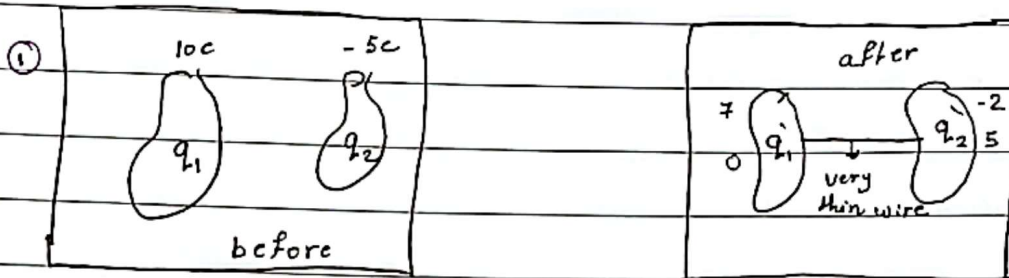
$$\vec{F}_{q_1 q_3} = \frac{9 \times 10^9 \times 6 \times 10^{-9} \times 5 \times 10^{-9}}{9 \times 10^{-2}} = 30 \times 10^{-7} \text{ N} (-\hat{i})$$

$$F = \sqrt{(\vec{F}_{12})^2 + (\vec{F}_{23})^2} = 1.38 \times 10^{-5} \text{ N}$$

$$\theta = \tan^{-1} \left(\frac{F_{23}}{F_{12}} \right) = 77.5$$

Notes:

- 1) The charge is conserved
- 2) The charge is quantized $(q = ne)$



$$q_T = q_1 + q_2$$

$$q_T = 5C$$

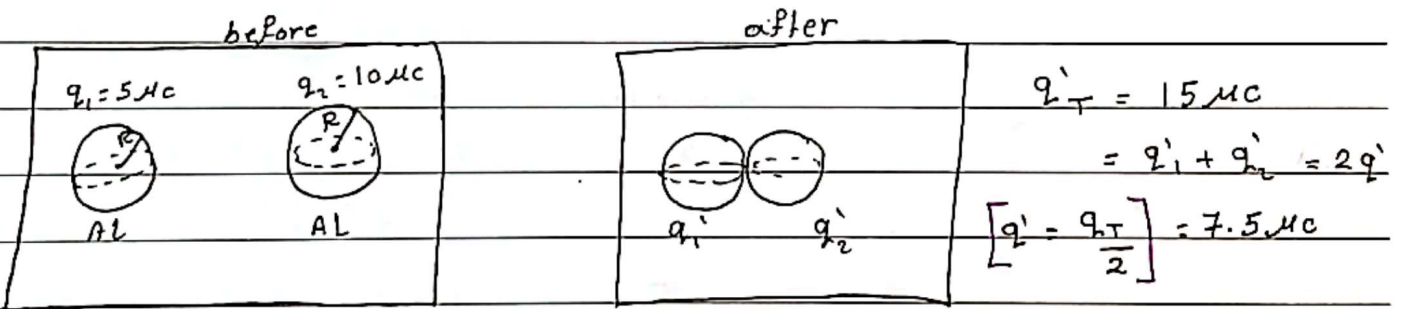
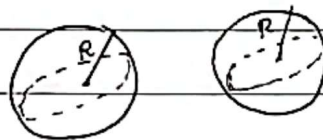
$$q'_T = q'_1 + q'_2$$

$$= 5C$$

* Identical object :- نفس الانجاء ونفس المادة

→ Two identical sphere

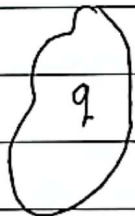
بعد التوصل تنقسم الشحنة بالتساوي - شحنة
ع المتساوي



$$q_T = 5 + 10 = 15\mu C$$

$$q'_1 = q'_2 = q'$$

②



$$q = N \cdot e$$

$$N = 0, \pm 1, \pm 2, \pm 3, \dots$$

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

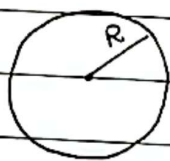
* How many electrons are transferred from an object to have a charge +20 nC?

$$N = \frac{q}{e} = \frac{20 \times 10^{-9}}{1.6 \times 10^{-19}} = \frac{20}{1.6} \times 10^{10}$$

$$= 12.5 \times 10^{10} \text{ electrons}$$

$$= 125000000000.$$

45/720 charge arc (قوس).

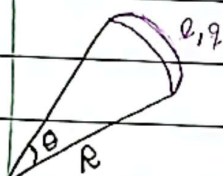


$$C = 2\pi R$$

$$\text{قوس} = \frac{1}{2} 2\pi R = \pi R$$

$$\text{قوس} = \frac{1}{4} 2\pi R = \frac{\pi R}{2}$$

$$q = \frac{Q}{\theta}$$



$$\Rightarrow l = R\theta \rightarrow \text{rad } \theta \text{ (و.ا)}$$

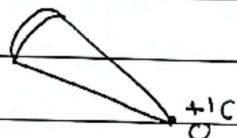
$$E_{\text{Arc}} = \frac{2Ke\lambda}{R} \sin\left(\frac{\theta}{2}\right)$$

Ex:

$$q = -5 \mu\text{C}$$

$$R = 10 \text{ cm}$$

$$\theta = 45^\circ$$

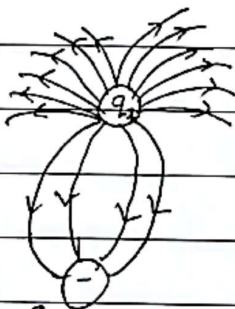


q) Find the λ linear charge density (λ)?

$$\lambda = \frac{q}{l} = \frac{q}{R\theta} = \frac{-5 \times 10^{-6}}{(0.1) \left(\frac{\pi}{4}\right)}$$

$$= -\frac{200}{3.14} \frac{\mu\text{C}}{\text{m}}$$

49/720



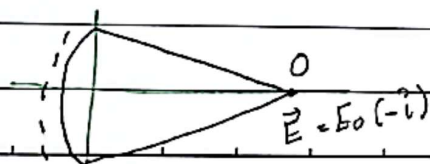
$$\frac{q_2}{q_1} = \frac{N_2}{N_1} = \frac{16}{4} = 4$$

$$q_2 = 4q_1$$

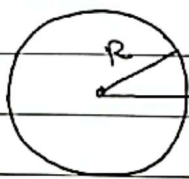
h) Find the electric field at the center of arc (o)?

$$E_{\text{Arc}} = \frac{2Ke\lambda}{R} \sin\left(\frac{\theta}{2}\right) = \frac{2 \times 9 \times 10^9 \times \frac{200}{\pi} \times 10^{-6}}{0.1} \sin(22.5^\circ)$$

0.1 "in words"



39/719

charged Ring, $R = 100 \text{ cm}$, $Q = 75 \mu\text{C}$ 

$$E_{\text{Ring}} = \frac{k_e Q x}{(x^2 + R^2)^{3/2}}$$

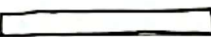
$$E = \frac{9 \times 10^9 \times 75 \times 10^{-6} \times 0.3}{(0.1^2 + 0.3^2)^{3/2}} (+\hat{i})$$

$x = 30 \text{ cm}$

45/720

charge arc

bent 8

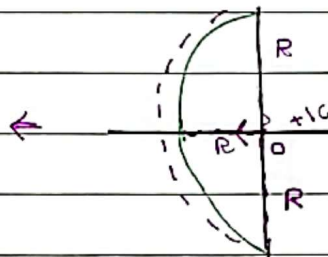


$$l = 14 \text{ cm}, q = -7.5 \mu\text{C}$$

Semi-circle 8

$$\theta = \pi$$

$$E_{\text{Arc}} = \frac{2 k_e \lambda \sin(\frac{\theta}{2})}{R}$$



$$\lambda = \frac{q}{l} = \frac{-7.5}{0.14} = \frac{\mu\text{C}}{\text{m}}$$

$$E_0 = \frac{2(9 \times 10^9) (\frac{7.5}{0.14}) \times 10^{-6} \sin(\frac{\pi}{2})}{0.14 / \pi} \quad \theta = R\theta = \frac{2\pi R}{2} = 0.14$$

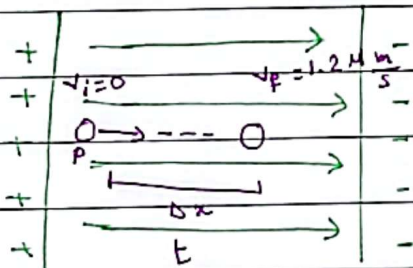
$$\vec{E} = E_0 (-\hat{i})$$

$$R = 0.14$$

51/720

proton, $m = 1.67 \times 10^{-27} \text{ kg}$, $+e = 1.6 \times 10^{-19} \text{ C}$, $\vec{F} = 640 \hat{i}$

a) the acceleration of the proton is



$$F_e = q_e E_0 = m_p a$$

$$a = \frac{e E_0}{m} = \frac{(1.6 \times 10^{-19}) (640)}{1.67 \times 10^{-27}}$$

$$a = 640 \times 10^8 \text{ m/s}^2$$

$$b) v = v_0 + at \Rightarrow t = \frac{v_f}{a} = \frac{1.2 \times 10^6}{6.4 \times 10^{10}} \text{ sec}$$

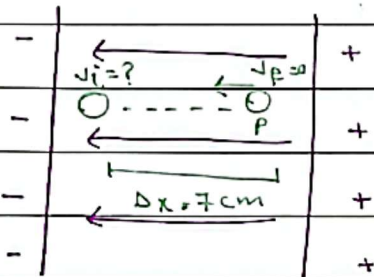
$$c) \Delta x = v_0 t + \frac{1}{2} a t^2 \checkmark \Rightarrow \Delta x = \frac{v_f^2}{2a} = \frac{(1.2 \times 10^6)^2}{(2)(6.4 \times 10^{10})} \text{ m}$$

$$v_f^2 = v_i^2 + 2 a \Delta x \checkmark$$

52/720

proton, $m = 1.67 \times 10^{-27} \text{ kg}$, $e = 1.6 \times 10^{-19} \text{ C}$

$$\vec{E} = -6 \times 10^5 \hat{i} \text{ N/C} = 6 \times 10^5 (-\hat{i})$$



$$a) \quad a = \frac{e E_0}{m} = \frac{(1.6 \times 10^{-19})(6 \times 10^5)}{1.67 \times 10^{-27}} = 6 \times 10^{13} \text{ m/s}^2 (-\hat{i}) = \vec{a}$$

$$a = 6 \times 10^{13} \text{ m/s}^2$$

$$b) \quad v_f^2 = v_i^2 + 2a\Delta x$$

$$v_{0i} = \sqrt{-2a\Delta x} = \sqrt{-(2)(6 \times 10^{13})(0.07)} \text{ m/s}$$

$$c) \quad v_f = v_i + at \Rightarrow t = \frac{-v_i}{a}$$

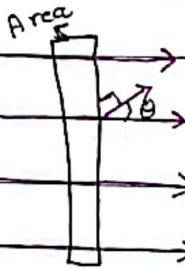
$$\Delta x = v_i t + \frac{1}{2} a t^2$$

$$v_f^2 = v_i^2 + 2a\Delta x \Rightarrow \Delta x = \frac{v_f^2}{2a} = \frac{(1.2 \times 10^6)^2}{2 \times 6.4 \times 10^{10}} \text{ m}$$

* The electric flux :-

التدفق الكهربائي

$$\vec{E} = E_0 \hat{i}$$



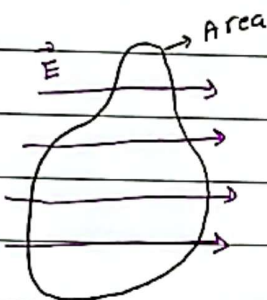
$$\Phi_E = E_0 A \cos \theta$$

$\hat{n}$ = Area normal vector

$$\hat{n} = \begin{cases} \hat{i}, -\hat{i} \\ \hat{j}, -\hat{j} \\ \hat{k}, -\hat{k} \end{cases}$$

$A \uparrow E \uparrow \rightarrow \Phi \uparrow$

$$= \vec{E} \cdot \vec{A}, \vec{A} = A\hat{n}$$



$$\left[\Phi_E = \int_{\text{Area}} \vec{E} \cdot d\vec{A} = \int_{\text{Area}} E \cos \theta_{\hat{n}, \vec{E}} dA \right]$$

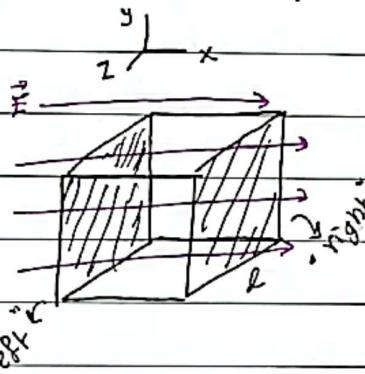
irregular الجسم

مغلق

Ex: Cubic shape in a uniform $\vec{E}$ -Field. (imersed)

$$E = 500 \hat{i}$$

Find the total flux through out the Cubic shape?



$$\begin{aligned} \phi \text{ From left one} &= \vec{E} \cdot \vec{A} \quad \text{or } (\hat{i}) \times (-\hat{i}) = -1 \\ &= \vec{E} \cdot (l^2) \cos 180^\circ \\ &= -\vec{E} l^2 \end{aligned}$$

$$\begin{aligned} \phi \text{ From right one} &= \vec{E} \cdot \vec{A} \quad \text{or } (\hat{i}) \times (\hat{i}) = 1 \\ &= \vec{E} \cdot (l^2) \cos 0^\circ \\ &= E_0 l^2 \end{aligned}$$

$$\Phi_T = 0$$

* التدفق على جسم مغلق مغروس في مجال خارجي = صفر

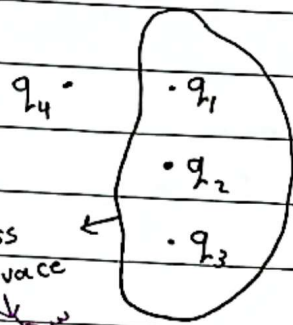
غير مغروس

* For a non charged object imersed totally on electric Field the Total flux = Zero

* Gauss law

فقط الشحنات الموجودة في السطح

قياسية

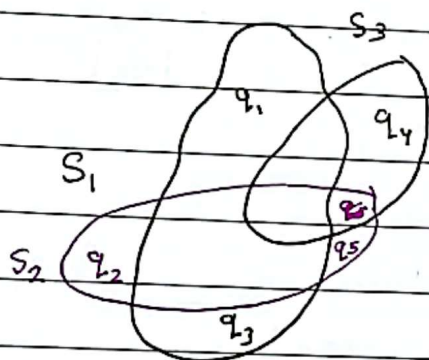


$$\Phi_E = \frac{\sum q_{in}}{\epsilon_0} \rightarrow$$

بجمعهم بالإشارة

$$= \frac{q_1 + q_2 + q_3}{\epsilon_0}$$

Gauss surface
سطح غاوسي
Ex 8



$$q_1 = 1 \mu C$$

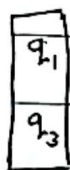
$$q_2 = -2 \mu C$$

$$q_3 = 10 \mu C$$

$$q_4 = 5 \mu C$$

$$q_5 = +2 \mu C$$

Find the Flux throughout each surface?



$$\Phi_1 = \frac{q_{in}}{\epsilon_0} = \frac{q_1 + q_3}{\epsilon_0} = \frac{1 \times 10^{-6} + 10 \times 10^{-6}}{8.85 \times 10^{-12}} = \frac{11 \times 10^{-6}}{8.85} \frac{N \cdot m^2}{C}$$

$$= \frac{11}{8.85} \frac{M N \cdot m^2}{C}$$

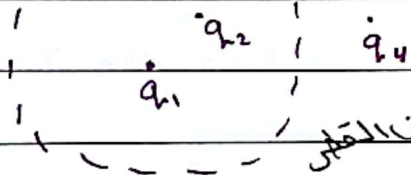
$$\Phi_2 = \frac{q_{in}}{\epsilon_0} = \frac{q_2 + q_5}{\epsilon_0} = \frac{-2 \times 10^{-6} + 2 \times 10^{-6}}{8.85 \times 10^{-12}} = \text{Zero}$$

$$\Phi_3 = \frac{q_{in}}{\epsilon_0} = \frac{q_4}{\epsilon_0} = \frac{5 \times 10^{-6}}{8.85 \times 10^{-12}} = \frac{5 \times 10^{-6}}{8.85 \times 10^{-12}} = \frac{5}{8.85} \frac{M N \cdot m^2}{C}$$

Gaussian surface

* What is the Flux through the Spherical

Gaussian surface?



$$\Phi = \frac{\sum q_{in}}{\epsilon_0} = \frac{q_1 + q_2}{\epsilon_0}$$

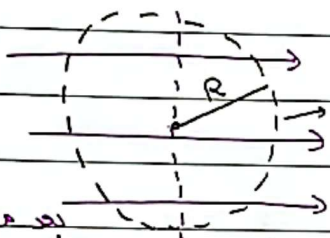
فقط الشحنات الموجودة في السطح

* calculating the $\vec{E}$ -field using Gauss law :-

$$\Phi_E = \int_{\text{Area}} \vec{E} \cdot d\vec{A} = \int_{\text{Area}} E \cos \theta dA = \frac{\sum q_{\text{in}}}{\epsilon_0}$$

→ Spherical shell قشرة كروية immersed totally in an electric field and non charged

$$\vec{E} = E_0 \hat{i}$$



$$\Phi_T = 0$$

لأن سطح غير مشحون
عازي

hemi-sphere

$$\Phi_{h-s} = -E_0 (4\pi R^2)$$

$$= -2\pi R^2 E_0$$

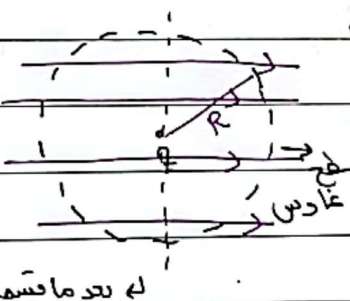
$$\Phi_{h-s} = E_0 (4\pi R^2)$$

$$= 2\pi R^2 E_0$$

$$\Phi_T = 0$$

⇒ charged spherical shell immersed in $\vec{E}$ -field المشحونة بالوسط

$$\vec{E} = E_0 \hat{i}$$



$$\Phi = \frac{q}{\epsilon_0}$$

$$\Phi_T = \Phi_q + \Phi_E = \frac{q}{\epsilon_0} + 0$$

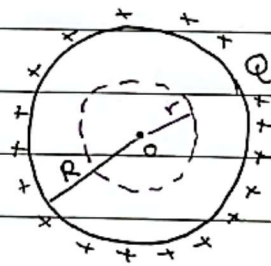
لأنه مشحون بالوسط

$$\Phi_T^{h-s} = \Phi_q + \Phi_E = \frac{q}{2\epsilon_0} + E_0 \frac{4\pi R^2}{2}$$

Right لأن المشحونة بالوسط

$$\text{Left} = \Phi_T = \Phi_q + \Phi_E = \frac{q}{2\epsilon_0} + (-E_0) \frac{4\pi R^2}{2}$$

→ The charge lies inside Gauss's Surface



$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} = \text{zero}$$

$$E_{in} = \text{Zero} ; r < R$$

zero = داخل الكرة E

* inside the sphere ($r < R$)

* what is the surface charge density? $\sigma = \frac{Q}{4\pi R^2}$

$$E_{out} =$$

$$\frac{K_e Q}{r^2} ; r > R$$

and

$$E_{in} = 0 ; r < R$$

Ex 8 Find the electric field

conducting (metallic).

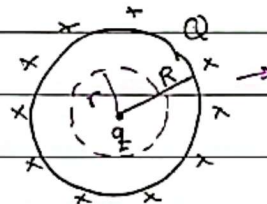
a) at $r = 15 \text{ cm}$

$$q = -10 \mu\text{C}$$

$$R = 20 \text{ cm}$$

$$Q = 26 \mu\text{C}$$

$$r = 15 \text{ cm}$$



$$E_{in} = \frac{K_e Q}{r^2} = 9 \times 10^9 \times \frac{10 \times 10^{-6}}{0.15^2} \frac{\text{N}}{\text{C}} \quad (\text{In wards})$$

$$\Phi = \frac{q_{in}}{\epsilon_0} = \frac{-10 \times 10^{-6}}{8.85 \times 10^{-12}} \frac{\text{N} \cdot \text{m}^2}{\text{C}}$$

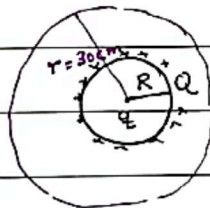
b) at $r = 30 \text{ cm}$

بمسألة حالي معدنية ؟

إذا السطحية تتوزع على السطح الخارجي

Q و q و سطح غاوس لهم نفس المركز

∴ غاوس



$$E_{out} = \frac{K_e (Q + q)}{r^2} ; r > R$$

$$= \frac{9 \times 10^9 (26 - 10) \times 10^{-6}}{0.3^2} \frac{\text{N}}{\text{C}} \quad (\text{outwards})$$

$$\Phi = \frac{q_{in}}{\epsilon_0} = \frac{26 - 10 \times 10^{-6}}{8.85 \times 10^{-12}}$$

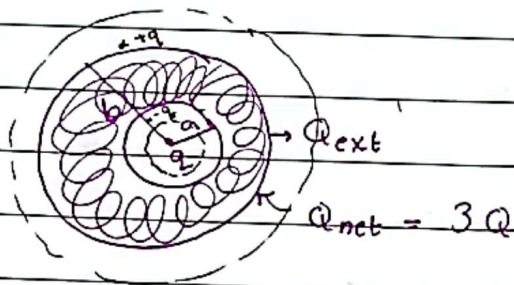
Q مجالها خارج من الكرة

لانها موجبة

q مجالها داخل لانها سالبة

Spherical shell

أشكال صلبة و الموصل في Conductor



$$① E_1 = ?? , r < a \Rightarrow E (4\pi r^2) = \frac{q}{\epsilon_0}$$

$$\Rightarrow E_1 = \frac{k_e q}{r^2}$$

$$② E_2 = ?? , r > b$$

$$\Rightarrow E_2 = (4\pi r^2) = \frac{q + 3Q}{\epsilon_0}$$

$$E_2 = \frac{k_e (q + Q_3)}{r^2} \rightarrow \text{نقوم بالاشارة}$$

$$③ E_3 = ?? , a < r < b$$

$$E_3 = 0$$

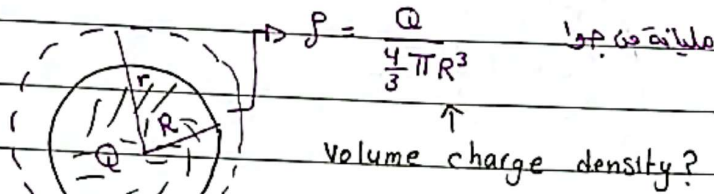
$$Q_{net} = Q_{ext} + (+q)$$

$$Q_{ext} = Q_{net} - q = 3Q - q$$

② Non-Conducting sphere

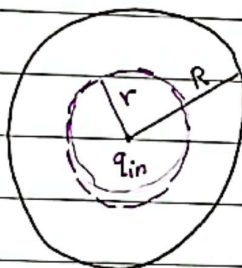
(non-metallic, Rubber, plastic)

→ the charge is distributed uniformly through its volume.



① $E_{out} = ?$; $r > R$

$$E(4\pi r^2) = \frac{Q}{\epsilon_0} \Rightarrow E = \frac{K_e Q}{r^2}, r > R$$



$$\rho = \frac{Q}{\frac{4}{3}\pi R^3} = \frac{q_{in}}{\frac{4}{3}\pi r^3} \Rightarrow q_{in} = \rho \frac{4}{3}\pi r^3$$

$$q_{in} = \frac{r^3}{R^3} Q$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} \Rightarrow E(4\pi r^2) = \frac{1}{\epsilon_0} \frac{r^3}{R^3} Q$$

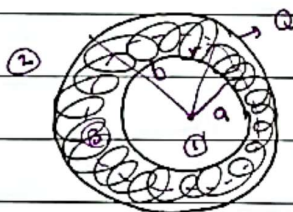
$$E_{in} = \frac{K_e Q}{R^3} r = \frac{\rho}{3\epsilon_0} r$$

$$E = \frac{K_e Q}{r^2} ; r > R$$

and

$$E = \frac{\rho}{3\epsilon_0} r, r < R$$

→ non conducting spherical shell



$$E_{in} = \text{Zero}, r < a$$

$$E_2 = \frac{K_e Q}{r^2}, r > b$$

$$\rho = \frac{Q}{\frac{4}{3}\pi (b^3 - a^3)}$$

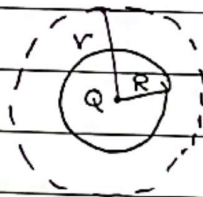
$$E_3 = E(4\pi r^2) = \frac{q_{in}}{\epsilon_0} \Rightarrow \rho = \frac{q_{in}}{\frac{4}{3}\pi (r^3 - a^3)} \Rightarrow q_{in} = \frac{4}{3}\pi \rho (r^3 - a^3)$$

Ex: Find the $\vec{E}$ -Field ?

$$Q = 90 \mu C$$

$$R = 30 \text{ cm}$$

$$\textcircled{a} r = 50 \text{ cm}$$

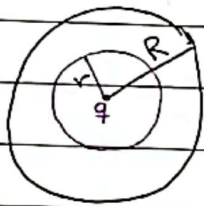


$$E(4\pi r^2) = \frac{Q}{\epsilon_0}$$

$$E_{out} = \frac{keQ}{r^2} = \frac{9 \times 10^9 \times 90 \times 10^{-6}}{0.5^2}$$

$$\frac{N}{C} \text{ (outwards)}$$

$$\textcircled{b} r = 10 \text{ cm}$$



$$\Rightarrow E(4\pi r^2) = \frac{q_{in}}{\epsilon_0}$$

$$\rho = \frac{Q}{\frac{4}{3}\pi R^3} = \frac{q_{in}}{\frac{4}{3}\pi r^3}$$

$$q_{in} = \frac{4}{3}\pi \rho r^3 = q_{in} = \frac{r^3}{R^3} Q$$

Sheet, plane, wall, large or infinite disk

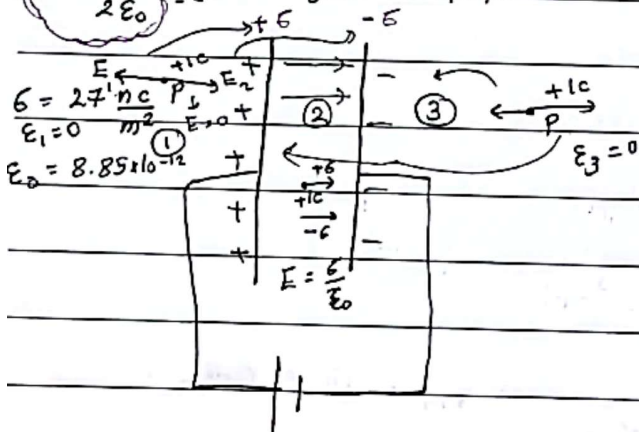
Surface charge density : $\sigma = \frac{Q}{\text{Area}}$

Conducting
 $E = \frac{\sigma}{\epsilon_0}$

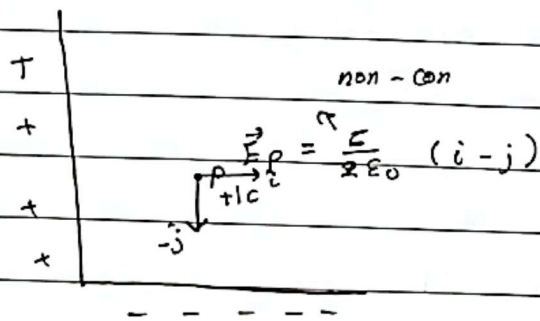
non-Conducting (insulator)
 $E = \frac{\sigma}{2\epsilon_0}$

Ex: Non-Conducting sheet (plane, large disk) Find the electric field in the

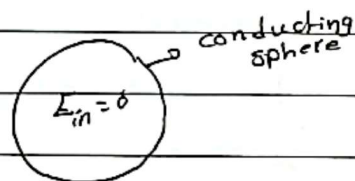
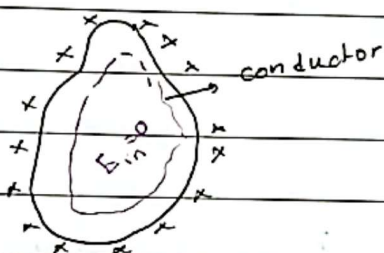
regions 1, 2, 3



+	-
+	-
+	-
+	-

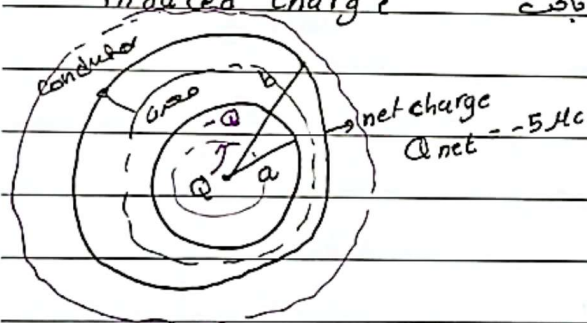


Conductors in electrostatic Equilibrium.



induced charge ; conducting spherical shell

قشرة كروية موصلة



Find E

E

E

inner and outer radius (a, b).

$a = 2\text{cm}, b = 6\text{cm}, q = 10\mu C$

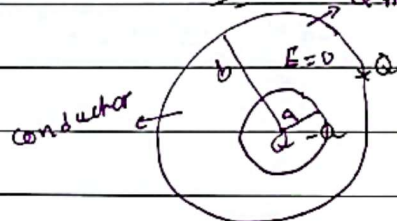
(a) $r = 1\text{cm}$ $E = \frac{Q}{4\pi\epsilon_0 r^2} = \frac{9 \times 10^9 \times 10 \times 10^{-6}}{(0.01)^2} \frac{N}{C}$ outward

(b) $r = 12\text{cm}$ $E = \frac{K_e (Q + Q_{net})}{r^2} = \frac{9 \times 10^9 (10 - 5) \times 10^{-6}}{(0.12)^2} \frac{N}{C}$ outwards.

(c) $r = 5\text{cm}$ $E = 0$

مجال كهربائي صفر

$Q_{net} = 3Q$



$Q_{net} = Q_{ext} + Q_{induced}$

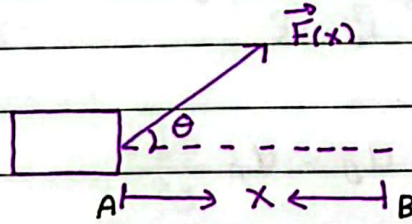
$3Q = ? + 10^{-6} Q$

$? = 2Q$

"The electric potential"

الجهد الكهربائي

① The electric potential :-

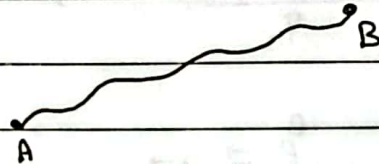


$$\rightarrow W_{A \rightarrow B} = Fx \cos \theta$$

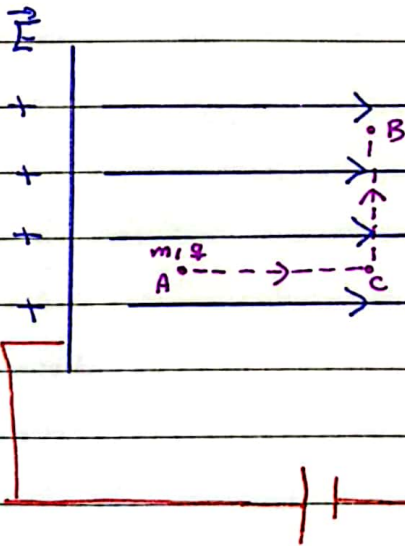
$$\rightarrow W_{A \rightarrow B} = \int_A^B \vec{F}(x) \cdot d\vec{x}$$

Work energy theorem :-

$$W_{A \rightarrow B} = -\Delta U \quad \text{; when } U \text{ is a potential energy "طاقة الوضع"}$$



② The electric potential energy difference :-



$$W_{A \rightarrow B} = \int_A^B \vec{F}_e \cdot d\vec{s}$$

$$d\vec{s} = \begin{cases} dx \hat{i} & \text{; } +x \\ -dx \hat{i} & \text{; } -x \\ dy \hat{j} & \text{; } +y \\ -dy \hat{j} & \text{; } -y \end{cases}$$

$$W_{A \rightarrow B} = W_{A \rightarrow C} + W_{C \rightarrow B} = \int_A^C q_0 \vec{E} \cdot (dx \hat{i}) + \int_C^B q_0 \vec{E} \cdot (dy \hat{j})$$

$$= q_0 \int_A^C (E_0 \hat{i}) \cdot dx \hat{i} + q_0 \int_C^B (E_0 \hat{i}) \cdot dy \hat{j}$$

$$\Rightarrow W_{A \rightarrow B} = q_0 E_0 d$$

$$W_{A \rightarrow B} = \int_A^B \vec{F}(x) \cdot d\vec{s} = -\Delta U = U_B - U_A$$

- We define, the electric potential energy difference :- ΔU

$$\Delta U_{A \rightarrow B} = -W_{A \rightarrow B} = - \int_A^B \vec{F}_e \cdot d\vec{s}$$

$$\Delta U_{A \rightarrow B} = -q_0 \int_A^B \vec{E} \cdot d\vec{s} = U_B - U_A$$

We define the electric potential :-

$$\Delta V_{A \rightarrow B} = \frac{\Delta U_{A \rightarrow B}}{q_0} \quad ; \quad E = \frac{F_e}{q_0}$$

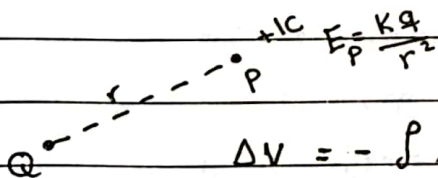
$$\Delta V_{A \rightarrow B} = - \int_A^B \vec{E} \cdot d\vec{s}$$

→ The $\vec{E}$ -Field - charge system is a conservative system :-

$$\Delta U_e + \Delta KE = 0$$

$$q_0 \Delta V + \Delta KE = 0$$

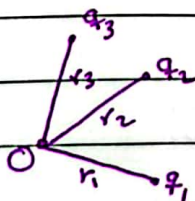
- The electric potential of a point charges :-



$$\Delta V = - \int E dr = - \int \frac{Kq}{r^2} dr$$

$$V = \frac{Kq}{r}, \quad V(r \rightarrow \infty) = 0$$

$$E(r, \infty) = 0$$



$$V_0 = V_1 + V_2 + V_3$$

$$= \frac{Kq_1}{r_1} + \frac{Kq_2}{r_2} + \frac{Kq_3}{r_3}$$

المسافات بقوتها بالإشارة

- obtaining the electric field from the electric potential:-

$$V = - \int E \, ds$$

$$V(x) = - \int E(x) \, dx$$

$$\bullet E(x) = - \frac{\partial V}{\partial x} \quad \bullet E(y) = - \frac{\partial V}{\partial y} \quad \bullet E(z) = - \frac{\partial V}{\partial z}$$

$$\vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

Ex8 Suppose the electric potential is $V(x) = \frac{1}{x}$, Find the electric field at $x = 0.1 \, \text{m}$.

$$E(x) = - \frac{\partial V}{\partial x} = - \left(-\frac{1}{x^2} \right) = \frac{1}{x^2}$$

$$E(0.1) = \frac{1}{(0.1)^2} = 100 \, \text{V/m (N/C)}.$$

Ex8 $V(x, y, z) = 5xyz$, Find the electric field at $(1, 0, -1)$.

$$E_x = - \frac{\partial V}{\partial x} = -5yz, \quad E_y = - \frac{\partial V}{\partial y} = -5xz, \quad E_z = - \frac{\partial V}{\partial z} = -5xy$$

$$\vec{E}(x, y, z) = -5yz \hat{i} - 5xz \hat{j} - 5xy \hat{k}$$

$$\vec{E}(1, 0, -1) = 5 \hat{j}, \quad |E| = 5 \, \text{V/m}$$

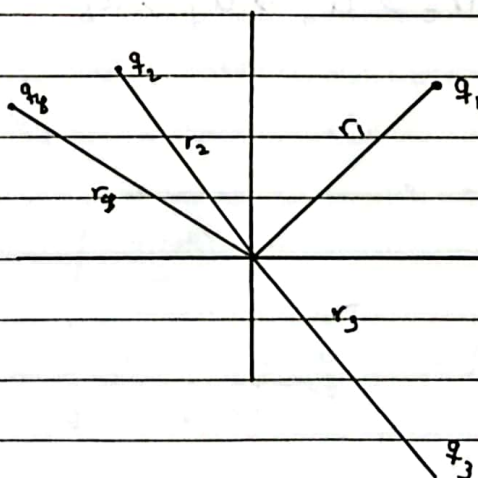
→ What is the electric potential energy stored in the system of charged particles?

→ What is the work required to assemble the system of charged particles

in their position? $\Delta V = \frac{\Delta U}{q} \Rightarrow U = Vq$

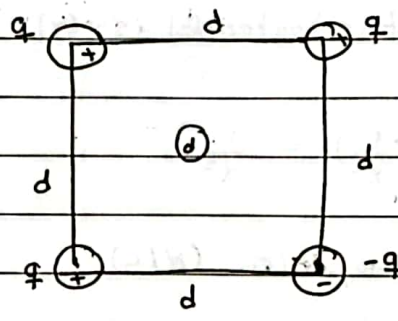
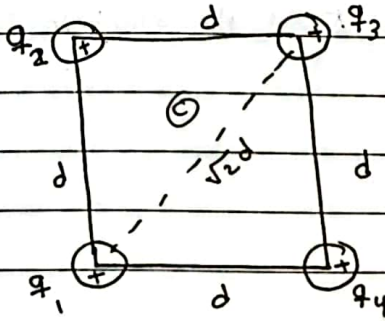
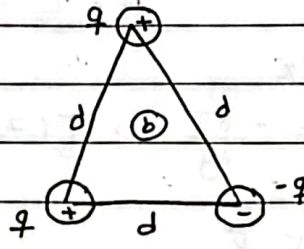
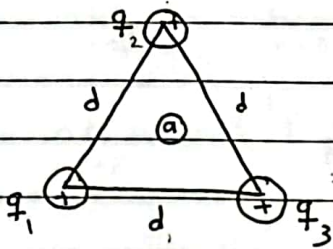
$$U = K_e \frac{q_1 q_2}{r_{12}} + K_e \frac{q_1 q_3}{r_{13}} + K_e \frac{q_1 q_4}{r_{14}}$$

$$+ K_e \frac{q_2 q_3}{r_{23}} + K_e \frac{q_2 q_4}{r_{24}} + K_e \frac{q_3 q_4}{r_{34}}$$



Q 9 / 768 electric potential energy from largest to small (Rank)

$$U = k_e \frac{q_1 q_2}{r_{12}}$$



$$U_a = k_e \frac{q^2}{d} [1 + 1 + 1] = \frac{2k_e q^2}{d}$$

$$U_b = k_e \frac{q^2}{d} [1 + -1 + -1] = -k_e \frac{q^2}{d}$$

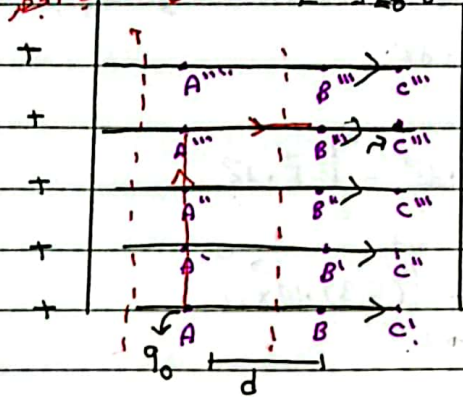
$$U_c = k_e \frac{q^2}{d} \left[1 + \frac{1}{\sqrt{2}} + 1 + 1 + \frac{1}{\sqrt{2}} + 1 \right]$$

$$U_d = k_e \frac{q^2}{d} \left[1 - \frac{1}{\sqrt{2}} + 1 + -1 + \frac{1}{\sqrt{2}} - 1 \right] = \text{Zero}$$

$$U_c > U_a > U_d > U_b$$

Equipotential surface : سطح متساوي الجهد

خط متساوي الجهد $\vec{E} = E_0 \hat{i}$



What is the work required to move the charged particle from A to C''' ?

$$W_{A \rightarrow C'''} = +q_0 \int_A^{C'''} \vec{E} \cdot d\vec{s}$$

$$= +q_0 \int_A^{A'''} (E_0 \hat{i}) \cdot (dy \hat{j}) + +q_0 \int_{A'''}^{C'''} (E_0 \hat{i}) \cdot (dx \hat{i})$$

$$= 0 + q_0 E_0 d$$

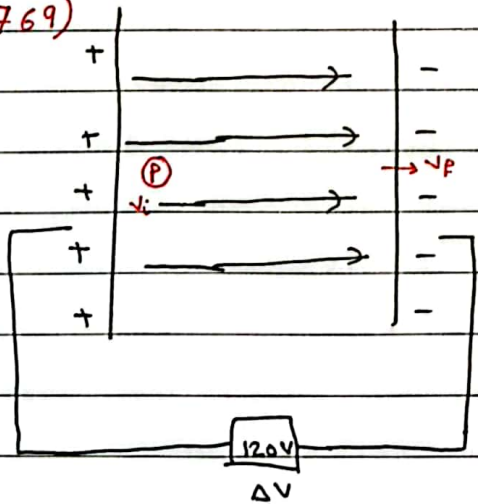
$$\Rightarrow W_{A \rightarrow C'''} = +q_0 E d$$

Recall: $W_{A \rightarrow B} = -\Delta U_{A \rightarrow B} = -q_0 \Delta V_{A \rightarrow B}$

$$= -q_0 (V_B - V_A) = +q_0 E d$$

$V_B - V_A = -E d$ إذا امتساح الجهد في اتجاه عمل القوة موجبة. $V_B < V_A$ و

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

$$m = 1.67 \times 10^{-27} \text{ g}$$

$$\Delta U + \Delta KE = 0$$

$$q_0 \Delta V + \frac{1}{2} m v^2 = 0$$

$$q_0 \Delta V + \frac{1}{2} m v_p^2 - \frac{1}{2} m v_i^2 = 0$$

$$\Delta KE_p = -q_0 \Delta V$$

$$\frac{1}{2} m v_p^2 = -q_0 \Delta V$$

بطرح موجب $\Rightarrow$

$$v_p = \sqrt{\frac{-2 q_0 \Delta V}{m}}$$

$$= \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 120}{1.67 \times 10^{-27}}} \text{ m/s}$$

5 / 769)

$$E = 325 \text{ V/m} \quad \vec{E} = 325(-j) \text{ V/m}$$

Find the potential difference $V_B - V_A$?

$(-0.2, 0.5)$

C — — — — — B $(0.4, 0.5) \text{ m}$

$$\Delta V_{A \rightarrow B} = - \int_A^B \vec{E} \cdot d\vec{s}$$

$$\downarrow \downarrow \downarrow E \quad V_B - V_A = - \int_A^C \vec{E} \cdot d\vec{s} - \int_C^B \vec{E} \cdot d\vec{s}$$

A $(-0.2, -0.3) \text{ m}$

$$V_B - V_A = - \int_{-0.3}^{0.5} (E_0 \hat{j}) \cdot (dy \hat{j}) - \int_{-0.2}^{0.4} (E_0 \hat{j}) \cdot (dx \hat{i})$$

$$= + \int_{-0.3}^{0.5} 325 dy = + 325(0.5 - -0.3) = 260 \text{ V}$$

مسئله مع المجال والجهد بنزير

the force for small charge: $F_e = K_e \frac{q_1 q_2}{r^2}$ لقوة q بدون إشارة

$$F_{12} = F_{21} \quad , \quad \vec{F}_{21} = -\vec{F}_{12}$$

The Electric Field for $q_0 = \vec{E} = \frac{K_e q_0}{r^2}$, $\vec{E} = \frac{\vec{F}}{q_0}$

$$\vec{F} = \epsilon_0 \vec{E}, \quad [\vec{E}] = N/C$$

نقص $+1cp$ وهي التي تمرر ، في هذا القانون نفوذ % بإسارتها

① خطوط الجبال لا تتقاطع.

② فخرج خطوط المحال من السَّحْنَة + وَدَخَلَ فِي -

⑤ عدد مضروب المجال متناسب مع مقدار السحنة $N \propto Q$

* اين نستخدم المحال ؟

① إذا كانت السخني متساويين في الأسارة نفهم بينهما وأقرب للصغرى (بدون أسارة).

" " " " laja " " " cimbiza " " " (2)

* حركة سحابة في uniform Electric Field

$$\underline{F = ma}$$

$$q_0 E_0 = ma$$

$$a = q_0 E_0$$

$$v_f = v_i + at, \quad v_f^2 = v_i^2 + 2ax, \quad \Delta x = v_i t + \frac{1}{2}at^2$$

* The charge distribution "charge density"

"The electric field of charge cont dist"

$$\textcircled{1} \quad 3D \Rightarrow \rho = \frac{Q}{V} = \frac{C}{m^2}$$

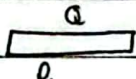
⇒ Sphere (كرة)  ⇒ $\rho = \frac{Q}{\frac{4}{3}\pi r^3}$

⇒ Cylinder (اسطوانة)  ⇒ $\rho = \frac{Q}{2\pi r^2 l}$

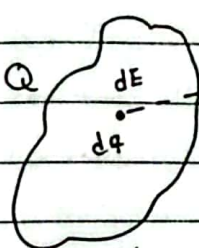
② 2D $\Rightarrow \sigma = \frac{Q}{A} = \frac{C}{m^2}$ (surface).

$\Rightarrow$ disk (قرص)  $\sigma = \frac{Q}{\pi r^2}$

③ 1D $\Rightarrow \lambda = \frac{Q}{l} = \frac{C}{m}$

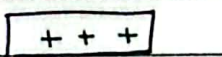
$\Rightarrow$ rod  $\Rightarrow \lambda = \frac{Q}{l}$

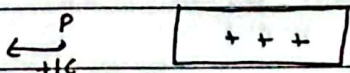
$\Rightarrow$ ring  $\Rightarrow \lambda = \frac{Q}{2\pi r}$

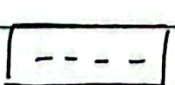
 $\Rightarrow dE = k_e \frac{dq}{r^2} \Rightarrow E = k_e \int \frac{dq}{r^2}$

* The electric field of charged rod: $E_p = \frac{k_e \lambda l}{a(a+l)}$

* " " " " " ring: $E = \frac{k_e Q \lambda}{(R^2 + x^2)^{3/2}}$

*  $\xrightarrow{+1C}$ out words ($\hat{i}$)

 $\xleftarrow{+1C}$ out words ($-\hat{i}$)

 $\xleftarrow{+1C}$ in words ($-\hat{i}$)

 $\xrightarrow{+1C}$ in words ($\hat{i}$)

out words $\oplus$ rod 1st

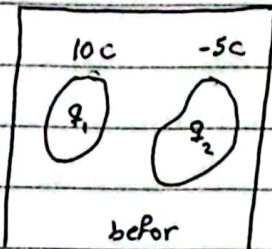
in words $\ominus$ " "

$$\Rightarrow q = N \cdot e$$

$$N = 0, \pm 1, \pm 2, \pm 3 \dots$$

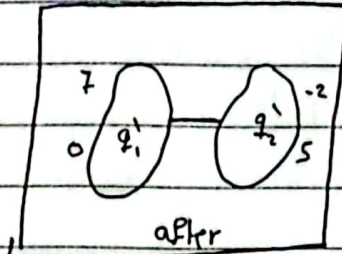
← "The charge is quantized"

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



$$q_T = q_1 + q_2$$

$$= 10 - 5 = 5c$$

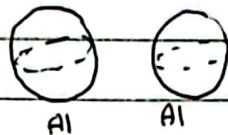


$$q'_T = q'_1 + q'_2$$

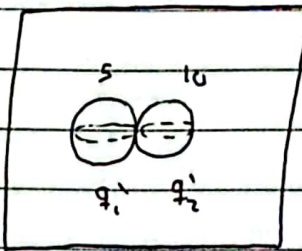
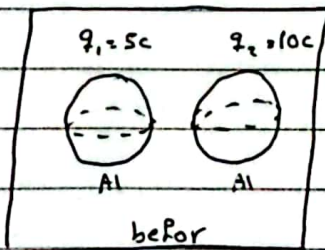
$$= 7 - 2 = 5c$$

* identical object :- نفس الأبعاد والمادة

→ two identical sphere :-



بجر التوصيل ← الشحنة على الألف
= المساحة على الألف



$$q'_T = 15c$$

$$q'_1 = q'_2 = \frac{q'_T}{2} = 7.5c$$

⇒ The charge is conserved

$$F_G = G \frac{m_1 m_2}{r^2}$$

= قوة الجذب الثقلي

$$E_{Arc} = \frac{K e 2 \lambda}{R} \sin\left(\frac{\theta}{2}\right)$$

$$, \theta \text{ Rad}$$

$$l = R\theta, \lambda = \frac{q}{l} \rightarrow \text{الكثافة}$$

electric Flux $\Phi_E = EA \cos \theta$, $\theta = \text{rad}$

$$\theta = \pi \Rightarrow \Phi = -EA$$

$$\theta = 0 \Rightarrow \Phi = EA \quad \text{For regular Surface}$$

$$\theta = \frac{\pi}{2} \Rightarrow \Phi = \text{Zero}$$

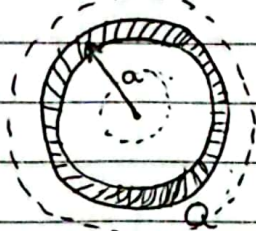
$$\Rightarrow \text{For irregular surface} \Rightarrow \Phi = \int \vec{E} \cdot d\vec{A} = \int E \cos \theta dA$$

$$\Rightarrow \text{For non charged object immersed in } \vec{E}\text{-field the } \Phi_T = \text{Zero}$$

$$\Rightarrow \text{Gauss law :- } \Phi = \frac{\sum q_{in}}{\epsilon_0} \quad \text{فلانحنى بالاشارة + سببى بالداخل}$$

$$\Rightarrow \Phi = \int \vec{E} \cdot d\vec{A} = \int E \cos \theta dA = \frac{\sum q_{in}}{\epsilon_0}$$

* spherical shell :- E -field due to a spherical shell at radius a and uniformly charged Q ?

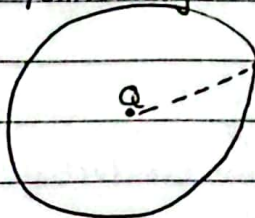


a) Inside the shell ($r < a$) ? " $E_{in} = \text{Zero}$ "

b) outside the shell ($r > a$) ?

$$\int \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} \Rightarrow E(4\pi r^2) = \frac{Q}{\epsilon_0} \Rightarrow E = \frac{k_e Q}{r^2} \quad \text{"out"}$$

* point charge



$$\int E \cdot dA = \frac{q_{in}}{\epsilon_0} \Rightarrow E(4\pi r^2) = \frac{Q}{\epsilon_0} \Rightarrow E = \frac{k_e Q}{r^2} \quad \text{"out"}$$

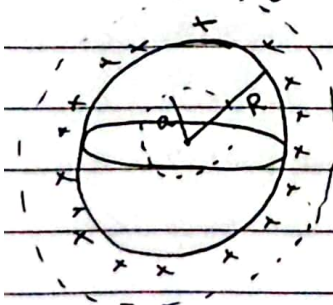
$$(\text{Area} = 4\pi r^2) \quad \text{Sphere}$$

- dot $\leftarrow -1c$ / + dot $\leftarrow +1c$

* Sphere :-

1. Conducting (Al, Cu, Pb, metallic) "جسم موصِّل"

$\Rightarrow$ The charge distribution uniformly on the Surface



a) inside $\Rightarrow E_{in} = \text{Zero}$ ($r < R$) $\text{Zero} = E_{in}$ "جسم موصِّل"

b) outside $\Rightarrow E_{out}(4\pi r^2) = \frac{Q}{\epsilon_0} \Rightarrow E_{out} = \frac{k_e Q}{r^2}$ ($r > R$)

* what is the Surface charge density ?

$$\sigma = \frac{Q}{A} = \frac{Q}{4\pi R^2}$$

outward $q(+)$

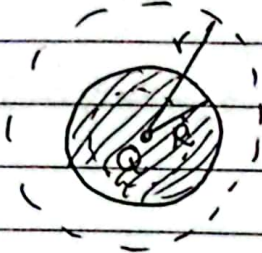
inward $q(-)$

2. non-conducting sphere (insulating, plastic, Rubber, non-metallic)

Solid, glass, air, air

* what is the volume charge density? $\rho = \frac{Q}{\frac{4}{3}\pi R^3}$

* the charge is distributed uniformly through its volume.



① E_{out} ? ($r > R$)

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} \Rightarrow E(4\pi r^2) = \frac{Q}{\epsilon_0}$$

$$E_{out} = \frac{k_e Q}{r^2}$$

$$\textcircled{2} E_{in} ? (r < R) \Rightarrow \oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} \Rightarrow E(4\pi r^2) = \frac{q_{in}}{\epsilon_0}$$

$$\rho = \frac{Q}{\frac{4}{3}\pi R^3} = \frac{q_{in}}{\frac{4}{3}\pi r^3} \Rightarrow q_{in} = \frac{r^3 Q}{R^3}$$

$$E(4\pi r^2) = \frac{\frac{r^3 Q}{R^3}}{\epsilon_0} \Rightarrow E_{in} = \frac{k_e Q r}{R^3}$$

* sheet, plane, wall, large, infinite disk

"finite ch 23"

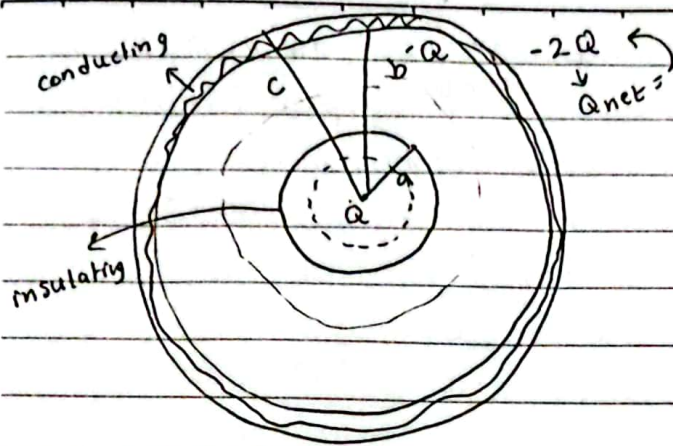
Surface charge density $\Rightarrow \sigma = \frac{Q}{A}$

↓
conducting

$$E = \frac{\sigma}{\epsilon_0}$$

↓
non-conducting

$$E = \frac{\sigma}{2\epsilon_0}$$



$$r < a \Rightarrow E = \frac{K_e Q r}{R^3 - a^3}$$

$$a < r < b \Rightarrow E = \frac{K_e Q}{r^2}$$

$$\text{in conductor} \Rightarrow E_{in} = \text{Zero} \quad b < r < c$$

$$r > c \Rightarrow E = \frac{K_e (-2Q + Q)}{r^2} = -\frac{K_e Q}{r^2}$$

$$-Q + Q_{ext} = -2Q$$

$$Q_{ext} = -Q$$

$$\Rightarrow \Phi_{\text{face}} = \frac{\Phi_T}{6} \quad \leftarrow \text{cube}$$

$$\Rightarrow \Phi_{\text{face}} = \frac{\Phi_T}{8} \quad \leftarrow \text{octagon}$$

$$\Rightarrow \Phi_{\text{Total}} \Rightarrow \Phi_{\text{half-shell}} = \Phi_T / 2$$

$$\text{quart-shell} \Rightarrow \Phi_T / 4$$

$$\Rightarrow \vec{E} - \text{field} \perp \text{surface}$$

$$\Rightarrow \vec{E} - \text{field} \parallel \text{surface}$$

$$\begin{array}{c} \vec{E} \uparrow \uparrow \vec{A} \\ \Rightarrow \theta = 0 \end{array}$$

$$\begin{array}{c} \vec{A} \uparrow \rightarrow \vec{E} \\ \Rightarrow \theta = \frac{\pi}{2} \end{array}$$

$$\Rightarrow \text{if the plane } \parallel \text{ to } yz \Rightarrow \theta = 0$$

$$\Rightarrow \text{ , , } \parallel \text{ to } xy \Rightarrow \theta = \pi/2$$

$$E_{\text{wire}} = E_{\text{cylinder}} = \frac{2K\epsilon\lambda}{r}$$

$$A_{\text{cylinder}} = (2\pi r\ell).$$

* cylindre shell

$$E_{\text{in}} = 0, \quad E_{\text{out}} = \frac{2K\epsilon\lambda}{r}$$

Electric potential $\Rightarrow \Delta V$ الجهد الكهربائي

potential energy $\Rightarrow U$ طاقة الوضع

electric potential energy difference $\Rightarrow \Delta U$ التغير في طاقة الوضع

work $\Rightarrow W$ الشغل

$$\Rightarrow W = F \times \cos \theta \quad d\vec{S} = \begin{cases} \hat{i} dx \\ -\hat{i} dx \\ \hat{j} dy \\ -\hat{j} dy \end{cases}$$

$$\Rightarrow W_{A \rightarrow B} = \int_A^B \vec{F}_e \cdot d\vec{S}$$

$$\Rightarrow W_{A \rightarrow B} = -\Delta U$$

$\vec{E}$

* the work done by the field on moving a q

from A to B ?

$$W_{A \rightarrow B} = \int_A^B \vec{F}_e \cdot d\vec{S}$$

$$= \int_A^C \vec{F}_e \cdot d\vec{S} + \int_C^B \vec{F}_e \cdot d\vec{S}$$

$$= \int_A^B q_0(E\hat{i}) dx(\hat{i}) + \int_C^B q_0(E\hat{i}) dy(\hat{j})$$

$$= q_0 E_0 d$$

$$\Rightarrow W_{A \rightarrow B} = \int_A^B \vec{F}_e \cdot d\vec{S} = q_0 E d = -\Delta U_{A \rightarrow B}$$

$$\Rightarrow \Delta U_{A \rightarrow B} = -W_{A \rightarrow B} = - \int_A^B \vec{F}_e \cdot d\vec{S} = -q_0 \int_A^B \vec{E} \cdot d\vec{S} = U_B - U_A$$

electric potential :

$$\Rightarrow \Delta V_{A \rightarrow B} = \frac{\Delta U_{A \rightarrow B}}{q_0} = - \int_A^B \vec{E} \cdot d\vec{S} \quad [V] = J/C = V$$

$$[E] = V/m = J/C$$

$$\Rightarrow \Delta V_{A \rightarrow B} = V_B - V_A = - \int_A^B \vec{E} \cdot d\vec{S}$$

$$\Rightarrow \Delta U = q \Delta V$$

$$\Rightarrow W = -\Delta U = -q \Delta V$$

$$\Rightarrow \Delta U + \Delta KE = 0$$

$$\Rightarrow q \Delta V + \Delta KE = 0$$

⇒ the electric potential of point charge q :-

⇒ $V = \frac{K_e q_1 q_2}{r}$ ، q بحرف بالكتابة

⇒ $V(r \rightarrow \infty) = 0$, $E(r \rightarrow \infty) = 0$

⇒ obtaining the $\vec{E}$ -Field From $\vec{E}$ -potential :-

$$V = - \int \vec{E} \cdot d\vec{s}$$

$$E(x) = -\frac{\partial V}{\partial x} \quad , \quad E(y) = -\frac{\partial V}{\partial y} \quad , \quad E(z) = -\frac{\partial V}{\partial z}$$

* what is the electric potential energy stored in the system of charged particles?

* what is the work required to assemble the system of charged particles in their position?

⇒ الجواب ⇒ $U = \frac{K_e q_1 q_2}{r_{12}}$ باخذ الصيغة مع الاكبر وهذا

⇒ $W = - \Delta U$

$A \rightarrow B$ $= - q_0 \Delta V$

$= - q_0 (V_B - V_A) = q_0 E d$

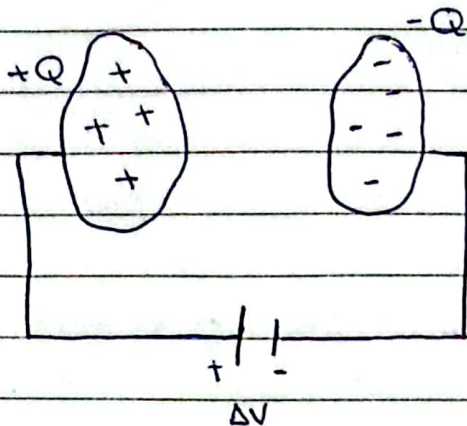
$E = -\frac{\Delta V}{\Delta x}$

لوف رسمه بين x ولا يكون يسر E على مراحل ←

"CH 26"

"The capacitance" ← المواسعة

① Definition of capacitance, we define the capacitance as :-



$$C = \frac{Q}{\Delta V}$$

$$[C] = \frac{C}{V} = \text{Farad}$$

$$mF, \mu F, nF, pF$$

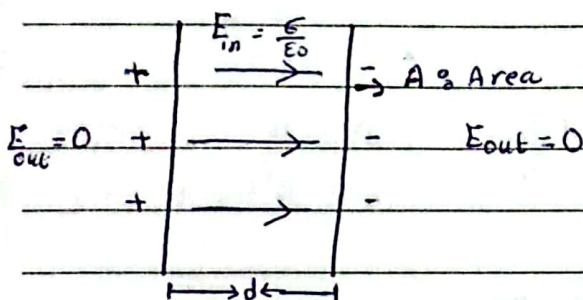
$$10^{-3} F, 10^{-6} F, 10^{-9} F, 10^{-12} F$$

$$\Rightarrow Q = C \Delta V$$

② calculating the capacitance :-

1. the parallel plate capacitor :-

المواسعة ذات المجالين المتوازيين



d's separation (distance between) the plates

$$C = \frac{Q}{\Delta V}, \Delta V = -\int E ds = -\int_0^d \frac{\epsilon}{\epsilon_0} dx = -\frac{\epsilon d}{\epsilon_0}$$

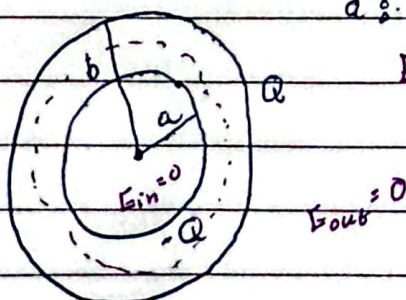
$$C = \frac{Q}{|\Delta V|} = \frac{Q}{\frac{\epsilon d}{\epsilon_0}}, \text{ but } \epsilon = \frac{Q}{A}$$

$$C = \frac{\epsilon_0 Q}{\frac{Q}{A} d} = \frac{\epsilon_0 A}{d} = C$$

2. the spherical capacitor :-

مواسعة كروية

a : inner radius, b : outer radius



$$E = \frac{-KQ}{r^2}, a \leq r \leq b$$

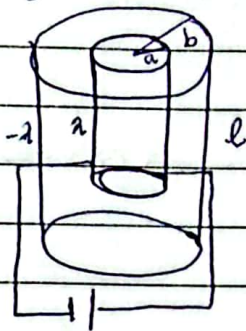
$$\Delta V_{a \leq r \leq b} = - \int E dr = - \int_a^b \frac{K_e Q}{r^2} dr = -K_e Q \left[\frac{1}{r} \right]_a^b$$

$$= -K_e Q \left[\frac{1}{b} - \frac{1}{a} \right] = +K_e Q \frac{a-b}{ab}$$

$$\Delta V = K_e Q \frac{b-a}{ab}$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{K_e Q \frac{b-a}{ab}} = \frac{4\pi \epsilon_0 ab}{b-a}$$

③ cylindrical capacitor :-



$$E_{in} = \frac{2K_e \lambda}{r}, \quad a \leq r \leq b$$

$$\Delta V = - \int_a^b \frac{2K_e \lambda}{r} dr$$

$$\Delta V = -2K_e \lambda \ln r \Big|_a^b = -2K_e \lambda \ln \left| \frac{b}{a} \right|, \quad \lambda = \frac{q}{l}$$

$$\therefore C = \frac{Q}{\Delta V} = \frac{\lambda l}{2K_e \lambda \ln \left(\frac{b}{a} \right)}$$

$$\therefore C = \frac{2\pi \epsilon_0 l}{\ln \left| \frac{b}{a} \right|}$$

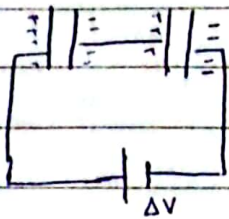
The capacitance per unit length ($\lambda = 1$)

$$\frac{C}{l} = \frac{2\pi \epsilon_0}{\ln \left| \frac{b}{a} \right|}$$

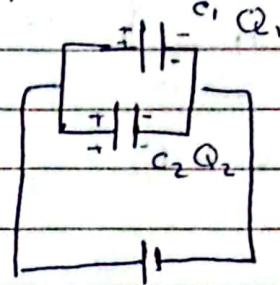
* The combinations of capacitor :- توصيل المكثفات

• The series combination (توصيل متسلسل)

$Q_1 \quad C_1 \quad C_2 \quad Q_2$



• The parallel combination (توصيل متوازي)



* The charge on each capacitor

• $Q_1 = Q_2 = Q_{eq}$ & $eq: eqv$

• $Q_{eq} = Q_1 + Q_2$

* The potential difference across each capacitor

• $\Delta V = \Delta V_1 + \Delta V_2$

• $\Delta V_1 = \Delta V_2 = \Delta V$

* The equivalent capacitance,

• $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

• $C_{eq} = C_1 + C_2$

* The energy stored in the capacitor.

$\Rightarrow U = \frac{1}{2} q \Delta V$, but $Q = C \Delta V$

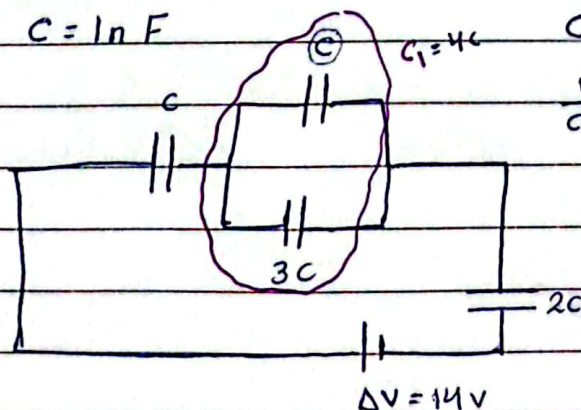
$\Rightarrow U = \frac{1}{2} C \Delta V^2$

$\Rightarrow U = \frac{1}{2} \frac{Q^2}{C}$

Ex:-

* what is the equivalent capacitance?

$C = 1nF$

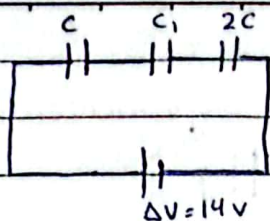


$C_1 = C + 3C = 4nF$

$\frac{1}{C_{1eq}} = \frac{1}{C} + \frac{1}{4C} + \frac{1}{2C}$

$= 1 + \frac{1}{4} + \frac{1}{2} = \frac{7}{4} nF$

$C_{eq} = \frac{4}{7} nF$



* what is the charge on each capacitor?

$$Q_{eq} = C_{eq} \Delta V = \frac{4}{7} \times 14 = 8 \text{ nC}$$

مستويات لا يتم توصيلها على التوالي.

$$\therefore Q_C = Q_{C1} = Q_{2C} = Q_{eq} = 8 \text{ nC}$$

$$\Delta V_C = \frac{Q_C}{C} = \frac{8 \text{ nC}}{1} = 8 \text{ V}$$

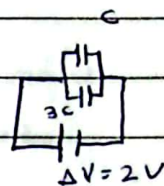
$$\Delta V_{C1} = \frac{Q_{C1}}{C1} = \frac{8 \text{ nC}}{4} = 2 \text{ V}$$

$$\Delta V_{2C} = \frac{Q_{2C}}{C_{2C}} = \frac{8}{2} = 4 \text{ V}$$

$$\Delta V_{\odot} = \Delta V_{3C} - \Delta V_{C1} = 2 \text{ V}$$

$$Q_{\odot} = C_{\odot} \Delta V_{\odot} = 1 \times 2 = 2 \text{ nC}$$

$$Q_{3C} = C_{3C} \Delta V_{3C} = 3 \times 2 = 6 \text{ nC}$$



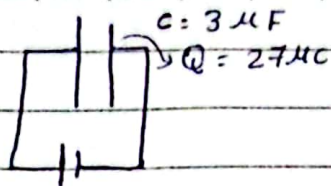
* what is the energy stored in the system?

$$U = \frac{1}{2} Q_{eq} \Delta V = \frac{1}{2} (8 \times 10^{-9}) (14) = 56 \text{ nJ}$$

* " " " " in 3C?

$$U_{3C} = \frac{1}{2} Q_{3C} \Delta V_{3C} = \frac{1}{2} (6 \times 10^{-9}) \times 2 = 6 \times 10^{-9} \text{ J} = \frac{Q^2}{2C}$$

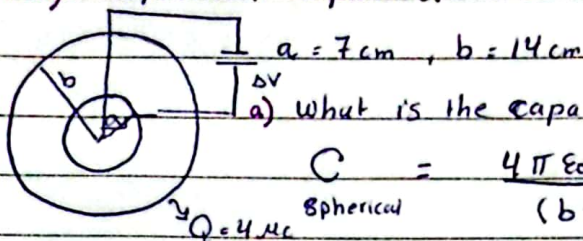
1/801) a)



$$\Delta V = ?$$

$$\Rightarrow Q = C \Delta V \Rightarrow \Delta V = \frac{Q}{C} = \frac{27}{3} = 9 \text{ V}$$

4/801) Spherical capacitor



a) what is the capacitance?

$$C = \frac{4\pi\epsilon_0 ab}{(b-a)} = \frac{4\pi \times 8.85 \times 10^{-12} \times 0.07 \times 0.14}{0.07} = \sim$$

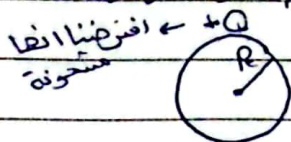
b) $\Delta V = \frac{Q}{C} = \frac{4 \times 10^{-6}}{\sim}$

11/801) special case From spherical capacitor

Isolated sphere $\Rightarrow$ كرة معزولة

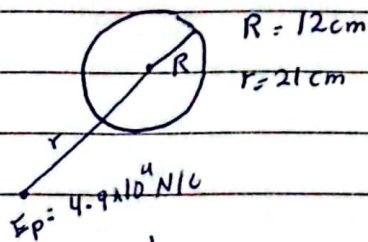
"او يمكن يكون قمره ماء"

what is its capacitance?



$$C = \lim_{b \rightarrow \infty} \frac{4\pi\epsilon_0 ab}{b-a} = 4\pi\epsilon_0 R$$

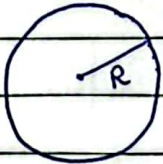
isolated sphere



$$\textcircled{a} E = \frac{K_e q}{r^2} \Rightarrow q = \frac{Er^2}{K_e} = \frac{(0.21)^2 (4.9 \times 10^4)}{9 \times 10^9} \text{ C}$$

$$\sigma = \frac{Q}{4\pi R^2} = \frac{Q}{4\pi (0.21)^2}$$

⑥ what is the capacitance? $C = 4\pi\epsilon_0 R = 4 \times 3.14 \times 8.85 \times 10^{-12} (0.12) \text{ F}$

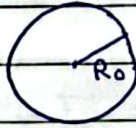


$$C = 4\pi\epsilon_0 R$$

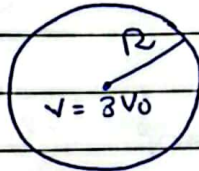
Spherical capacitor

$$\text{Volume} = V_0$$

$$\text{Capacitance} = C_0$$



$$C = P C_0$$



$$- C_0 = 4\pi\epsilon_0 R_0$$

$$- V_0 = \frac{4}{3}\pi R_0^3$$

$$C = 4\pi R$$

$$V = 3V_0$$

$$\frac{4}{3}\pi R^3 = 3 \cdot \frac{4}{3}\pi R_0^3 \Rightarrow R^3 = 3R_0^3$$

$$R = \sqrt[3]{3} R_0$$

$$\Rightarrow C = 4\pi\epsilon_0 R = (4\pi\epsilon_0) \sqrt[3]{3} R_0$$

$$= \sqrt[3]{3} (4\pi\epsilon_0 R_0) \Rightarrow \frac{C}{C_0} = \sqrt[3]{3}$$

3) identical capacitor $\Rightarrow C_1, C_1, C_1, \dots, C$

$$C_p = \underbrace{C + C + C + \dots + C}_{N \text{ terms}}$$

$$C_p = N C$$

$$\Rightarrow C_p = 100 C_s$$

Number of capacitor?

$$\frac{1}{C_s} = \frac{1}{C} + \frac{1}{C} + \dots + \frac{1}{C}$$

$$= \frac{N}{C}$$

$$\Rightarrow C_p = N C_s \quad \text{و} \quad C_s = \frac{C}{N}$$

$$C_p = 100 C_s$$

$$N C_s = 100 C_s \Rightarrow N^2 = 100 \Rightarrow N = 10$$

$$* \text{ الجواب} = \sqrt{\text{الرقم}}$$

$$27) C_1 \text{ و } C_2, \quad C_p = 9 \text{ pF}, \quad C_s = 2 \text{ pF}$$

$$C_p = C_1 + C_2 = 9$$

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{2}$$

$$\frac{C_1 + C_2}{C_1 C_2} = \frac{1}{2} \Rightarrow C_1 C_2 = 2(C_1 + C_2)$$

$$\Rightarrow C_1 C_2 = 18 \quad \text{but} \quad C_p = 9 - C_2$$

$$C_2(9 - C_2) = 18 \Rightarrow C_2^2 - 9C_2 + 18 = 0$$

$$(C_2 - 3)(C_2 - 6) = 0 \Rightarrow C_2 = 3, 6$$

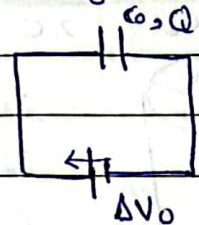
$$C_1 = 6, 3$$

Capacitance of Dielectric

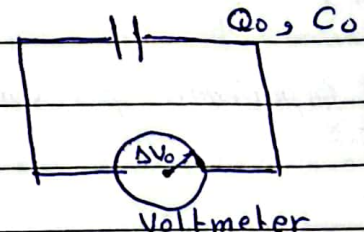
مواد ثنائية القطب الكهربائية

a) charging the capacitor with potential difference ΔV_0 while filled with air $\Rightarrow C = \frac{Q_0}{\Delta V_0}$

$$Q_0 = C_0 \Delta V_0$$

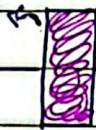


b) Disconnecting the capacitor from the battery while it is in Air



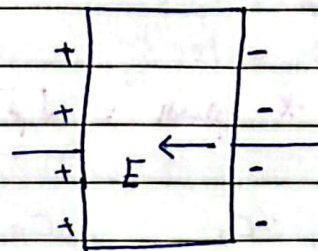
c) Filling the capacitor with dielectric Material $\vec{E} = 500$

Dielectric Material



$$Q = Q_0$$

$$\Delta V = \frac{\Delta V_0}{K}, \Delta V < \Delta V_0, K > 1$$



$$\Delta V = Ed$$

$$C = KC_0$$

$$Q = C\Delta V$$

$$Q_0 = C \frac{\Delta V_0}{K}$$

$$C = K \frac{Q_0}{\Delta V_0} \Rightarrow C = KC_0$$

* what is the energy required to insert the dielectric material inside the capacitor?

$$W = -\Delta U, U = \frac{Q^2}{2C}$$

$$= -(U_f - U_i)$$

$$= U_0 - U_K$$

$$= \frac{Q_0^2}{2C_0} - \frac{Q_0^2}{2C}, C = KC_0$$

57)



$$2a = 2.58 \text{ mm}$$

$$2b = 7.27 \text{ mm}$$

$$Q = 7.1 \mu\text{C}$$

$$l = 50 \text{ m}$$

$$\lambda = \frac{Q}{l}$$

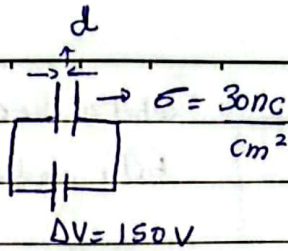
$$C = \frac{2\pi\epsilon_0 l}{\ln\left(\frac{b}{a}\right)} = \frac{2 \times 3.14 \times 8.85 \times 10^{-12} \times 50}{\ln\left|\frac{7.27}{2.58}\right|}$$

$$= \sim F$$

$$\text{capacitance per unit length } \frac{C}{l} = \frac{2 \times 3.14 \times 8.85 \times 10^{-12}}{\ln\left|\frac{7.27}{2.58}\right|} = \sim \text{ F/m}$$

Final

7) parallel plate



$d = ??$

$$\begin{aligned} \text{cm}^2 &\rightarrow 10^{-4} \text{ m}^2 \\ \text{mm}^2 &\rightarrow 10^{-6} \text{ m}^2 \end{aligned}$$

$$E = \frac{\sigma}{\epsilon_0}, \Delta V = Ed, C = \frac{\epsilon_0 A}{d}$$

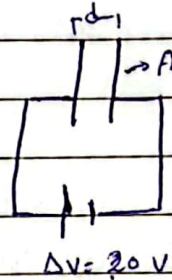
$$\Delta V = \frac{\sigma}{\epsilon_0} d \Rightarrow d = \frac{\Delta V \epsilon_0}{\sigma} = \frac{8.85 \times 10^{-12} \times 150}{30 \times 10^{-9}} = 10^{-4}$$

9) parallel plate capacitor

$$A = 7.6 \text{ cm}^2$$

$$d = 1.8 \text{ mm}$$

$E = ??$



$$\text{a) } \Delta V = Ed$$

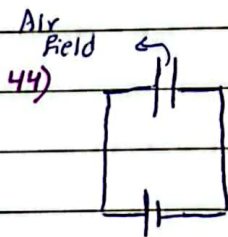
$$E = \frac{\Delta V}{d} = \frac{20}{1.8 \times 10^{-3}} = 11.1 \text{ V/m}$$

$$\text{b) } E = \frac{\sigma}{\epsilon_0} \Rightarrow \sigma = \epsilon_0 E = 8.85 \times 10^{-12} \times 10.2 \times 10^3 \text{ C/m}^2$$

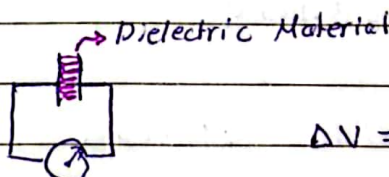
$$\text{c) } \sigma = \frac{Q}{A} \Rightarrow Q = \sigma A = 11.1 \times 7.6 \times 10^{-4}$$

$$\text{d) capacitance ?? } C_p = \frac{\epsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 7.6 \times 10^{-4}}{1.8 \times 10^{-3}}$$

$$\text{e) the energy stored in the capacitor ? } U = \frac{1}{2} Q \Delta V$$



$$\Delta V = 85 \text{ V}$$



Voltmeter

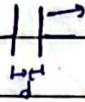
$$\Delta V = 25 \text{ V}$$

Dielectric constant K

$$\Delta V = \frac{\Delta V_0}{K} \Rightarrow K = \frac{\Delta V_0}{\Delta V}$$

$$= \frac{85}{25} = 3.4$$

45)

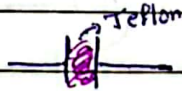


$$A = 1.75 \text{ cm}^2$$

what is the capacitance

$$d = 0.04 \text{ mm}$$

before and after?



(K = 2.1) dielectric

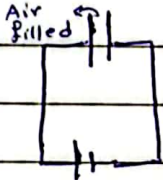
K_{vac}

constant

$$C_0 = \frac{\epsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 1.75 \times 10^{-4}}{0.04 \times 10^{-3}} = \sim \mu\text{F}$$

$$C = KC_0 = 2.1 \times \sim$$

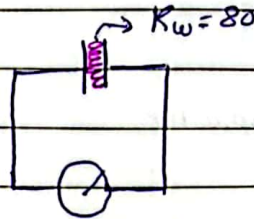
47)



$$d = 1.5 \text{ cm}$$

$$A = 25 \text{ cm}^2$$

$$\Delta V_0 = 250 \text{ V}$$



Voltmeter

When Filled with air $\Rightarrow Q_0, C_0, \Delta V_0$

$$\Delta V_0 = 250 \text{ V}$$

$$C_0 = \frac{\epsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 25 \times 10^{-4}}{1.5 \times 10^{-2}} = 147.5 \times 10^{-14} \text{ F}$$

$$= 1.48 \text{ pF}$$

$$Q_0 = C_0 \Delta V_0 = 1.48 \times 250 \times 10^{-12} = 368.75 \times 10^{-12} \text{ C}$$

$$= 36.9 \text{ nC}$$

When Filled with water $\Rightarrow$

$$Q = Q_0 \Rightarrow 36.9 \text{ nC}$$

$$\Delta V = \frac{\Delta V_0}{K} = \frac{250}{80} = 3.125 \text{ V}$$

$$C = KC_0 = (80)(148) \times 10^{-12} = 118.4 \text{ pF}$$

$$* \text{ what is the work? } W = U_p^K - U_i^{\text{air}} = \frac{U_i}{K} - U_i$$

$$= U_0 \left(\frac{1}{K} - 1 \right) = U_0 \left(1 - \frac{1}{K} \right)$$

منه مع الماء

$$= \frac{1}{2} Q_0 \Delta V_0 \left(1 - \frac{1}{K} \right) = \frac{1}{2} \times 36.9 \times 10^{-9} \times 250 \left(1 - \frac{1}{80} \right)$$

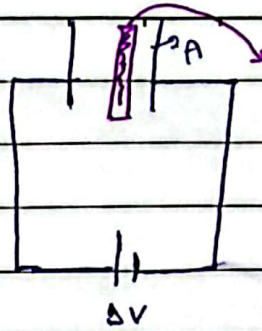
$$= \sim \text{ J}$$

Note 1:- Metallic slab

قالب معدني

$$C = \frac{\epsilon_0 A}{d - \Delta}$$

$$C = \frac{8.85 \times 10^{-12} \times 25 \times 10^{-4}}{(1.5 \times 10^{-2} - 1.25 \times 10^{-3})}$$



metallic slab of

thickness: Δ

$$A = 25 \text{ cm}^2$$

$$d = 1.5 \text{ cm}$$

$$\Delta = 1.25 \text{ mm}$$

Note 2:- The energy density of parallel plate capacitor

$$u = \frac{U}{\text{Volume}}$$

$$\sigma = \frac{Q}{A}, \Delta V = Ed$$

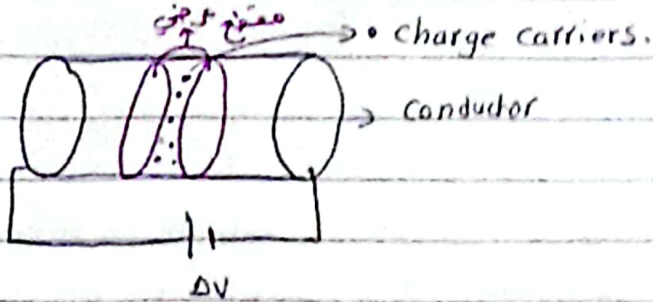
$$U = \frac{1}{2} Q \Delta V \Rightarrow \frac{1}{2} \epsilon A E d$$

$$= \frac{1}{2} \epsilon E (\underbrace{Ad}_{\text{Volume}}) \Rightarrow u = \frac{U}{\text{volume}} = \frac{U}{Ad} = \frac{1}{2} \epsilon E, E = \frac{\sigma}{\epsilon_0}$$

$$= \frac{1}{2} \epsilon_0 \sigma^2 = \frac{1}{2} \frac{\sigma^2}{\epsilon_0}, \sigma = \epsilon_0 E$$

$$u = \frac{1}{2} \epsilon_0 E^2 \frac{\text{J}}{\text{m}^3}$$

- Current definition

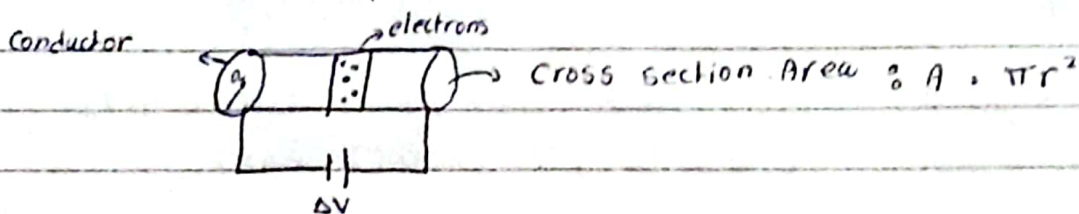


- We define the current: $I = \frac{\text{charge in charge}}{\text{average change in time}} = \frac{\Delta Q}{\Delta t} = \frac{Q_f - Q_i}{t_f - t_i}$

$$I = \frac{C}{s} = [A] \cdot \text{Ampere}$$

- the instantaneous current: $I = \frac{dQ}{dt}$

- The microscope picture of the current:-



$$I = ne v_d A$$

n :- عدد الإلكترونات → كثافة الإلكترونات

L , electrons number density ($\frac{e}{m^3}$)

e.g. $1.6 \times 10^{19} C$

v_d :- drift speed

A :- Cross section Area

$$4 mm^2 = 4 \times 10^{-6} m^2$$

$$4 cm^2 = 4 \times 10^{-4} m^2$$

ohm's law:-

- The current density

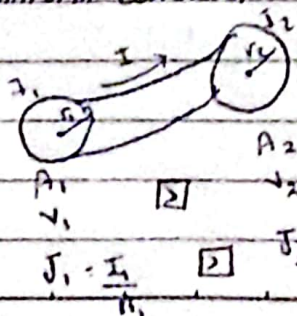
Non-uniform conductor

$$V_1 > V_2, A_1 < A_2, I_1 = I_2$$

$$J_1 > J_2$$

$$A_1 = \pi r_1^2$$

$$A_2 = \pi r_2^2$$



$$J_1 = \frac{I_1}{A_1}$$

$$J_2 = \frac{I_2}{A_2}$$

current density :- $\vec{J} \Rightarrow$ Jordan (Vector)

$$J = \frac{\text{Current}}{\text{Area}} = \frac{I}{A}$$

$$I = A_1 J_1 = A_2 J_2$$

Ohm's Law: $\vec{J} \propto \vec{E}$

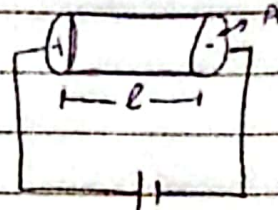
$$J = \sigma E$$

σ : Conductivity

ρ : resistivity

$$J = \frac{1}{\rho} E \Rightarrow \frac{I}{A} = \frac{1}{\rho} \frac{\Delta V}{l}$$

$$\Delta V = \frac{\rho L}{A} I$$



where $\Delta V = RI$

$R = \frac{\rho L}{A}$ is called resistance

$$\Delta V = E l$$

$$J = \frac{I}{A}, \vec{J} = \sigma \vec{E}, \Delta V = RI, R = \frac{\rho L}{A}, I = en A V_d$$

power :- القدرة [Watt], $R(T) = R_0 (1 + \alpha \Delta T)$

$$P = I \Delta V$$

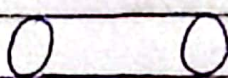
$$\Delta T = T - T_0$$

$$= R I^2$$

$$= \frac{V^2}{R}$$

Temperature dependent resistance:-

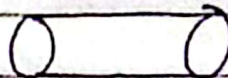
when cold



$T_0 = 20^\circ C$

$$R_0 = \frac{\rho_0 L}{A}$$

when



hot $T > T_0$

$$R(T) = R_0 [1 + \alpha (T - T_0)]$$

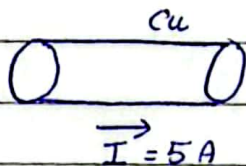
$$R_0 = \frac{\rho_0 L}{A}$$

α : thermal resistance coefficient

"نقطة بالمقاومة"

$$[\alpha] = \frac{1}{^\circ C} = ^\circ C^{-1}$$

3/826)



$$A = 4 \times 10^{-6} \text{ m}^2$$

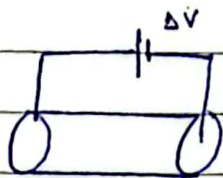
$$V_d = ??$$

$$\text{given } \Rightarrow n = 8.49 \times 10^{24} \frac{e}{\text{m}^3}$$

$$I = neAV_d \Rightarrow V_d = \frac{5}{8.49 \times 10^{24} \times 1.6 \times 10^{-19} \times 4 \times 10^{-6}}$$

$$= \dots \text{ m/s}$$

7)



$$I(t) = I_0 e^{-\frac{t}{a}} ; a > 0$$

* how many charge passing the conductor between $0 \leq t \leq a$
 ΔQ ?

$$I(t) = \frac{dQ}{dt} \Rightarrow \Delta Q = \int I(t) dt$$

$$\Delta Q = I_0 \int_0^a e^{-\frac{t}{a}} dt \Rightarrow = I_0 (-a) e^{-\frac{t}{a}} \Big|_0^a$$

$$\Delta Q = -a I_0 [e^{-1} - 1] = I_0 a [1 - \frac{1}{e}] = \Delta Q$$

$$I_0 a [1 - \frac{1}{e}] = Ne$$

$$\therefore N = \frac{I_0 a (1 - \frac{1}{e})}{e}$$

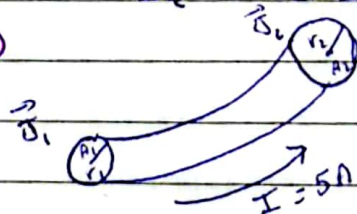
$$(b) \Delta Q : 0 \leq t \leq 10a$$

$$\Delta Q = a I_0 (1 - \frac{1}{e^{10}}) ; e \approx 2.7$$

$$(c) \Delta Q : 0 \leq t \leq \infty \quad (\text{large time})$$

$$\Delta Q = a I_0$$

8)



$$r_1 = 0.4 \text{ cm}$$

$$J_1 > J_2$$

$$(a) \text{ the current density at } r_1? \quad I_1 = I_2 = I = 5$$

$$J = \frac{I}{A} \quad V_1 > V_2$$

$$= \frac{5}{\pi (0.4 \times 10^{-1})^2} = \frac{A}{\text{m}^2}$$

$$(b) I_2 = I_1 = 5A$$

$$(c) J_2 \text{ less than } J_1, J_2 < J_1$$

$$J_2 = \frac{I}{A_2}$$

d) Assume $A_2 = 4A_1$

$$\pi r_2^2 = 4\pi r_1^2$$

$$r_2 = 2r_1 = 0.8 \text{ cm}$$

$$J_2 = \frac{5}{\pi(0.8 \times 10^{-2})^2} \frac{\text{A}}{\text{m}^2}$$

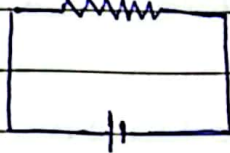
9) $q(t) = 4t^3 + 5t + 6$ [C]

a) the instantaneous current? at $t = 1 \text{ s}$

$$I(t) \Big|_{t=1 \text{ s}} = \frac{dq}{dt} = (12t^2 + 5) \Big|_{t=1} = 17 \text{ A}$$

b) $A = 2 \text{ cm}^2 \Rightarrow J = \frac{I}{A} = \frac{17}{2 \times 10^{-4}} \text{ A/m}^2$

14) $R = 240 \Omega$

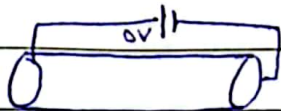


$$\Delta V = 120 \text{ V}$$

$$I ?? \Rightarrow V = IR$$

$$I = \frac{V}{R} = \frac{120}{240} = 0.5 \text{ A}$$

15)



$$l = 50 \text{ m}, \Delta V = 9.11$$

$$D = 2 \text{ mm} \Rightarrow r = 1 \text{ mm}, I = 36 \text{ A}$$

a) what is the resistivity? (ρ)

$$R = \frac{\Delta V}{I} = \frac{9.11}{36} = 0.25 \Omega$$

$$R = \frac{\rho l}{A} \Rightarrow \rho = \frac{RA}{l} = \frac{0.25 \times \pi \times (1 \times 10^{-3})^2}{50} \Omega \cdot \text{m}$$

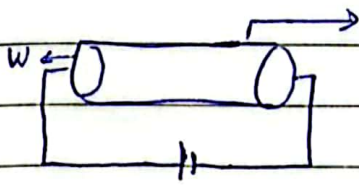
b) what is the electric field? $\Delta V = El$

$$E = \frac{\Delta V}{l} = \frac{9.11}{50} \text{ V/m}$$

c) given $\Rightarrow n = 8 \times 10^{28} \text{ c/m}^3$, what is the drift speed?

$$I = neAV_d \Leftarrow$$

16)



$$l = 1.5 \text{ m}$$

$$\rho = 5.6 \times 10^{-8} \text{ } \Omega \cdot \text{m}$$

$$A = 0.6 \text{ mm}^2 \Rightarrow 0.6 \times 10^{-6} \text{ m}^2$$

$$V = 0.9$$

$$I = ?$$

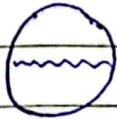
$$\Delta V = R I, \quad R = \frac{\rho L}{A} = \frac{5.6 \times 10^{-8} \times 1.5}{0.6 \times 10^{-6}} = 0.14 \text{ } \Omega$$

$$0.9 = 0.14 I$$

$$I = \frac{0.9}{0.14} = \sim 6.4 \text{ A}$$

$$\text{power} = \frac{V^2}{R} = \frac{0.9^2}{0.14} \text{ watt}$$

26)



$$R_0 = 19 \text{ at } T_0 = 20^\circ \text{C} \rightarrow \text{cold}, \quad \alpha = 4.5 \times 10^{-3} \text{ } ^\circ\text{C}^{-1}$$

$$R(T) = 140 \rightarrow \text{when hot} \quad T = ?$$

$$R(T) = R_0 (1 + \alpha \Delta T)$$

$$\Delta T = \frac{R(T)}{R_0} - 1 = \frac{140}{19} - 1 = 6.315789 \approx 6.32$$

$$\Delta T = T - T_0 \Rightarrow T = \Delta T + T_0 = 6.32 + 20 = 26.32^\circ\text{C}$$

33) wire AL, $D = 0.1 \text{ mm}$, $E = 0.2$, $T = 50^\circ\text{C}$ 

$$R(T) = R_0 (1 + \alpha \Delta T)$$

$$\Delta T = T - T_0$$

$$\alpha = 3.9 \times 10^{-3} \text{ } ^\circ\text{C}^{-1}$$

$$R_0 = \frac{\rho_0 L}{A} = \frac{2.82 \times 10^{-8} \times \pi (0.05 \times 10^{-3})^2}{\pi (0.05 \times 10^{-3})^2}$$

$$= 50 - 20$$

$$\rho_0 = 2.82 \times 10^{-8} \text{ } \Omega \cdot \text{m}$$

$$= 30^\circ\text{C}$$

$$\Delta V_0 = R_0 I, \quad \Delta V = E L$$

$$\Delta V_0 = I_0 R_0$$

$$\Delta V_0 = \frac{\rho_0 L}{A} I$$

$$R_0 = \frac{\Delta V_0}{I_0} = \frac{0.2}{0.056} \text{ } \Omega$$

$$E = \frac{\Delta V_0}{L} = \frac{\rho_0 I}{A}$$

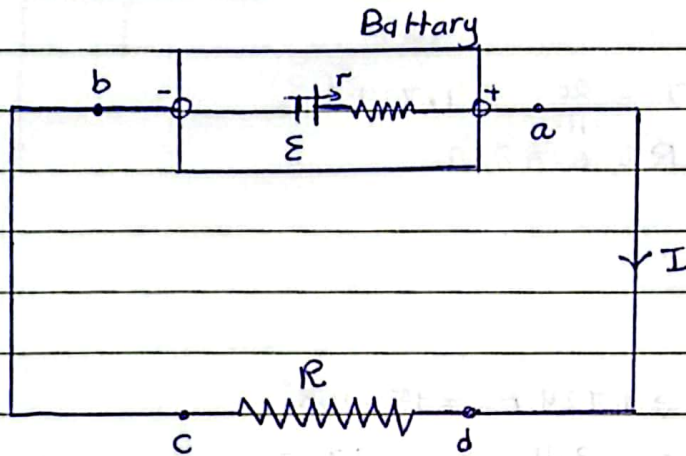
$$0.2 = \frac{2.82 \times 10^{-8} I}{\pi (0.05 \times 10^{-3})^2}$$

$$I = 0.056 \text{ A}$$

"CH 28"

"Direct current circuits"

- The electromotive Force and terminal Voltage.



$\mathcal{E}$: electromotive Force (EMF)

القوة الدافعة الكهربائية

r : Battery internal resistance

R : external (Load) resistance

$$\mathcal{E} = Ir + RI$$

$$= I(r+R)$$

$$I = \frac{\mathcal{E}}{r+R}$$

$$\Delta V_{ab} = IR = \mathcal{E} - Ir$$

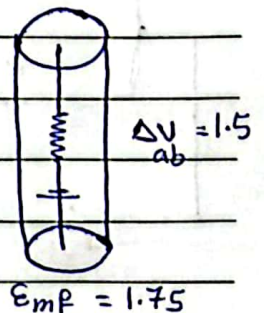
$$P_R = I^2 R, \quad P_{\text{battery}} = I \Delta V$$

Terminal voltage

$$\Delta V_{ab} = IR = \mathcal{E} - rI$$

⇒ The battery deliver a power of $\mathcal{E}$ (produce).

⇒ " resistance dissipate power $\mathcal{E}$ (يستهلكه)"



1/857) $\mathcal{E} = 15\text{V}$, $\Delta V = 11.6\text{V}$, $P_R = 20\text{W}$
 $\downarrow$
 produce

@ $R = ?$

$$P_R = I^2 R = I \Delta V$$

$$20 = I(11.6) \Rightarrow I = \frac{20}{11.6} = 1.724\text{A}$$

$$\Rightarrow 20 = (1.724)^2 R \Rightarrow R = 6.78\Omega$$

$$\mathcal{E} = Ir + IR$$

$$\Delta V_{ab} = IR = \mathcal{E} - Ir$$

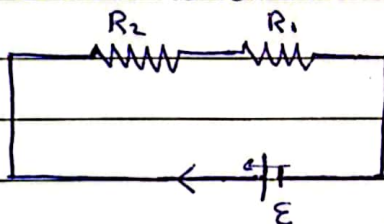
$$Ir = \mathcal{E} - \Delta V \Rightarrow 1.724r = 15 - 11.6$$

$$r = \frac{3.4}{1.724} = 1.97\Omega$$

• Combination of Resistance:

✓ Series combination

تسلسلي



✓ The current $\Rightarrow I = I_1 = I_2$

✓ Potential difference

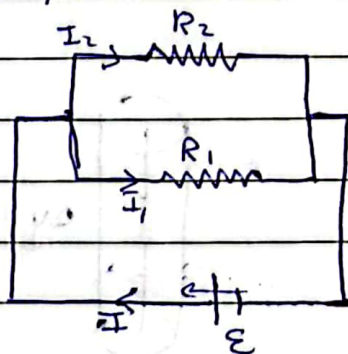
$$\mathcal{E} = \Delta V_1 + \Delta V_2$$

✓✓ Equivalent Resistance

$$R_{eq} = R_1 + R_2$$

✓ parallel combination

توازي



✓ " " $\Rightarrow I = I_1 + I_2$

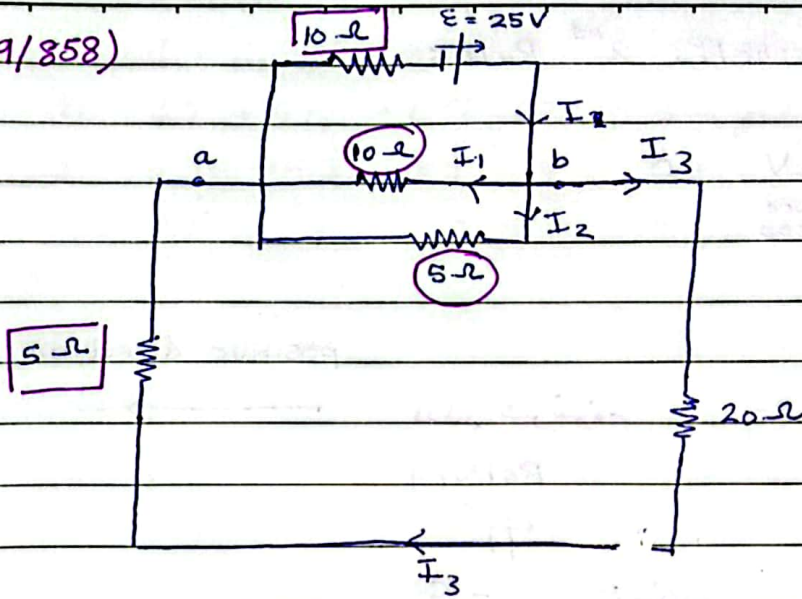
✓✓ " "

$$\mathcal{E} = \Delta V_1 = \Delta V_2$$

✓✓✓ " "

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

9/858)

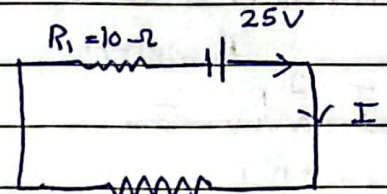


$$I = I_1 + I_2 + I_3$$

$$R_1 = 5 + 20 = 25 \Omega$$

$$\frac{1}{R_2} = \frac{1}{25} + \frac{1}{10} + \frac{1}{10}$$

$$= \frac{47}{140}$$



$$R_{eq} = 10 + \frac{47}{140} = \frac{610}{47}$$

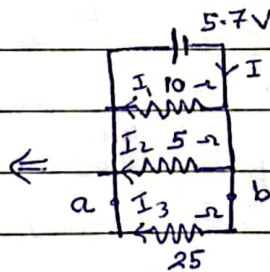
$$\mathcal{E} = R_{eq} I$$

$$I = \frac{\mathcal{E}}{R_{eq}} = \frac{25}{\frac{610}{47}} = 1.93 \text{ A}$$

$$\begin{aligned} \Delta V_{10} &= I_{10} R_{10} \\ &= (1.93)(10) \\ &= 19.3 \text{ V} \end{aligned}$$

$$\Delta V_{ab} = 5.7 \text{ V}$$

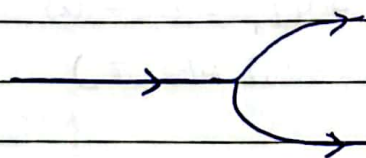
$$I_3 = \frac{5.7}{25} = \sim \text{A}$$



$$\begin{aligned} \Delta V_{R_2} &= (1.93) \left(\frac{140}{47} \right) \\ &= 5.7 \text{ V} \end{aligned}$$

• Kirchhoff's Rules:-

1. Conservation of charge :- Kirchhoff's First Rule.

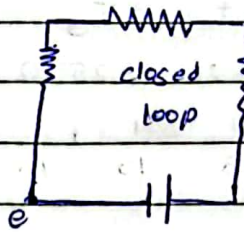


$$I = I_1 + I_2$$

$$\sum I_{in} = \sum I_{out}$$

$$I = \frac{\text{charge}}{\text{time}}$$

2. Conservation energy : Kirchoff's 2nd Rule :-



$$\sum \Delta V = 0$$

closed loop

positive direction

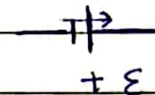
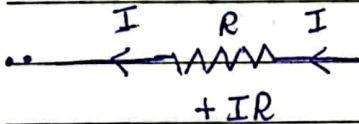
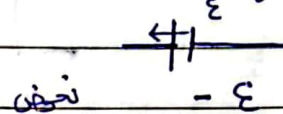
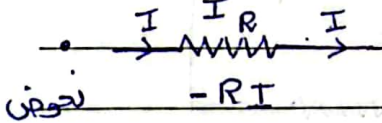
Kirchoff's convention :-

تقليد كيرشوف

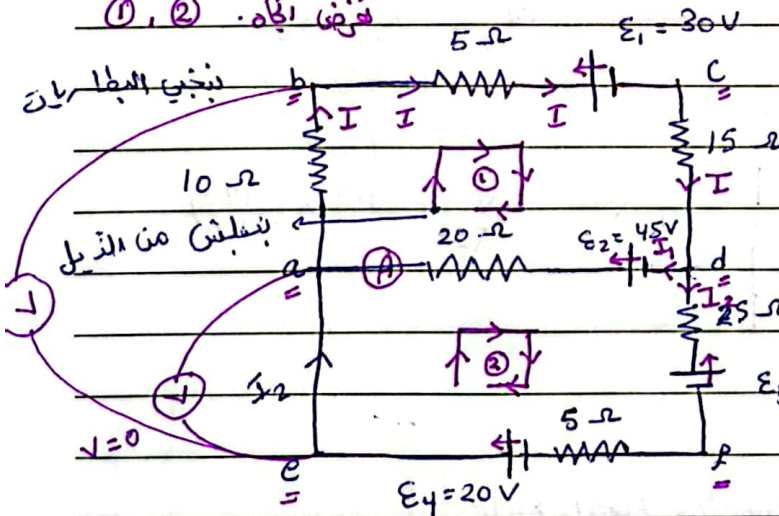


Resistors

Battery



①, ② نفق ايجاد



$$I = I_1 + I_2 \quad \text{--- ①}$$

$$I - I_1 - I_2 = 0 \quad \text{--- ①}$$

$$\sum \Delta V = 0$$

closed loop 1

$$-10I - 5I + (-30) + (-15I) + 2(45) + (-20I_1) = 0$$

$$(-30I - 20I_1 + 15 = 0) \div -5$$

$$6I + 4I_1 = 3 \quad \text{--- ②}$$

$$\sum \Delta V = 0 \Rightarrow +20I_1 + (-45) + (-25I_2) + (30I_2) + (-10) + (20)$$

$$= 20I_1 - 30I_2 - 35 = 0$$

$$4I_1 - 6I_2 = 7 \quad \text{--- ③}$$

$$\begin{aligned}
 (1) \quad I - I_1 - I_2 &= 0 & I &= x = \frac{1}{42} & \text{التي } 0 \\
 (2) \quad 6I + 4I_1 + 0 I_2 &= 3 & I &= y = \frac{5 \times 6}{7 \times 6} = \frac{30}{42} & \text{من } d \text{ و } d \\
 (3) \quad 0 I + 4I_1 - 6I_2 &= 7 & I_2 &= z = \frac{-29}{42} & \text{من } d \text{ و } F
 \end{aligned}$$

الأميت A يفتح على التوالي
القول للميت لا التوازي

* Find $V_a - V_e = ??$

$$V_a + \dots = V_e$$

$$V_a + (+20 \times \frac{30}{42}) + (-2 \times 45V) + (-30 \times \frac{-29}{42}) + (-10) + (+20) = V_e$$

$$V_a + 35 + (-35) = V_e$$

$$V_a - V_e = 0$$

$$\Rightarrow V_e - V_b = ??$$

$$V_b - V_e = ? \Rightarrow V_b + \dots = V_e$$

$$V_b + (-20 \times \frac{1}{42}) + (-30) + (-30 \times \frac{-29}{42}) + (-10) + (+20) = V_e$$

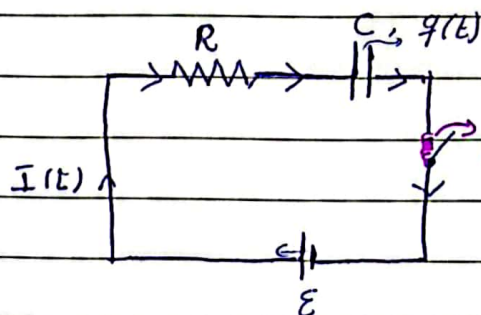
$$\Rightarrow V_b + 20 \cdot 24 + -20 = V_e \Rightarrow V_e - V_b = 0.24 V$$

$$\Rightarrow V_a - V_b = ?$$

RC - Circuit

• charging the RC-circuit :-

Function of time



$$\mathcal{E} = \Delta V_R(t) + \Delta V_C(t)$$

$$\frac{dq}{dt} = I(t)$$

$$R(I(t)) + \frac{q(t)}{C} = \mathcal{E}$$

$$R \frac{dq}{dt} + \frac{q}{C} = \mathcal{E}$$

$$\frac{dq}{dt} + \frac{q}{RC} = \frac{\mathcal{E}}{R}$$

$$\tau = RC \text{ [sec]}$$

is called time constant (characteristic time).

$$\frac{dq}{dt} + \frac{q}{\tau} = \frac{\varepsilon}{R}$$

Solution $\Rightarrow q(t) = Q_{\max} (1 - e^{-\frac{t}{\tau}})$ where

$$Q_{\max} = \varepsilon C$$

The current :- $I = \frac{dq}{dt} = \frac{Q_{\max}}{\tau} e^{-\frac{t}{\tau}}$

$$= \frac{\varepsilon C}{RC} e^{-\frac{t}{RC}}$$

$$I(t) = \frac{\varepsilon}{R} e^{-t/\tau}$$

$$= I_{\max} e^{-\frac{t}{\tau}}, \quad I_{\max} = \frac{\varepsilon}{R}$$

* The energy stored in the capacitor

$$U_c(t) = \frac{q^2(t)}{2C} = \frac{1}{2} \epsilon^2 C (1 - e^{-\frac{t}{RC}})^2$$

* The power dissipated in the resistor

$$p(t) = R I^2(t) = \frac{\epsilon^2}{R} e^{-2t/\tau}$$

• Discharging RC-circuit

- $[R, C]$

- [The capacitor is fully charged]

$$\Delta V_R(t) + \Delta V_C(t) = 0$$

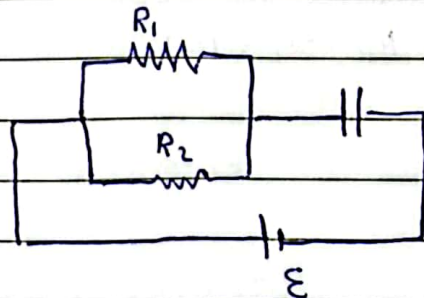
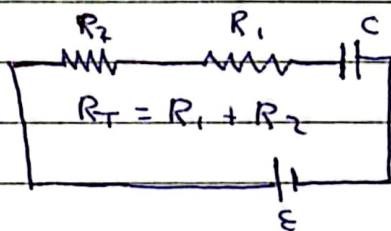
$$R I(t) + \frac{q(t)}{C} = 0$$

$$R \frac{dq}{dt} + \frac{q(t)}{C} = 0$$

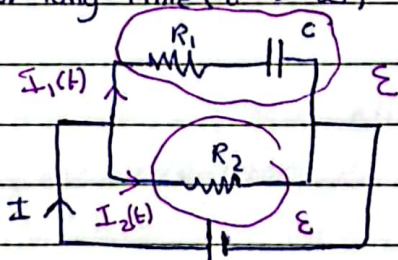
$$q(t) = Q_0 e^{-\frac{t}{RC}}, \quad \tau = RC$$

$$I(t) = -\frac{Q_0}{RC} e^{-\frac{t}{\tau}} = -I_{\max} e^{-t/\tau}$$

Notes:-



* For long time ($t \rightarrow \infty$)

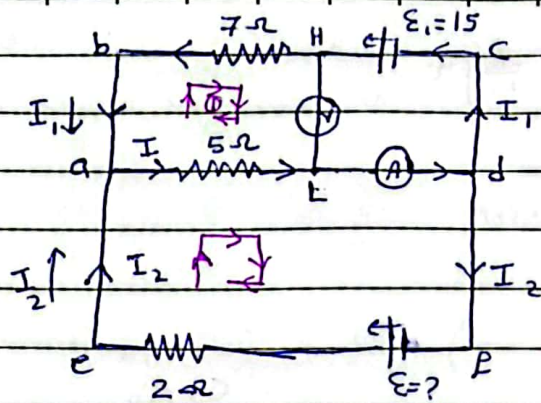


For long time

$$I(t) = 0$$

$$I \rightarrow I_2(t)$$

29)



$$I = I_1 + I_2 = 2 \quad \text{--- (1)}$$

$$\sum \Delta V_{\text{closed loop}} = 0$$

$$+7I_1 + (-15) + (+2 \times 5) = 0$$

$$7I_1 - 5 = 0$$

$$I_1 = \frac{5}{7} \text{ A}$$

$$I_A = 2 \text{ A} = I$$

$$I_2 = 2 - \frac{5}{7} = \frac{9}{7} \text{ A}$$

$$\sum \Delta V_{\text{adfe}} = 0 \Rightarrow (-5 \times 2) + (+\epsilon) + (-2 \times \frac{9}{7}) = 0$$

$$\epsilon - 10 - \frac{18}{7} = 0 \Rightarrow \epsilon = \frac{88}{7} \text{ V}$$

* Find $V_H - V_L$?

$$V_L + \text{---} = V_H$$

$$(+5)(2) + (7 \times \frac{5}{7}) = V_H \Rightarrow V_L + 15 = V_H$$

$$V_H - V_L = 15 \text{ V}$$

$$V_H + \text{---} = V_L$$

$$V_H - 15 = V_L$$

$$V_H - V_L = 15 \text{ V}$$

37/861) uncharged capacitor, $R, C, \mathcal{E}$

$$R = 100 \Omega$$

$$q(t) = Q_{\max} (1 - e^{-\frac{t}{\tau}})$$

$$\mathcal{E} = 9 \text{ V}$$

$$C = 20 \mu\text{F}$$

$$\tau = RC, \quad Q_{\max} = \mathcal{E}C$$

بيجى كتن
a) Find the time constant? $\tau = RC = 100 \times 20 \times 10^{-6} = 2 \times 10^{-3} \text{ sec}$
 $= 2 \text{ msec.}$

b) " " maximum charge? $Q = \mathcal{E}C = 9 \times 20 \times 10^{-6} = 180 \mu\text{C}$

c) $q(t) \big|_{at = \tau} = 180(1 - e^{-1})$

d) what is the potential difference on the capacitor after 4 msec?
after (2 times constant)

$$\Delta V_c(t) = \mathcal{E} (1 - e^{-\frac{t}{\tau}})$$
$$= 9(1 - e^{-2})$$

e) the maximum current? at $t = 2\tau$

$$I(t) = \frac{\mathcal{E}}{R} e^{-\frac{t}{RC}} = \frac{9}{100} e^{-2} \text{ A.}$$

$$I_{\max} = \frac{\mathcal{E}}{R}$$

f) what is the time at which the charge on the capacitor is $\frac{3}{4}$ (75%) of its maximum value?

$$\frac{q(t)}{Q_{\max}} = 1 - e^{-\frac{t}{\tau}} \Rightarrow 0.75 = 1 - e^{-t/\tau}$$

$$e^{-\frac{t}{\tau}} = 0.25 \Rightarrow -\frac{t}{\tau} = \ln 0.25$$

$$t = -\tau \ln(0.25)$$

$$= 1.386\tau$$

$$2 \text{ msec} = 2.77 \text{ msec}$$

g) Find the potential difference on the resistor when the energy stored in the capacitor 80% of its max value?

$$U_c(t) = \frac{Q^2}{2C} = \frac{Q_{\max}^2}{2C} (1 - e^{-\frac{t}{\tau}})^2$$

$$80\% = (1 - e^{-\frac{t}{\tau}})^2 \Rightarrow \sqrt{0.8} = (1 - e^{-\frac{t}{\tau}})$$

$$e^{-\frac{t}{\tau}} = 1 - \sqrt{0.8}$$

مو

$$t = -\tau \ln(1 - \sqrt{0.8}) \quad , \quad -\tau \ln(1 + \sqrt{0.8})$$

لا نه الزمان لا مو ✓

x

$$V_R(t) = \varepsilon e^{-\frac{t}{\tau}} = 9 e^{-2.25}$$

$$* \text{ power } = R I^2(t)$$

$$p(t) = \underline{P_{max}} e^{-\frac{2t}{\tau}}$$

$$39) C = 2 \text{ nF} \quad , \quad Q_0 = 5.1 \mu\text{C} \quad , \quad \text{dis charged} \quad , \quad R = 1.3 \text{ K} \Omega$$

$$q(t) = Q_0 e^{-\frac{t}{\tau}}$$

$$\textcircled{a} I(t) \Big|_{t=9 \mu\text{s}} = \frac{Q_0}{t} e^{-\frac{t}{\tau}} \quad , \quad \tau = RC = 1300 \times 2 \times 10^{-9} = 2.6 \mu\text{sec}$$

$$I(t) = \frac{5.1}{2.6 \times 10^{-6}} e^{-\frac{9 \mu}{2.6 \mu}} \text{ A}$$

$$\textcircled{b} q(t) \Big|_{t=8 \mu\text{s}} = 5.1 e^{-\frac{8}{2.6}} \mu\text{C}$$

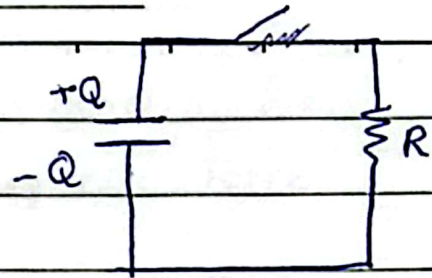
$$\textcircled{c} \text{ maximum current? } \quad \text{التي اكبر ما } \text{max}$$

$$I_{\text{max}} = \frac{Q_0}{\tau} = \frac{5.1}{2.6} \text{ A}$$

✓ the current For along time = Zero

✓ the charge " " " = Zero

45)



$$\tau = 1.5 \text{ sec} = RC$$

discharge.

$$\text{closed} \Rightarrow q(t) = \frac{75}{100} Q_0$$

$$t = ?$$

$$\frac{q(t)}{Q_0} = e^{-\frac{t}{\tau}} \quad \ln(0.75) = -\frac{t}{\tau}$$

$$t = -\tau \ln(0.75) = -1.5 \ln(0.75)$$

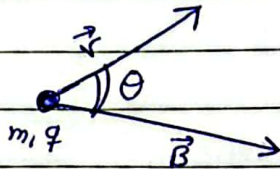
⑥ if $R = 250 \text{ K}\Omega$, $C = ?$ $\tau = RC$

$$1.5 = 250 \times 10^3 * C$$

"CH 29"

"The magnetic Field"

- The magnetic Force



الكتلة m

partical : Mass : m

charge : q

velocity of the partical : $\vec{v}$

$\vec{B}$: magnitec Field (Vector) [Tesla]

$mT = 10^{-3} T$, $\mu T = 10^{-6} T$

θ : The angle btw the magnit'ic Field and the velocity and the particle

* The magnitec Force is given by :-

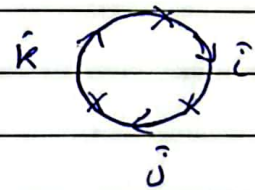
$$\rightarrow \vec{F}_m = q \cdot \vec{v} \times \vec{B} \sin \theta$$

$$\rightarrow \vec{F}_m = q \cdot \vec{v} \times \vec{B}$$

$$\begin{aligned} & \vec{v} = 0 \\ & F_m = 0 \\ & \theta = 0, \text{ parallel (in same direction } \vec{v}, \vec{B}) \\ & \theta = \pi, \text{ opposite direction } \vec{v}, \vec{B} \end{aligned}$$

$$\begin{aligned} & \theta = \frac{\pi}{2} \\ & F_m = \text{max} \\ & \theta = \frac{3\pi}{2} \end{aligned}$$

$$\begin{aligned} \hat{i} \times \hat{i} &= \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0 \\ \hat{i} \times \hat{j} &= \hat{j} \times \hat{k} = \hat{k} \times \hat{i} = \hat{i} \end{aligned}$$



$$\begin{aligned} \hat{i} \times \hat{j} &= \hat{k} \\ \hat{j} \times \hat{k} &= \hat{i} \\ \hat{k} \times \hat{i} &= \hat{j} \end{aligned}$$

والعكس سالبة .