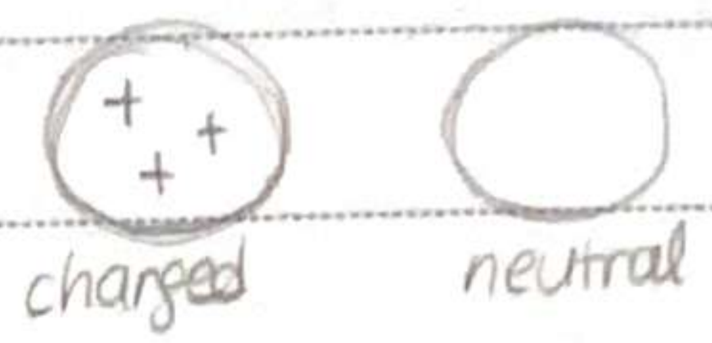
CHAPTER 21 ELECTRIC CHARGE AND ELECTRIC FIELD

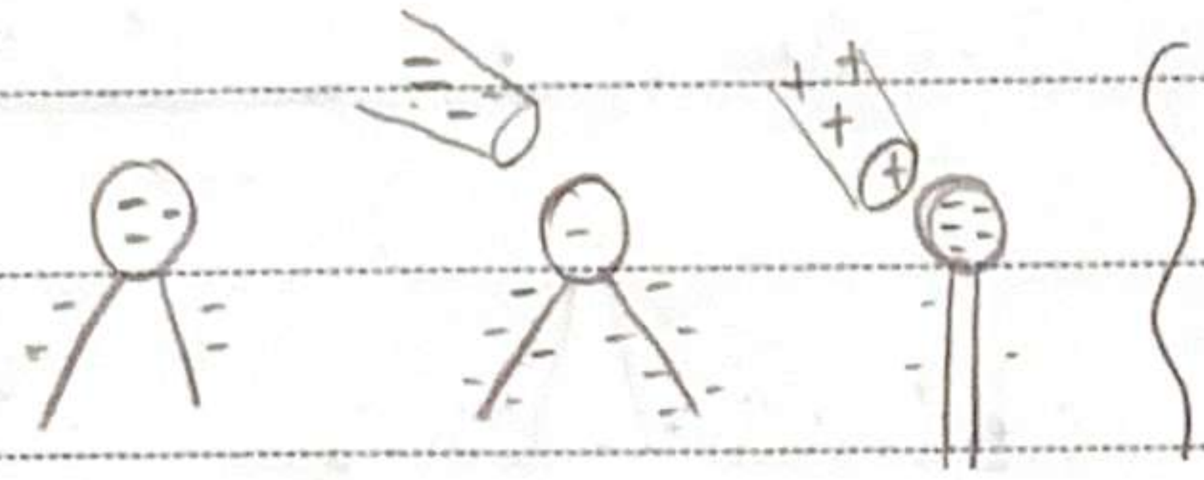
~electric charge is conserved

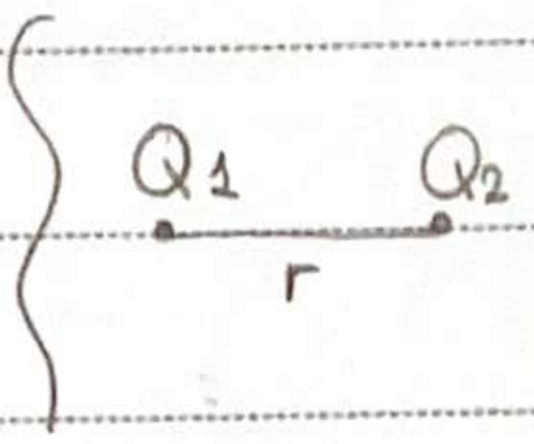
conductor : charge flows freely metals



Insulator = almost no charge flows

some materials are semiconductors (silicon and germanium)





$$F = k.\frac{Q_1 . Q_2}{r^2}$$

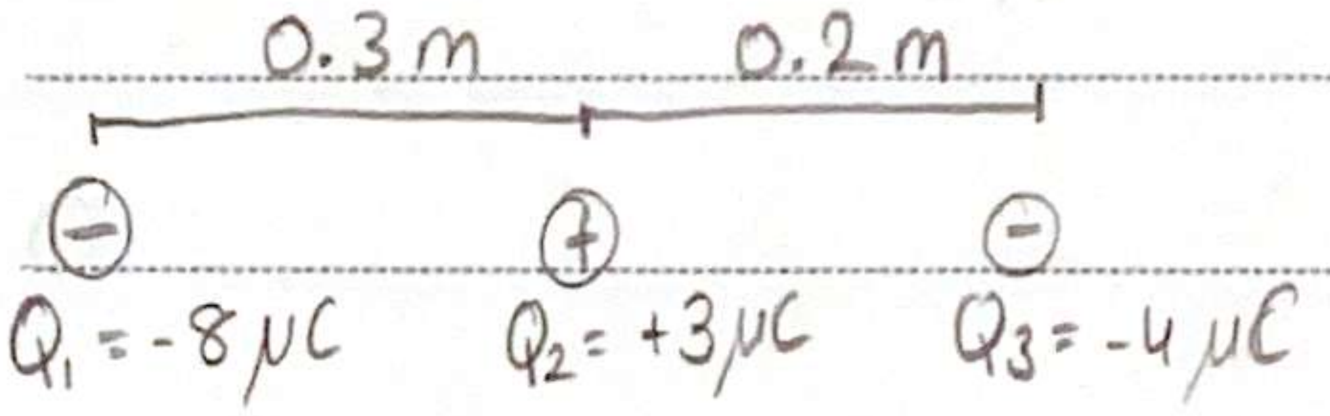
Coulomb's law

ex 21-1 // Two positive point charges, $Q_1 = 50\,\mu C$ and $Q_2 = 1\,\mu C$, are separated by a distance ℓ. Which is larger in magnitude, the force that Q_1 exerts on Q_2 or the force that Q_2 exerts on Q_1?

the force on $Q_1 = F_{12} = k.\dfrac{Q_1 . Q_2}{\ell^2}$ on $Q_2 = F_{21} = k.\dfrac{Q_1 . Q_2}{\ell^2}$

$\approx F_{12} = F_{21}$ } they are same.

ex 21-2 // Three charged particles are arranged in a line, as shown. Calculate the net electrostatic force on particle 3 due to the other two.



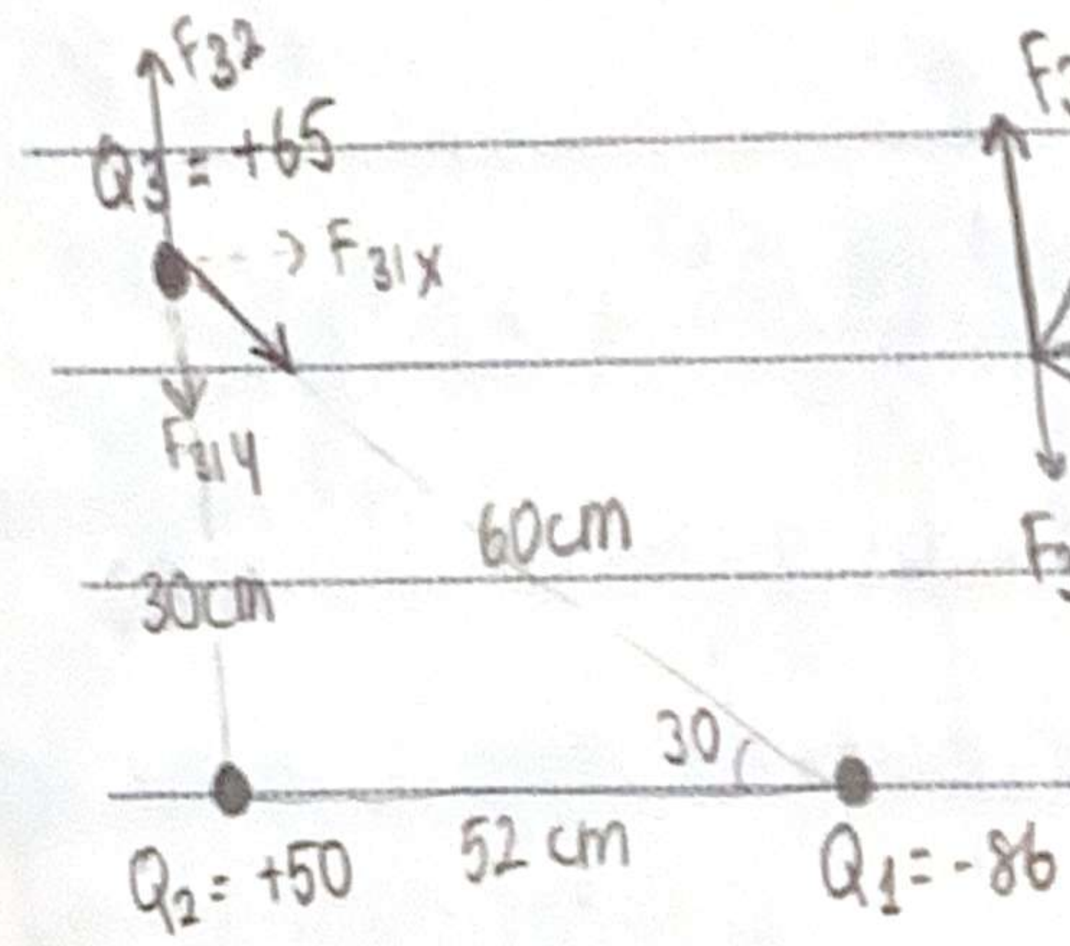
$$F_{31} = k.\frac{Q_1 . Q_3}{r^2} = \frac{(9.10^9\,N.m^2/C^2)\,(-4.10^{-6})(-8.10^{-6})}{(0.5m)^2}$$

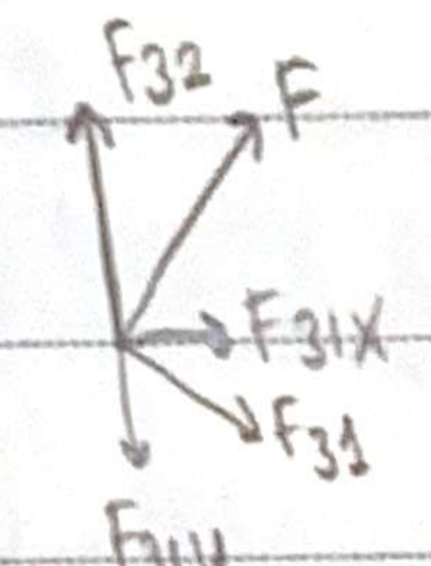
$F_{31} = 1.2\,N$ //

$$F_{32} = k.\frac{Q_3 . Q_2}{r^2} = \frac{(9.10^9\,Nm^2/C^2)(-4.10^{-6})(3.10^{-6})}{(0.2)^2} = -2.7\,N //$$

$$F = (-2.7) + (1.2) = -1.5\,N //$$

ex 21-3 // Calculate the net electrostatic force on charge Q_3 shown in the figure due to the charges Q_1 and Q_2.



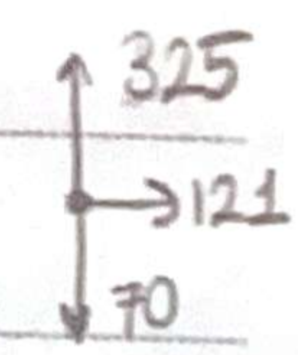


$$F_{31} = \frac{k.Q_1.Q_3}{r^2} = \frac{(9.10^9)(6{,}5.10^{-5})(8{,}6.10^{-5})}{(0.6m)^2} = 140N_{//}$$

$$F_{32} = \frac{k.Q_2.Q_3}{r^2} = \frac{(9.10^9)(6{,}5.10^{-5})(5.10^{-5})}{(0.3m)^2} = 325N_{//}$$

$F_{31x} = F_{31} \cdot \cos 30 = 121N_{//}$

~~$F_{31y} = F_{31} \cdot \sin 30 = 70N_{//}$~~

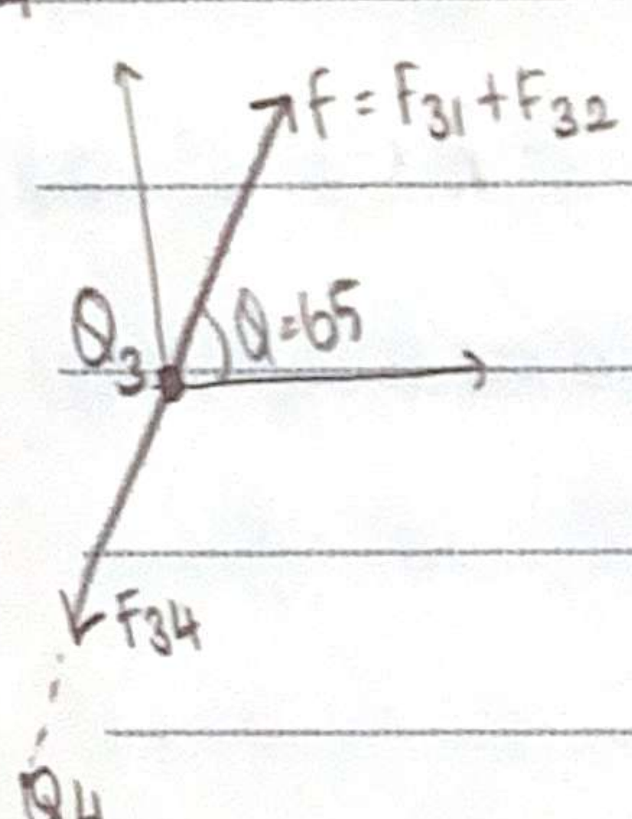


$F = \sqrt{121^2 + 255^2}$

$\boxed{= 280N_{//}}$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = 65$

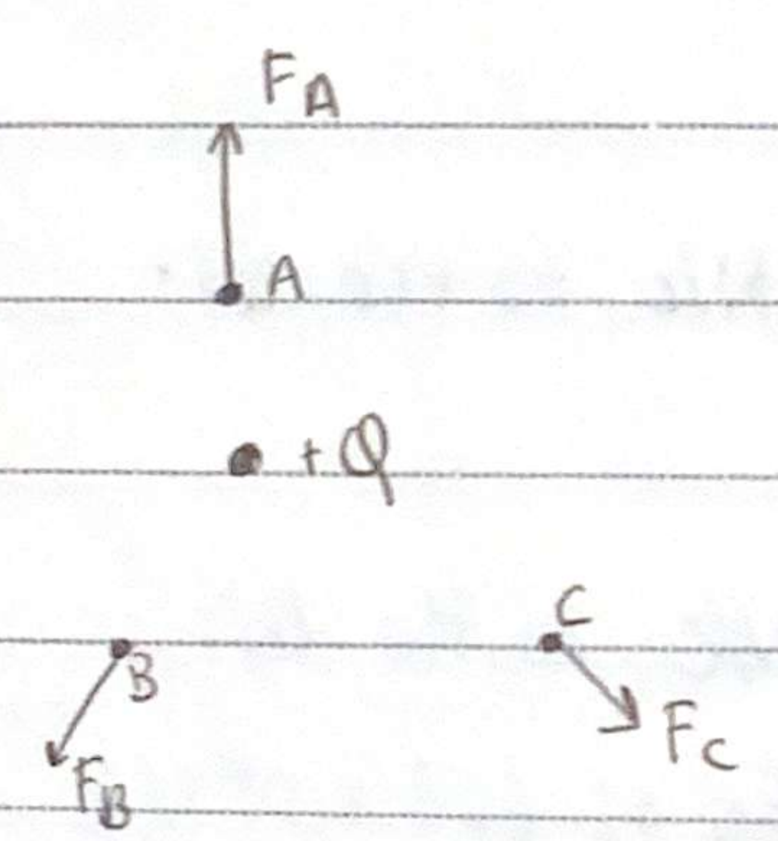
ex 21-4 // Where could you place a fourth charge $Q_4 = -50$, so that the net force on Q_3 would be zero?



$$F_{34} = \frac{k.Q_3.Q_4}{r^2}$$

$$|F_{34}| = |F| \Rightarrow F_{34} = 280N = \frac{(9.10^9)(5.10^{-5})(6{,}5.10^{-5})}{r^2}$$

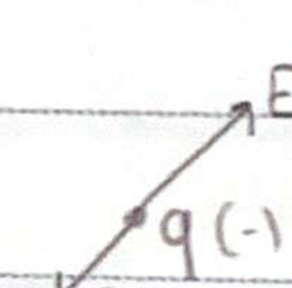
$r \cong 0.320m_{//}$



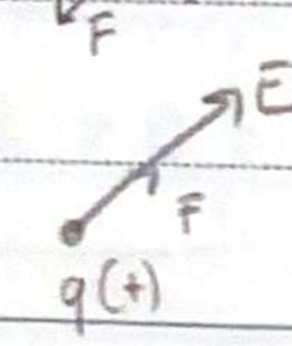
$$E = \frac{F}{q} = \frac{k.q.Q}{r^2.q} = \frac{k.Q}{r^2}$$

electric field

if q is negative →

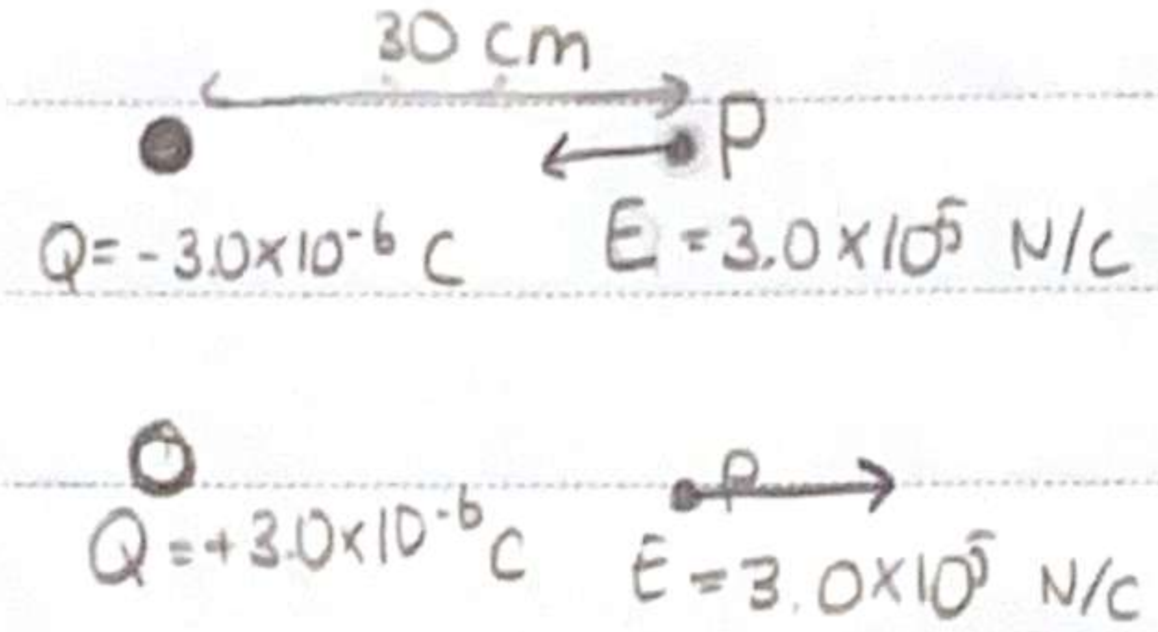


if q is positive →



Record : / /

ex 21-6 // calculate the magnitude and direction of the e field at a point P which is 30 cm to the right of a point charge $Q = -3.0\times10^{-6}$ C



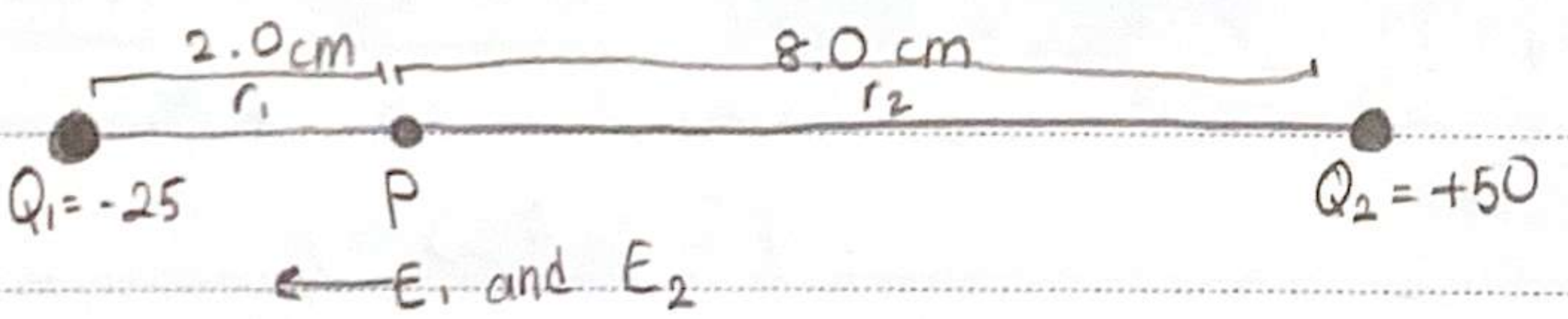
$$E = k.\frac{Q}{r^2} = \frac{(9.10^9)(3.10^{-6})}{(0.3)^2} = 3.10^5 \text{ N/C}$$ // magnitude

a) direction of E is toward the charge Q, to the left

b) to the right, outward

ex 21-7 // two point charges are separated by a distance of 10.0 cm. One has a charge of -25 μC and the other +50 μC (a) determine the direction and magnitude of the electric field at a point P between the two charges that is 2.0 cm from the negative charge.

b) if an electron (mass = 9.11×10^{-31} kg) is placed at rest at P and then released. What will be its initial acceleration? (direction and mag)



a) For Q_1

$$E_1 = k.\frac{Q_1}{r^2} = \frac{(9.10^9)(25\times10^{-6})}{(0.02\text{ m})^2} = 5.62\times10^8 \text{ N/C to the left}$$

For Q_2

$$E_2 = k.\frac{Q_2}{r^2} = \frac{(9.10^9)(50\times10^{-6})}{(0.08)^2} = 7\times10^7 \text{ N/C to the left}$$

$$E = E_1 + E_2 = \boxed{6.3\times10^8 \text{ N/C to the left}}$$ //

b) $F = m.a$ $\quad E = \frac{F}{q}$ $\quad F = E.q$

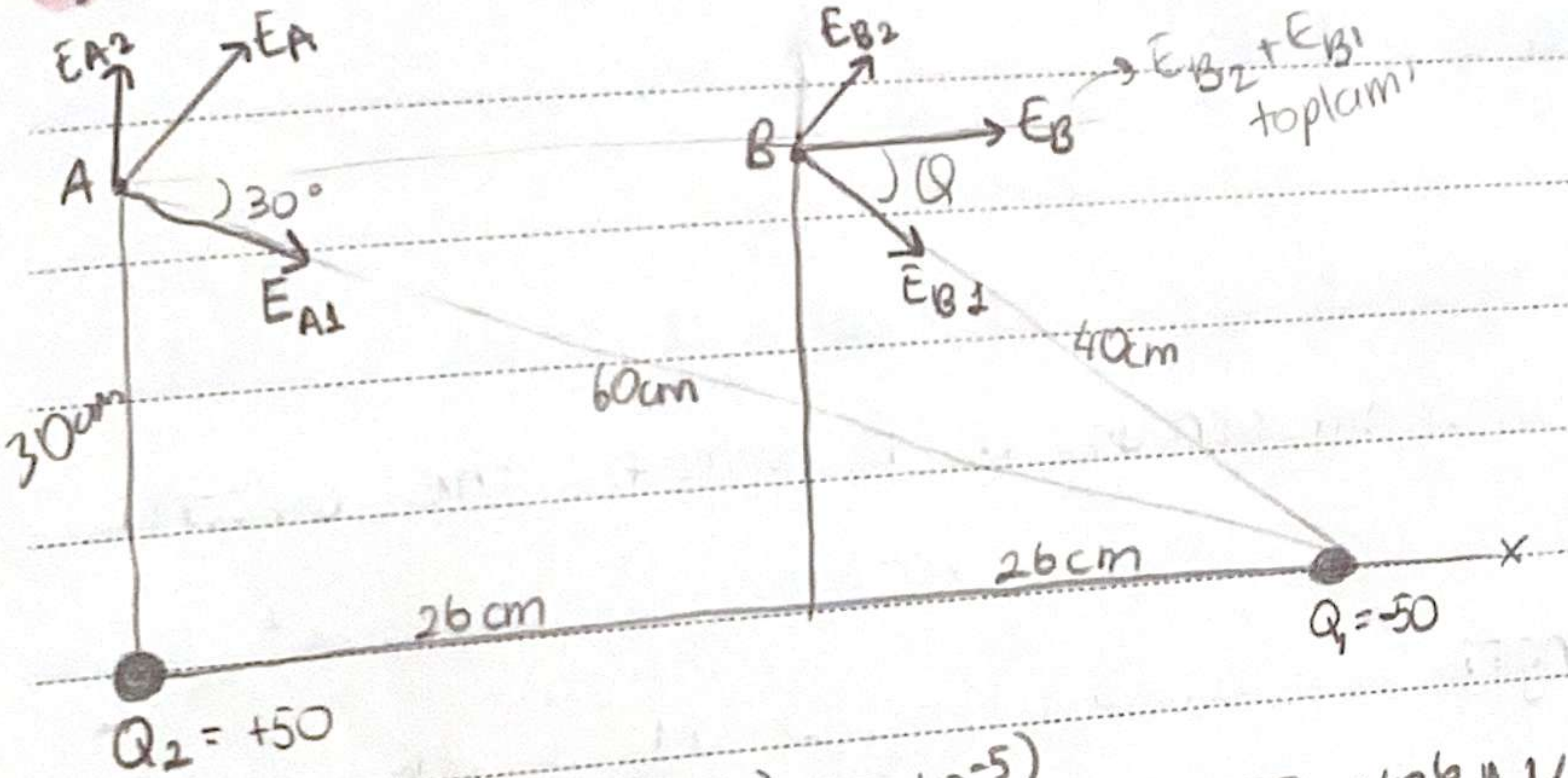
$$a = \frac{F}{m} = \frac{q.E}{m} = \frac{(1.602\times10^{-19}\text{ C})(6.3\times10^8)}{(9.11\times10^{-31})} = \boxed{a = 1.1\times10^{20} \text{ m/s}^2}$$ //

Express

Record :

ex 21-8 // calculate the total electric field a) at point A

b) at point B in the figure due to both charges Q_1 and Q_2?



$E_{A1x} = E_{A1} \cdot \cos 30 = 1.08 \times 10^6$ N/C

$E_{A1y} = E_{A1} \cdot \sin 30 = -6.25 \times 10^5$ N/C

a) $E_{A1} = \dfrac{k \cdot Q_1}{r_1^2} = \dfrac{(9 \cdot 10^9)(5 \cdot 10^{-5})}{(60 \cdot 10^{-2})^2} = 1.25 \times 10^6$ N/C

$E_{A2x} = 0$

$E_{A2y} = 5 \cdot 10^6$ N/C

$E_{Ax} = E_{A1x} + E_{A2x} = 1.08 \times 10^6$

$E_{Ay} = 4.34 \times 10^6$

$E_{A2} = k \cdot \dfrac{Q_2}{r_2^2} = \dfrac{(9 \cdot 10^9)(5 \cdot 10^{-5})}{(0.03)^2} = 5 \times 10^6$ N/C

b) $|E_{B1}| = |E_{B2}|$ $(r_1 = r_2)$

$\theta = \tan^{-1}\left(\dfrac{30cm}{26cm}\right) = 49°$

$E_{B1x} = E_{B1} \cdot \cos 49 = 1.8 \times 10^6$

$E_{B1} = E_{B2} = k \cdot \dfrac{Q_2}{r^2} = 2.8 \cdot 10^6$

$E_{B1y} = -E_{B1} \cdot \sin 49 = -2.1 \times 10^6$

$E_{B2x} = E_{B2} \cdot \cos 49 = 1.8 \times 10^6$

$E_{B2y} = E_{B2} \cdot \sin 49 = +2.1 \times 10^6$

$E_{By} = 0$, $E_{Bx} = 3.6 \times 10^6$

$E = \sqrt{E_{Bx}^2} = 3.6 \times 10^6$ //

Express

Record :

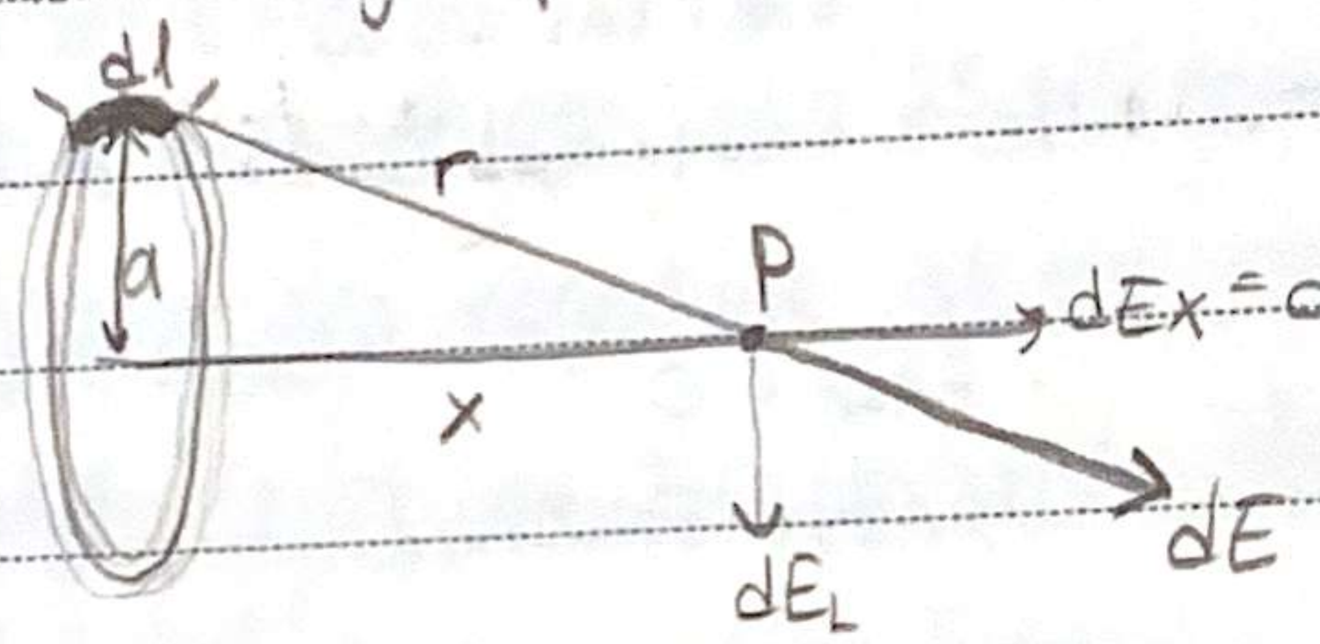
The linear charge density $\lambda = \frac{Q}{\ell}$

The surface charge density $\sigma = \frac{Q}{A}$

The volume charge density $\rho = \frac{Q}{V}$

$$dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{dQ}{r^2}$$

ex 21-9 // A thin, ring-shaped object of radius a holds a total charge $+Q$ distributed uniformly arround it. Determine the electric field at a point P on its axis a distance x from the center. Let λ be the charge per unit length.



$$dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{dQ}{r^2}$$

$$\lambda = \frac{Q}{2\pi a} = \frac{dQ}{dl} \Rightarrow dQ = \lambda . dl$$

The whole rings length $= 2\pi a$

$$dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\lambda . dl}{r^2}$$

$$E_x = \int dE_x = \int dE\cos\theta = \frac{1}{4\pi\varepsilon_0} \cdot \lambda \int \frac{dl\cos\theta}{r^2}$$

$E_y = 0$ (due to symetry)

$$E = E_x = \frac{1}{4\pi\varepsilon_0} \cdot \lambda \cdot \int \frac{dl\cos\theta}{r^2}$$

$$\cos\theta = \frac{x}{r} = \frac{x}{(x^2+a^2)^{1/2}}$$

$$E = \frac{\lambda}{4\pi\varepsilon_0} \cdot \frac{x}{(x^2+a^2)^{3/2}} \int_0^{2\pi a} dl = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\lambda x 2\pi a}{(x^2+a^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qx}{(x^2+a^2)^{3/2}}$$

For $x \gg a$

$$E = \frac{Q}{4\pi\varepsilon_0 x^2}$$

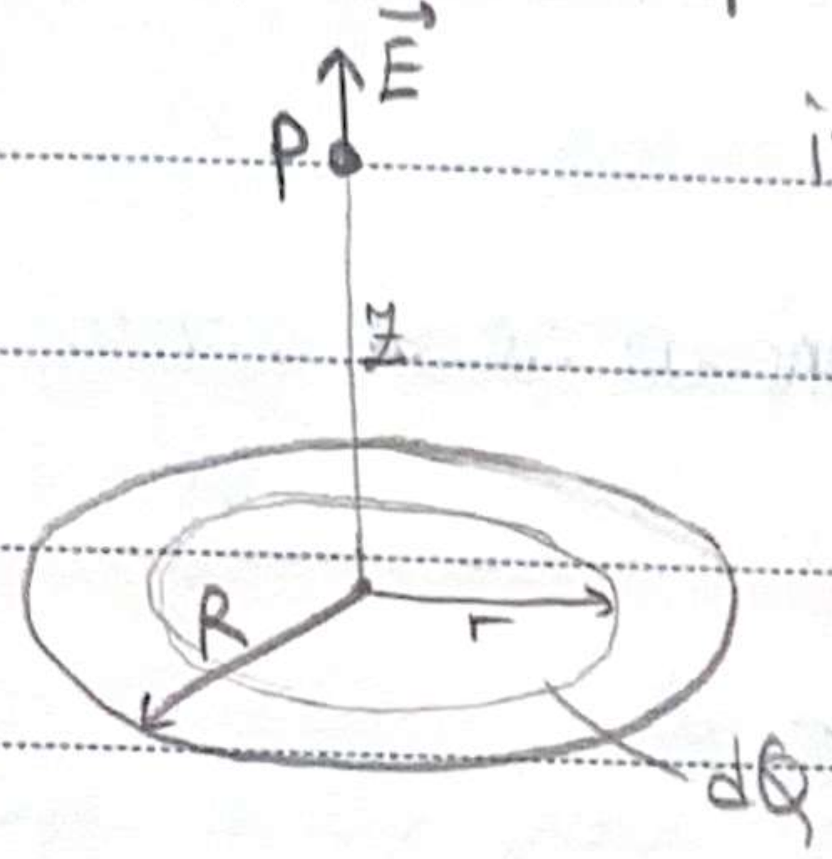
For $x = 0$

$E = 0$

all compenents will cancel at the center of ring.

Express

ex 21-12 // Charge is distributed uniformly over a thin circular disk of radius R. The charge per unit area (C/m^2) is σ. Calculate the electric field at a point P on the axis of the disk, a distance z above its center.



$$dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{dQ\, z}{(z^2+r^2)^{3/2}}$$ = for ex 21.9 //

The ring has area $(dr)(2\pi r)$

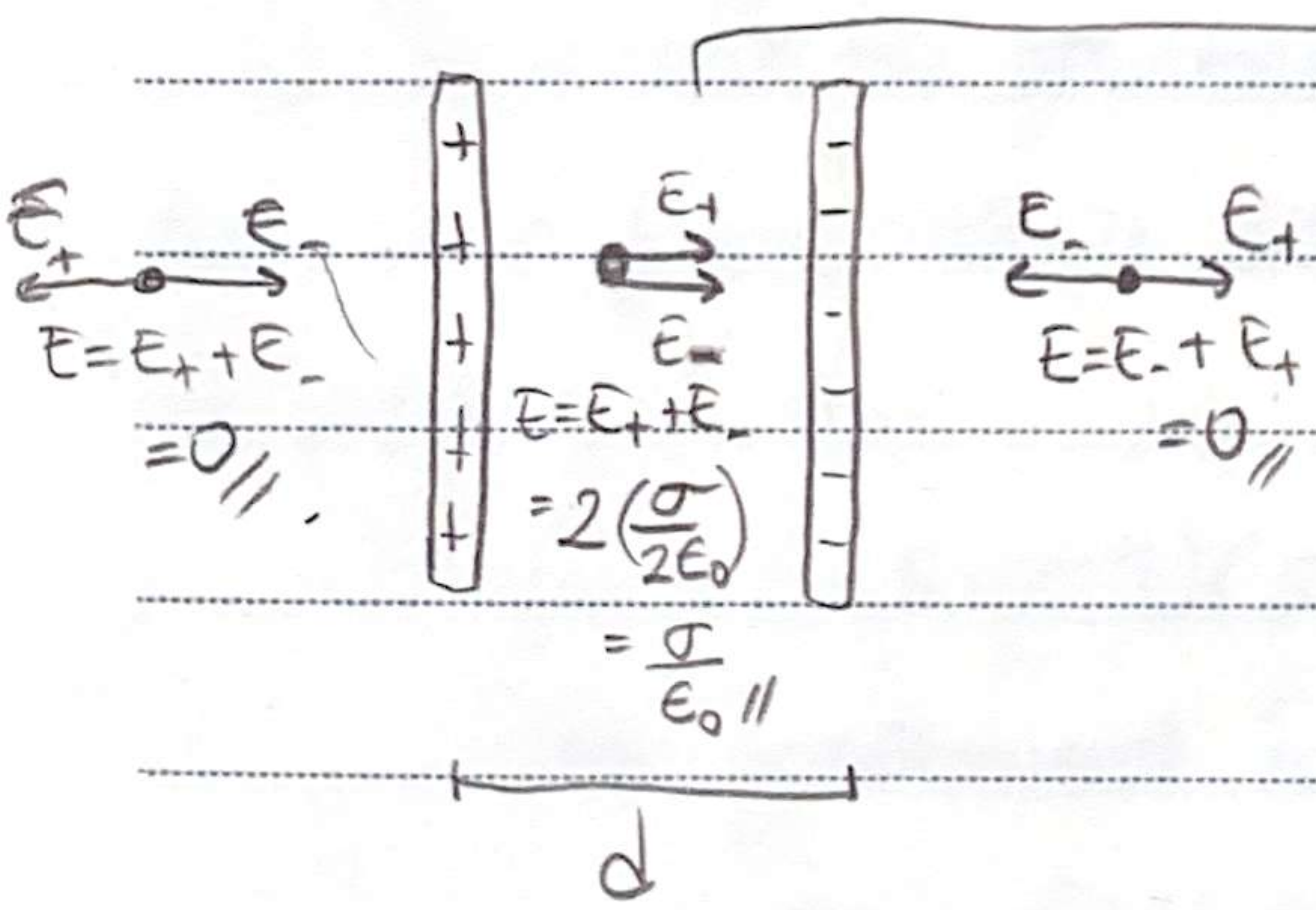
$$\sigma = \frac{dQ}{dA} = \frac{dQ}{(dr)(2\pi r)} \qquad dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{z\,\sigma\, 2\pi r\, dr}{(z^2+r^2)^{3/2}} = \frac{z\,\sigma\, r\, dr}{2\varepsilon_0 \cdot (z^2+r^2)^{3/2}}$$

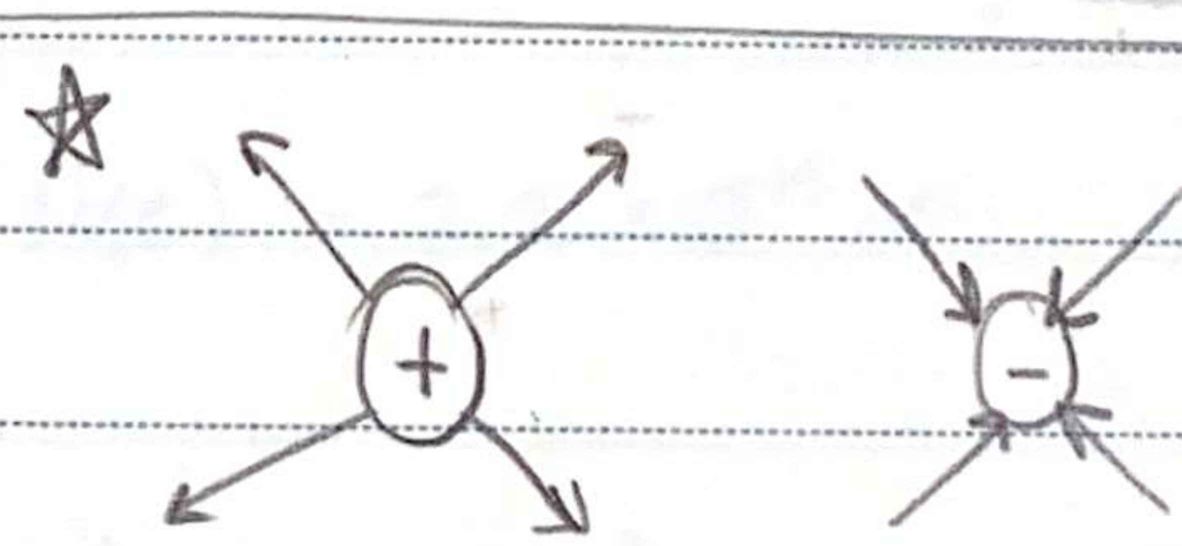
$$E = \frac{z \cdot \sigma}{2\varepsilon_0} \int_0^R \frac{r\, dr}{(z^2+r^2)^{3/2}} = \frac{z \cdot \sigma}{2\varepsilon_0} \left[-\frac{1}{(z^2+r^2)^{1/2}} \right]_0^R = \frac{\sigma}{2\varepsilon_0} \left[1 - \frac{z}{(z^2+R^2)^{1/2}} \right] //$$

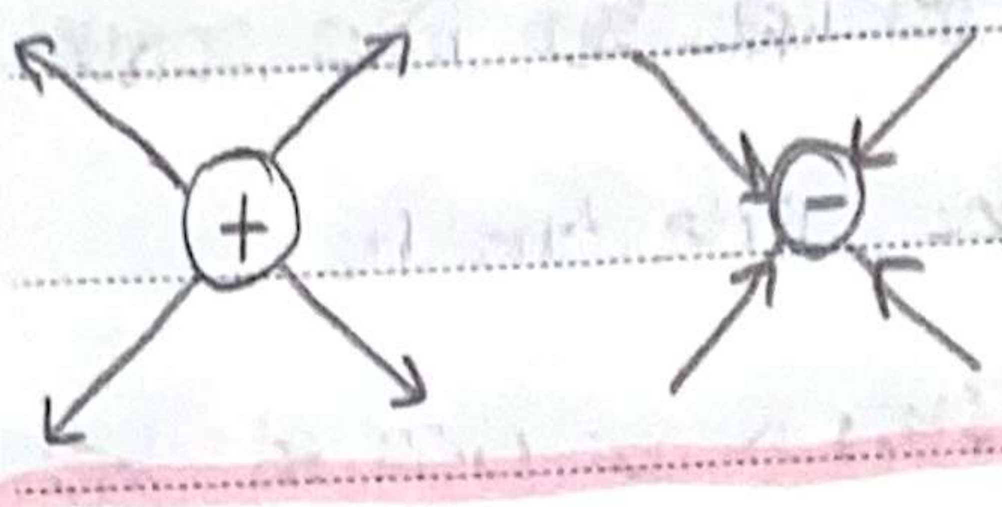
$E = \dfrac{\sigma}{2\varepsilon_0}$ } This result is valid for any point above on infinite plane at any shapes.

ex 21.13 // Determine the electric field between two large parallel plates or sheets, which are very thin and are seperated by a distance d which is small compared to their height and width. One plate carries a uniform surface charge density σ and the other carries a uniform surface charge $-\sigma$ as shown.

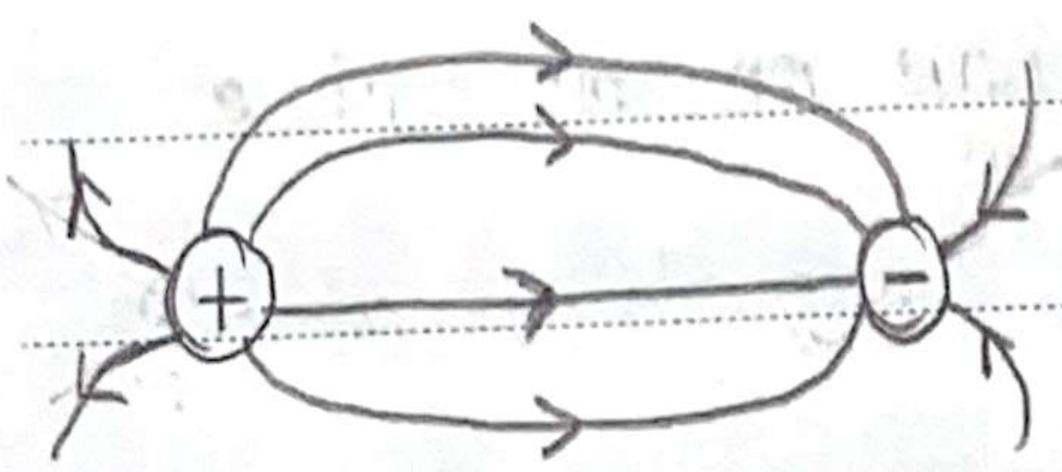
$\dfrac{\sigma}{\varepsilon_0}$ ⇒ this field is uniform but // outsides plates, the field is cancel





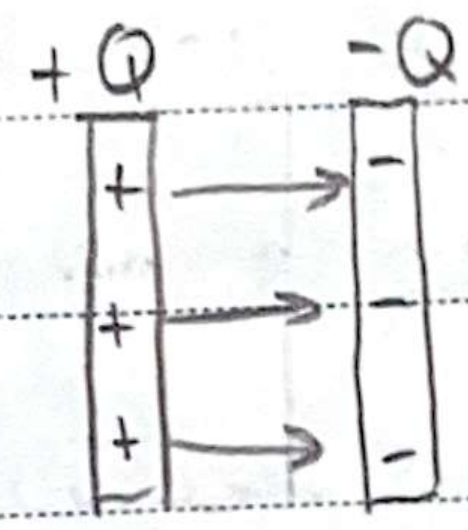


⇒ these lines start on a positive charge and on a negative charge



⇒ this combination known as an electric dipole

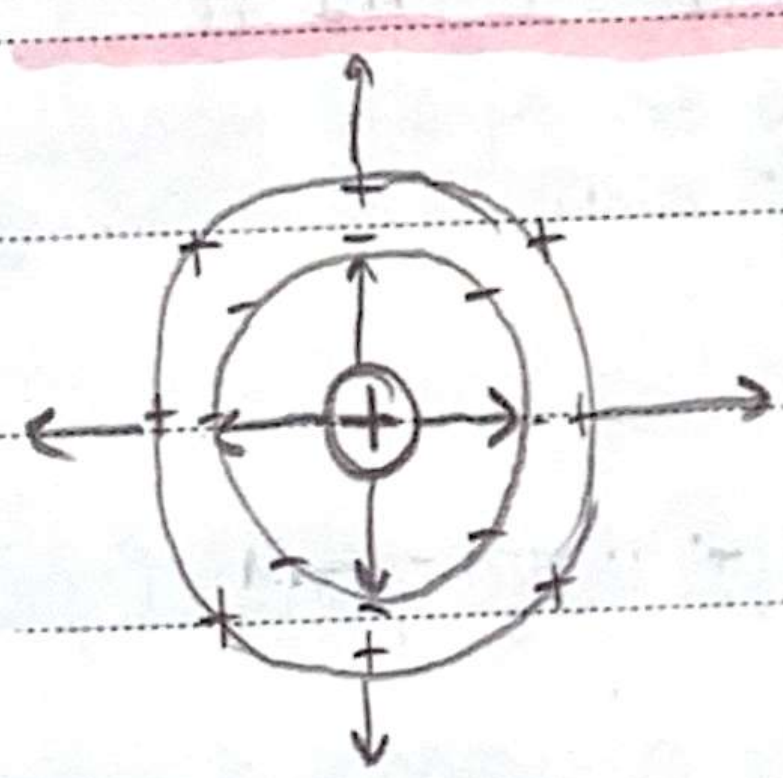
dipol = iki kutuplu şey



⇒ The electric field between two closely spaced, oppositely charged parallel is constant.

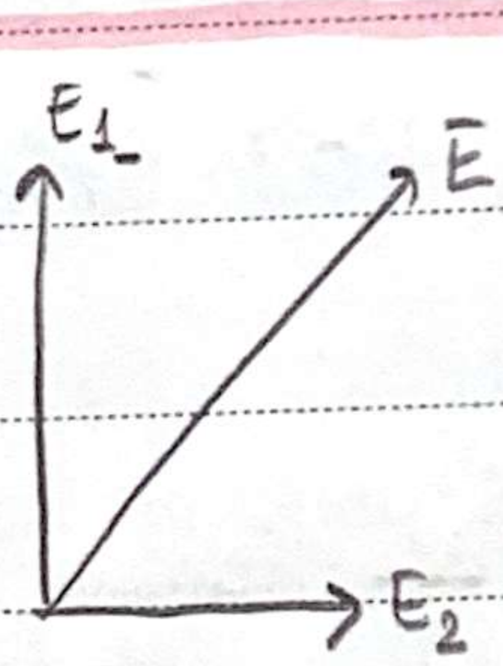
⇒ The electric field has the same magnitude at all points.

$E = \text{constant} = \frac{\sigma}{\varepsilon_0}$



⇒ the static electric field inside a conductor is zero, if it is not zero, the charges would move.

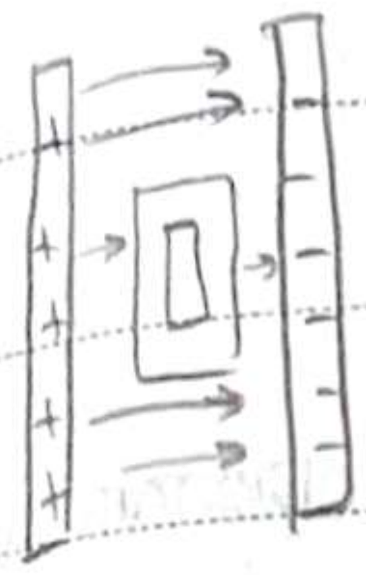
⇒ The net charge on a conductor resides on its outer surface



⇒ The electric field is perpendicular to the surface of a conductor - again, if it were not, charges would move.

dik

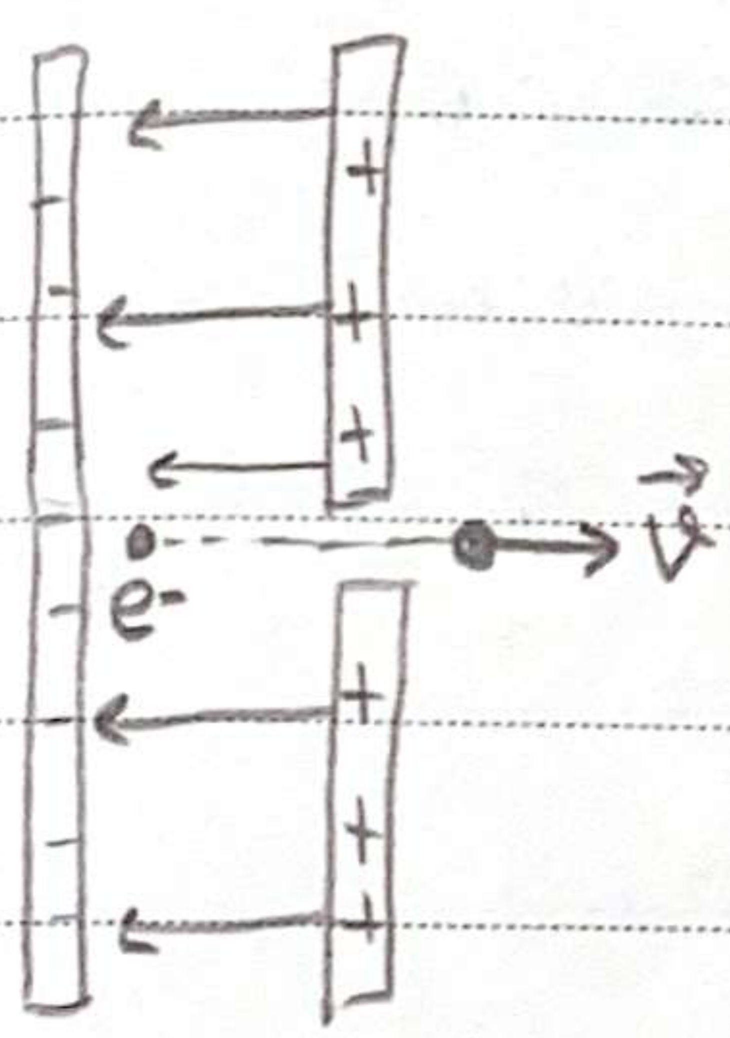
ex 21.14 // A neutral hollow metal box is placed between two parallel charged plates as shown. What is the field like inside the box.



⇒ For hollow box, the external field is not changed because electrons in the metal can only move on the surface

⇒ The person or object inside the cage is not affected

ex 21.15 // An electron (mass $m = 9.11 \times 10^{-31}$ kg) is accelerated in the uniform field E ($E = 2.0 \times 10^{4}$ N/C) between two parallel charged plates. The seperation of the plates is 1.5cm. The electron is accelerated from rest near the negative plate and passes through a tiny hole in the positive plate. a) With what speed does it leave the hole?



$F = qE = m \cdot a$

$(1.6 \times 10^{-19}\,C)(2 \times 10^{4}\,N/C) = (9.11 \times 10^{-31}\,kg) \cdot a$

$a = 3.5 \times 10^{15}\,m/s^2$

$x = 1.5 \times 10^{-2}\,m$

★ $v^2 = \underbrace{v_0^2}_{0} + 2ax = 2ax \Rightarrow v = \sqrt{2 (3.5 \times 10^{15})(1.5 \times 10^{-2})}$

$v = 1 \cdot 10^{7}\,m/s$ //

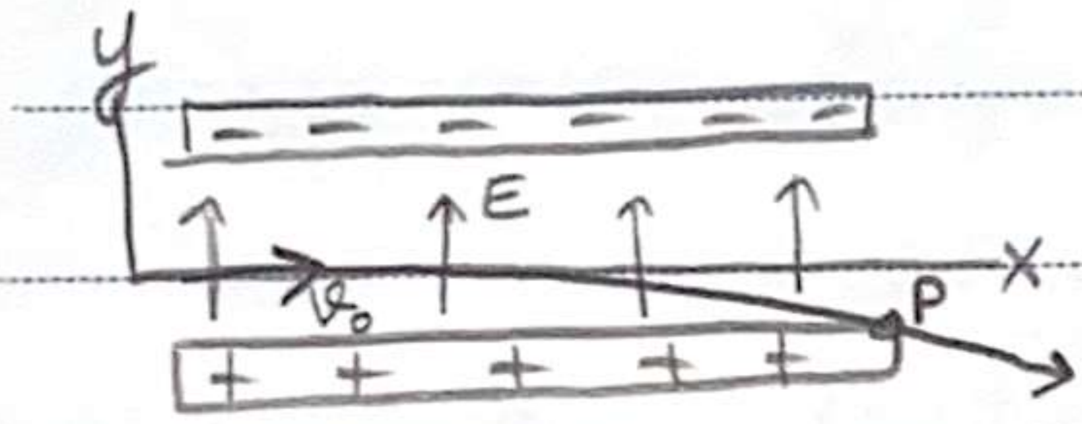
b) Show that the gravitational force can be ignored. Assume the hole is so small that it does not affect the uniform field between the plates.

$F = qE = (1.6 \times 10^{-19}\,C)(2 \times 10^{4}\,N/C) = 3.2 \times 10^{-15}\,N$

the gravitational force

$mg = (9.11 \times 10^{-31}\,kg)(9.8\,m/s^2) = 8.9 \times 10^{-30}\,N$

ex 21.16 // Suppose an electron travelling with speed $v_0 = 1.0\times10^{7}$ m/s enters a uniform electric field $\vec{E}$, which is at right angles to v_0 as shown. Describe its motion by giving an equation of its path while in the electric field. Ignore gravity.



x direction = no force → v_{0x} = constant $= v_0$

y direction = $F = Eq = m.a_y$

$q = e = -1.6\times10^{-19}$ C

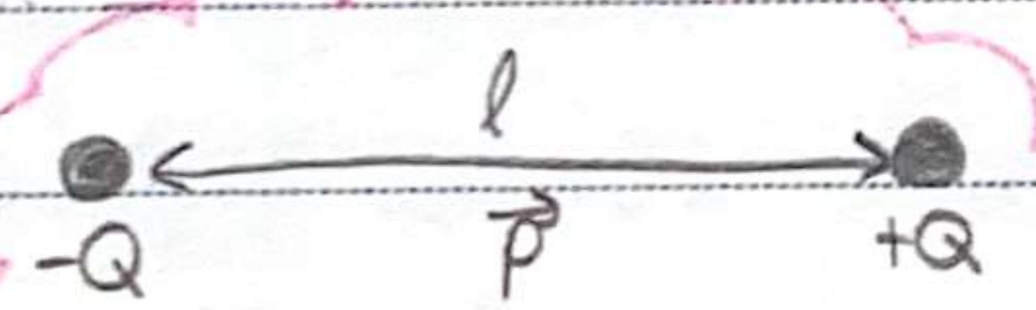
$a_y = -\frac{E.e}{m}$

$x = v_{0x}.t \Rightarrow t = \frac{x}{v_0}$

$y = y_0 + v_{0y} + \frac{1}{2}a_y t^2$ $(y_0 = 0, v_{0y} = 0)$

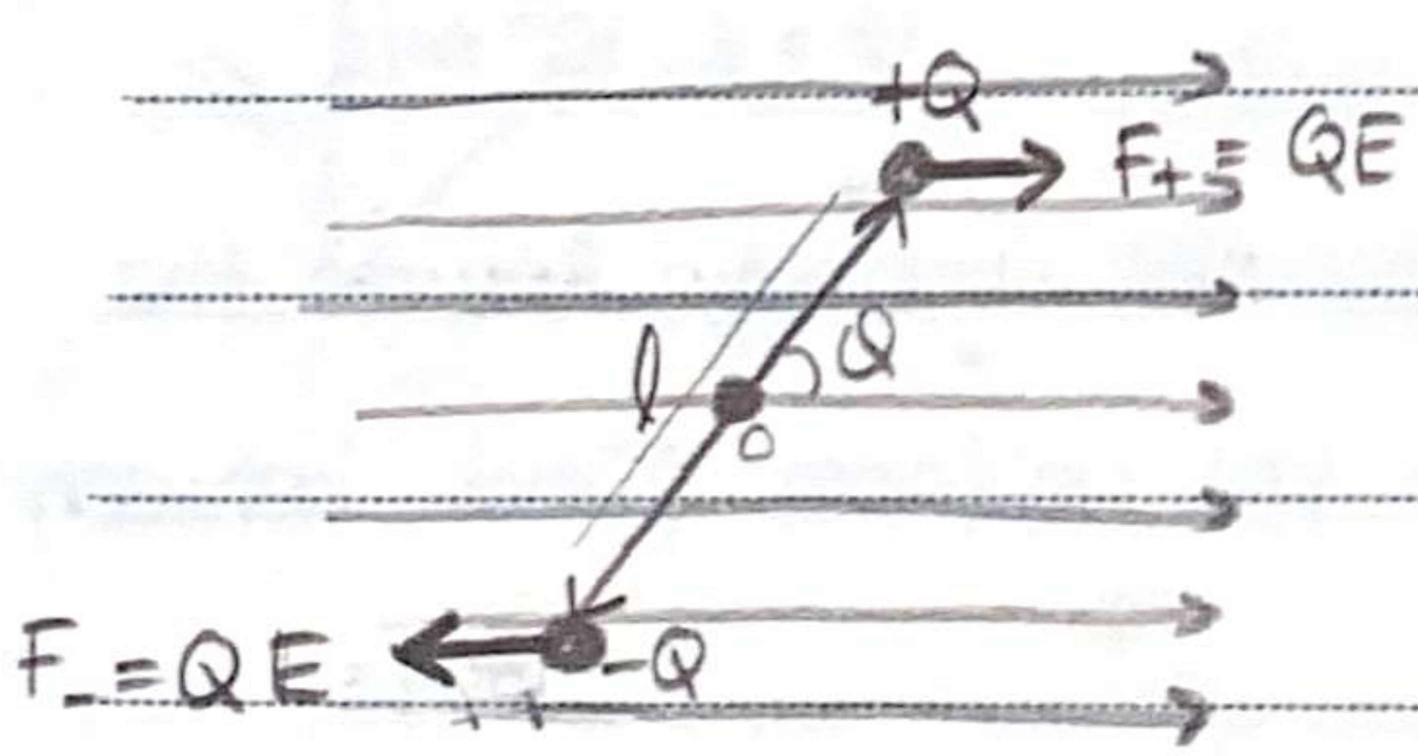
$y = \frac{at^2}{2} = -\frac{Ee}{2m}\cdot\frac{x^2}{v_0^2}$

$y = -\frac{Eex^2}{2mv_0^2}$ ⇒ projectile motion //



$\vec{p} = Ql$

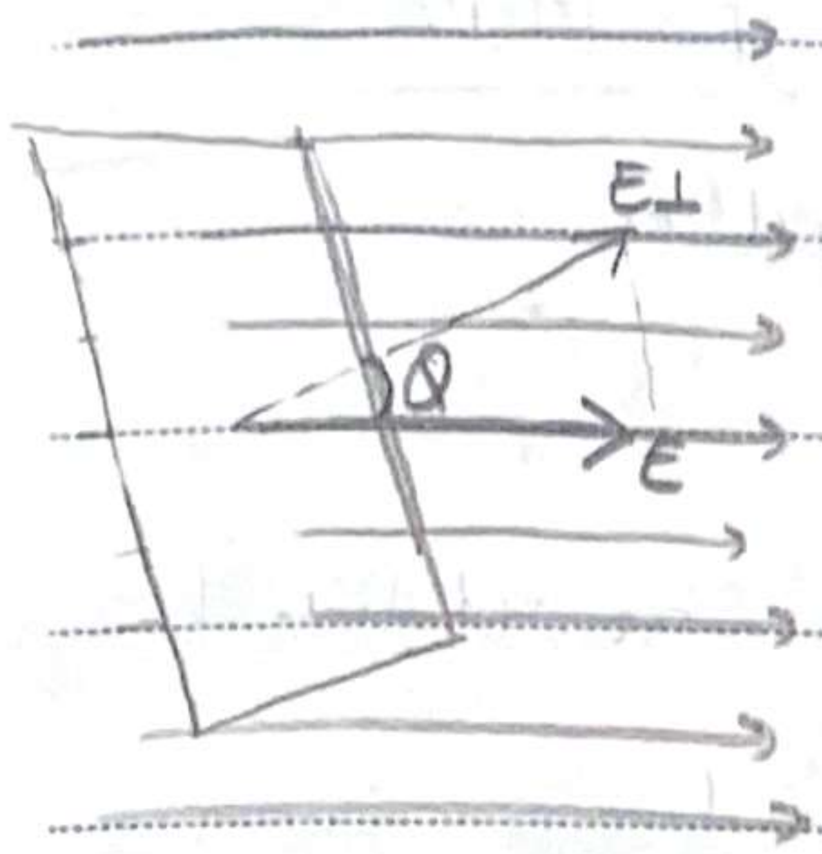
⇒ dipole moment



$\tau = \vec{p}E\sin\theta = \vec{p}\times E$

$\tau = \vec{p}\times E$

~ CHAPTER 22 GAUSS'S LAW ~



flux

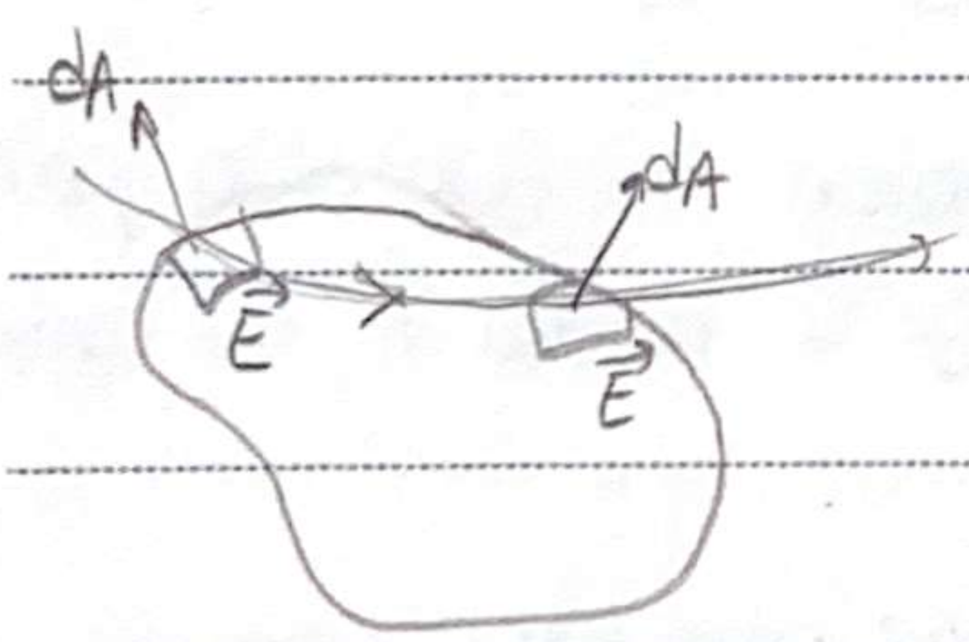
$$\Phi_E = E.A.\cos Q = E_{\perp}A$$

ex 22.1 // Calculate the electric flux through the rectangle shown. The rectangle is 10 cm by 20 cm. The electric field is uniform at 200 N/C, and the angle is 30° (görsel yukarıdakinin aynısı bi daha asla çizemem.)

$$\Phi = \vec{E}.\vec{A} = E.A.\cos Q$$

$$= (200\ N/C)(0.1\ m \times 0.2\ m)\cos 30 = 3.5\ N.m^2/C$$

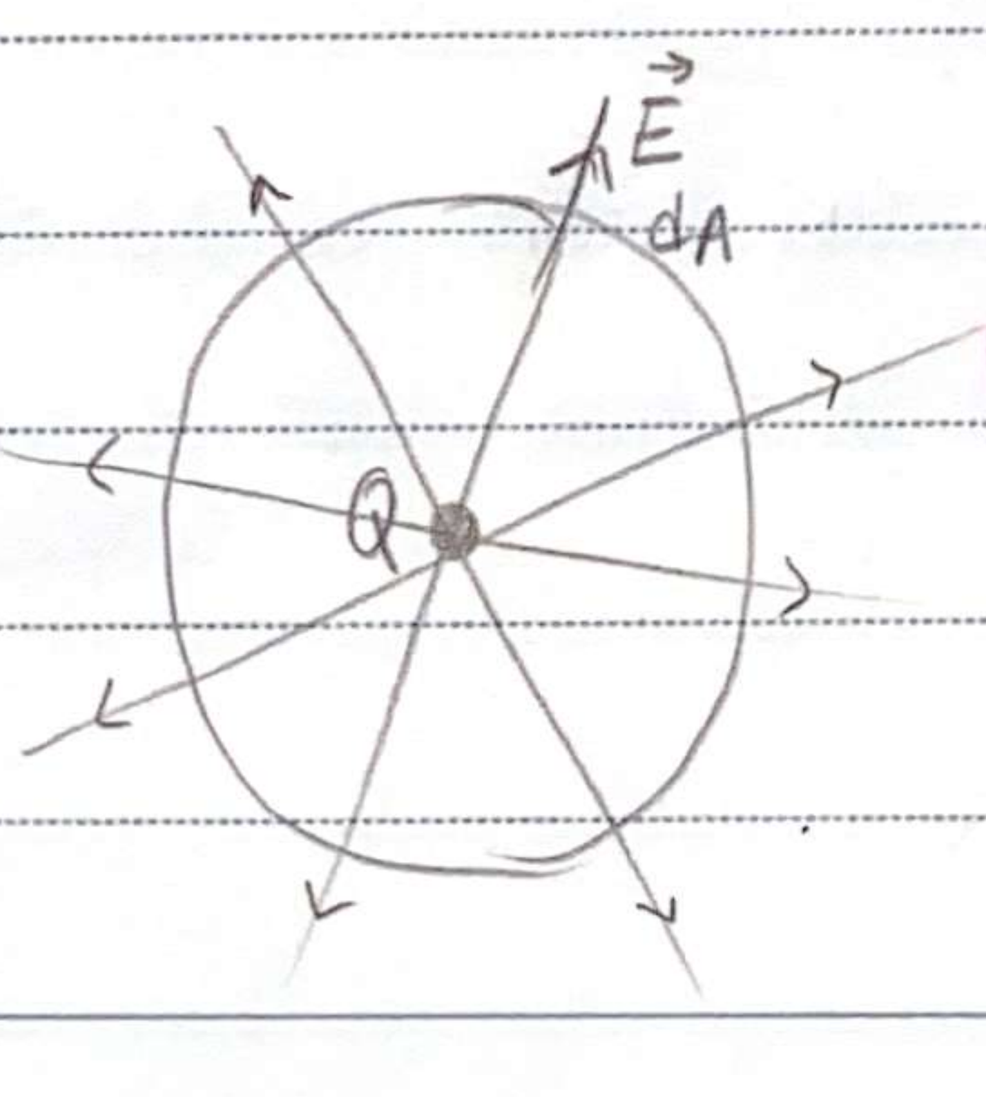
(unit of $\Phi = \frac{N.m^2}{C}$)



$$\Phi = \oint \vec{E}.d\vec{A}$$

$$\Rightarrow$$

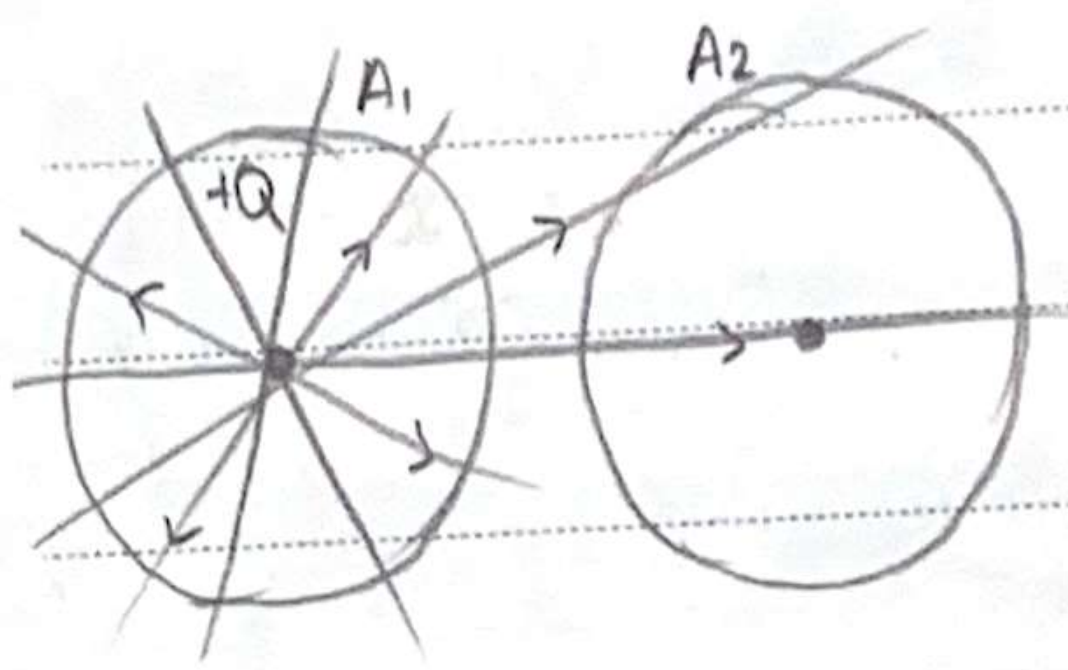
$$\Phi = \oint \vec{E}.dA = \frac{Q}{\varepsilon_0}$$



$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$ the electric field form of coulombs law

$$\sum Q_i = Q_{encl}$$

ex 22.2 // Consider the two gaussian surfaces, A_1 and A_2 as shown. The only charge present is the charge Q at the center of surface A_1. What is the net flux through each surface, A_1 and A_2?



For surface A_1,

the net flux through A_1

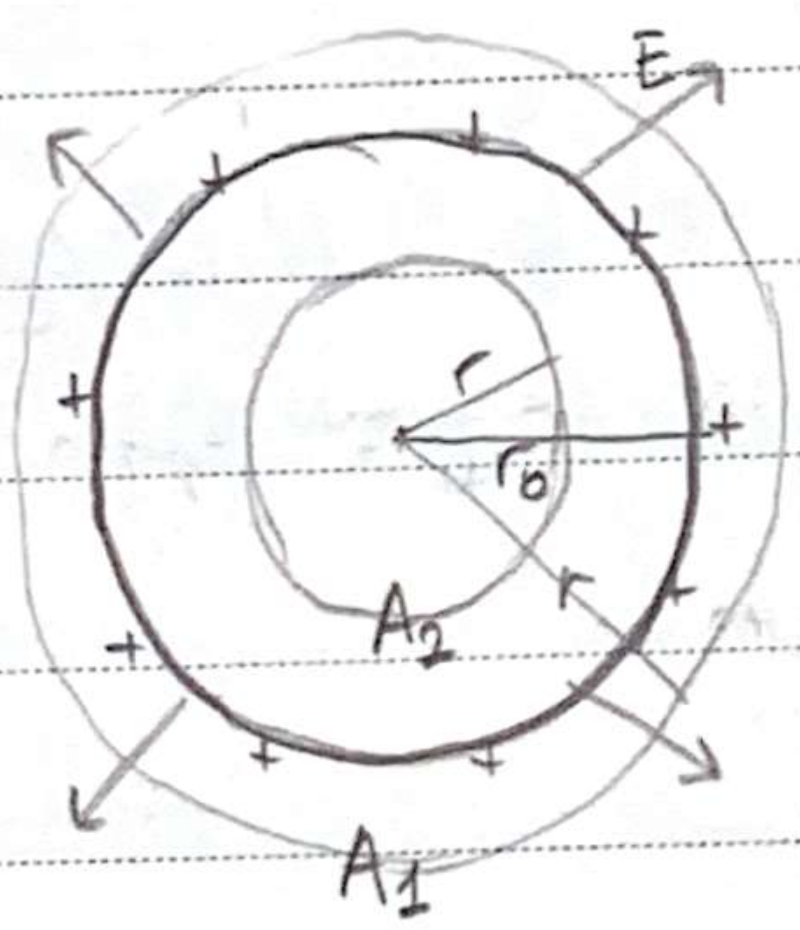
$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} = \frac{+Q}{\varepsilon_0}$$

For surface A_2

the net flux through A_2 $= 0$ //

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} = \frac{0}{\varepsilon_0} = 0 \text{ //}$$

ex 22.3 // A thin spherical shell of radius r_0 possesses a total net charge Q that is uniformly distributed on it. Determine the electric field at points a) outside the shell



for $r > r_0$, $\vec{E}$ is parallel to $d\vec{A}$

cosine of the angle between $\vec{E}$ and $d\vec{A}$ is always 1 //

$$(E \cdot A \cdot \cos Q) = \frac{Q}{\varepsilon_0}$$

$$\oint \vec{E} \cdot d\vec{A} = E \cdot (4\pi r^2) = \frac{Q_{encl}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2}$$ } is equivalent the field of a point charge Q located at the center.

$$E \cdot 4\pi r^2 = \frac{Q}{\varepsilon_0} \Rightarrow E = \frac{1}{4\pi r^2} \cdot \frac{Q}{\varepsilon_0}$$

b) within (inside) the shell

$Q_{encl} = 0$ inside the shell

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} = 0$$

$\Rightarrow E = 0$ //

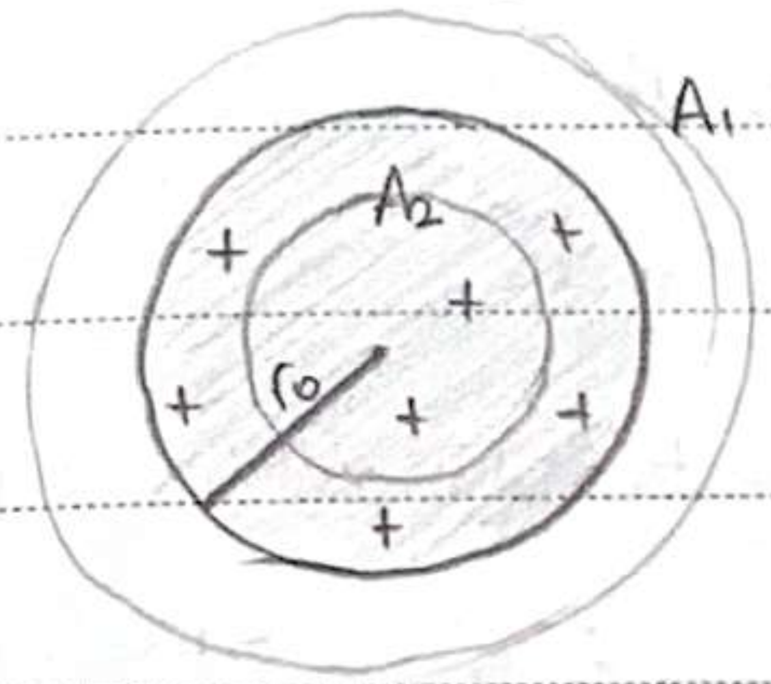
c) What if the conductor were a solid sphere?

$\Rightarrow$ We obtain same results because all charge would lie in a thin layer at the surface.

enclosed = kapalı (Q_{encl})

Record :　　　　/　　/

ex 22.4 // An electric charge Q is distributed uniformly throughout a nonconducting sphere of radius r_0. Determine the electric field



a) outside the sphere ($r>r_0$)

For $r>r_0$

$$\oint \vec{E}\,d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}$$

$$E\cdot(4\pi r^2) = \frac{Q}{\varepsilon_0} \Rightarrow E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}$$

obtain same results with a point charge located at the center of sphere

b) inside the sphere ($r<r_0$)

for ($r<r_0$) $\Rightarrow \oint \vec{E}\,d\vec{A} = E\cdot(4\pi r^2) = \frac{Q_{encl}}{\varepsilon_0}$ → Q_{encl} is the charge enclosed by A_2; the total charge Q is not equal to Q_{encl} but only a portion of it.

$\rho_E = \frac{dQ}{dV}$; ρ_E = constant

⇓

the charge density

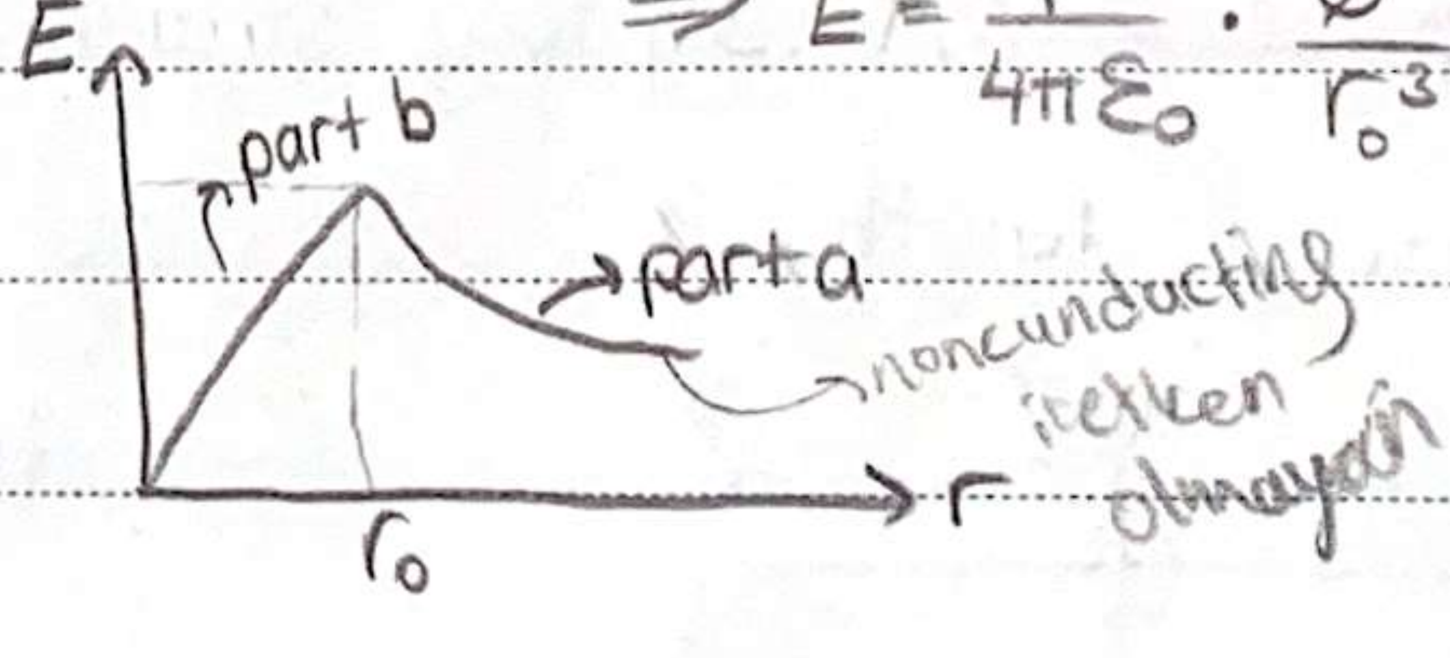
$\frac{4}{3}\pi r_0^3$ — Q

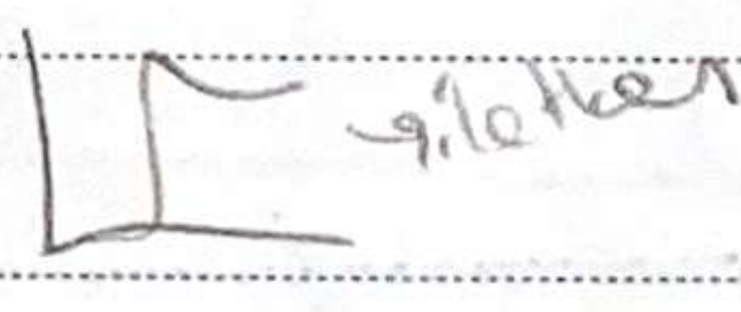
$\frac{4}{3}\pi r^3$ — Q_{encl}

$$Q_{encl} = \frac{\frac{4\pi r^3}{3}}{\frac{4\pi r_0^3}{3}}Q = \frac{r^3}{r_0^3}\cdot Q$$

$$E\cdot 4\pi r^2 = \frac{r^3}{r_0^3}\cdot\frac{Q}{\varepsilon_0}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r_0^3}\cdot r$$

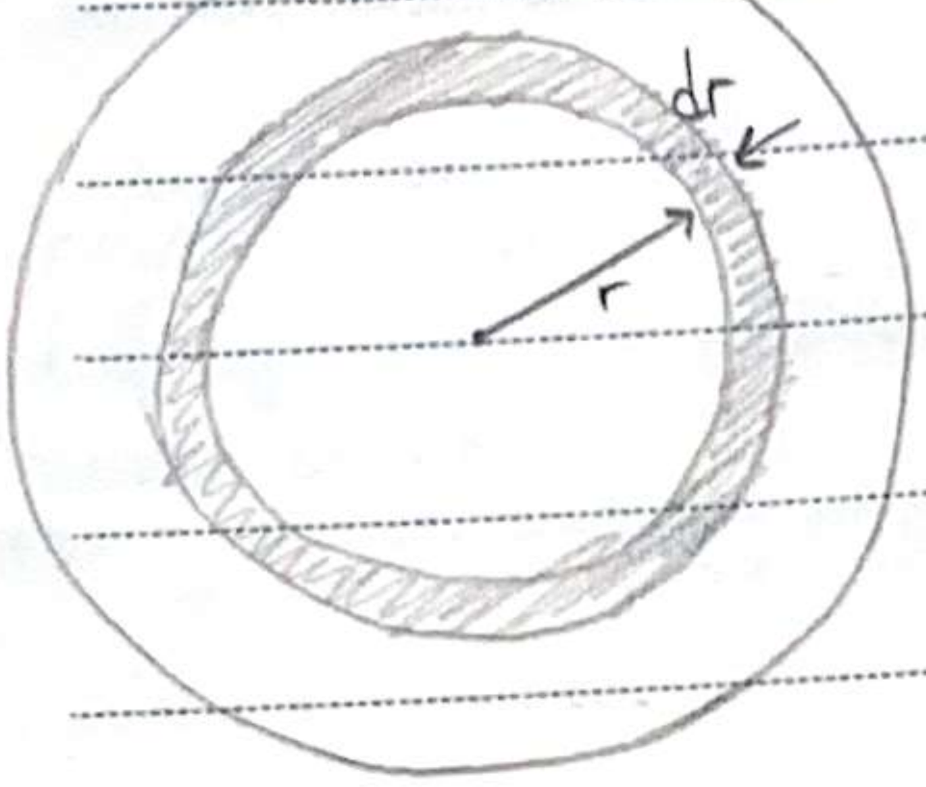




Record :

ex 22.5 // Suppose the charge density of a solid sphere is given by $\rho_E = a.r^2$, where a is constant.

a) Find a in terms of the total charge Q on the sphere and its radius r_0.



$dQ = \rho_E . dV$

$Q = \int \rho_E . dV$

$dV = (4\pi r^2) dr$

$Q = \int (a.r^2).(4\pi r^2) dr$

$Q = a.4\pi \int_0^{r_0} r^4 dr = \frac{4\pi a}{5} . r^5$

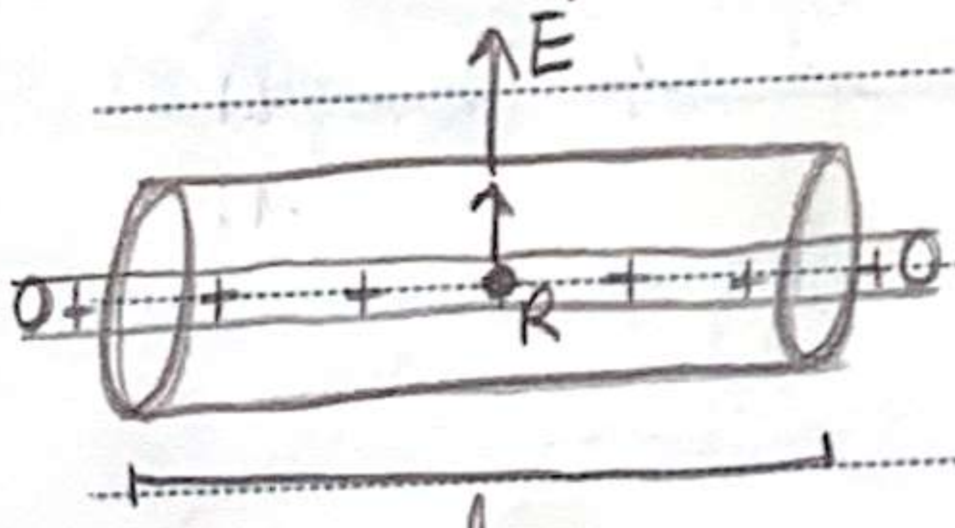
$a = \frac{5Q}{4\pi r^5}$ //

b) Find the electric field as a function of r inside the sphere.

$Q_{encl} = \int_0^r \rho_E . dV = \int_0^r (a.r^2)(4\pi r^2) dr \; \} \; \int_0^r \left(\frac{5Q . r^2}{4\pi r_0^5}\right)(4\pi r^2) dr = \frac{Q r^5}{r_0^5}$

$\Rightarrow \frac{Q r^5}{r_0^5} \Rightarrow \oint \vec{E} d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} \Rightarrow E(4\pi r^2) = \frac{Q . r^5}{r_0^5 . \varepsilon_0} \Rightarrow E = \frac{Q . r^3}{4\pi r_0^5 \varepsilon_0}$

ex 22.6 // A very long straight wire possesses a uniform positive charge per unit length, λ. Calculate the electric field at points near (but outside) the wire, far from the ends.



$\Rightarrow$ because of symmetry, $\vec{E}$ to be directed radially outward.

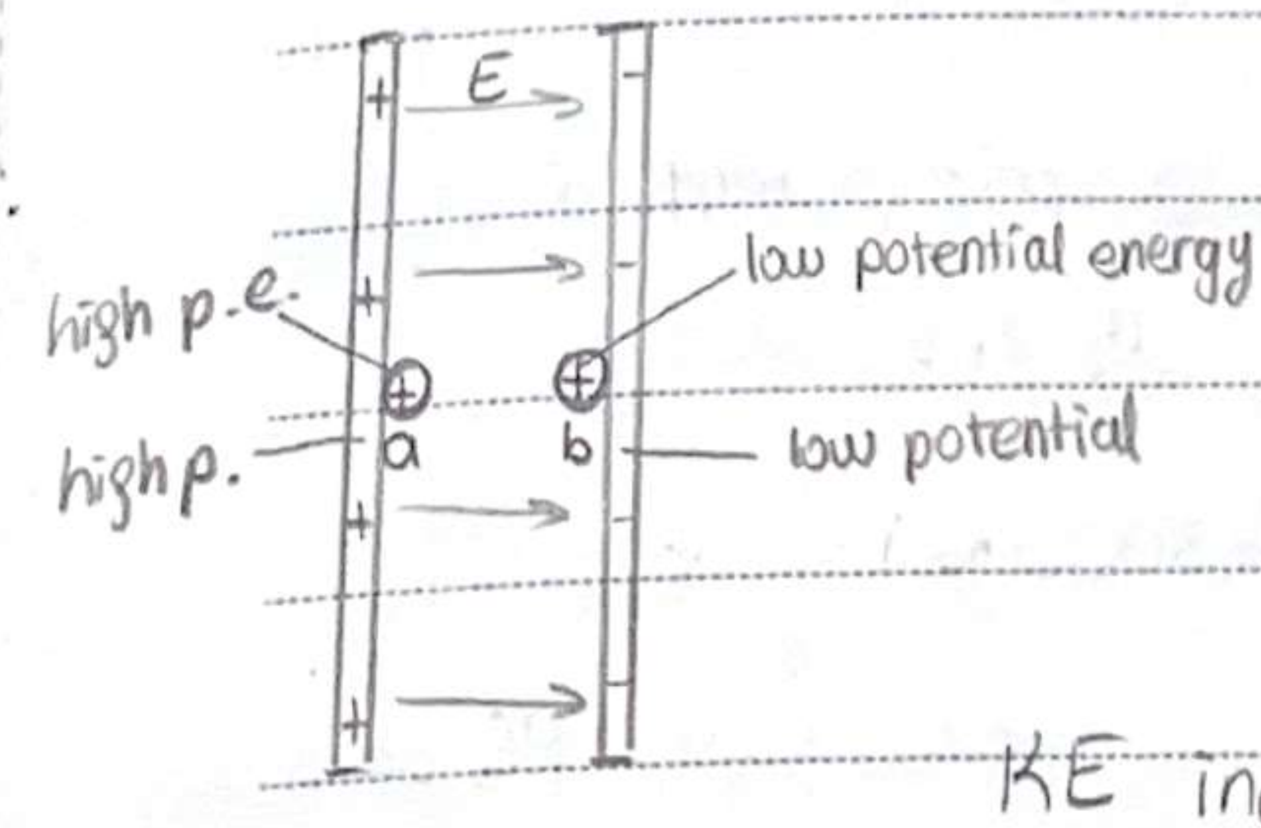
$$\oint \vec{E} d\vec{A} = E(2\pi R l) = \frac{Q_{encl}}{\varepsilon_0} = \frac{\lambda . l}{\varepsilon_0}$$

$\hookrightarrow E = \frac{1}{2\pi \varepsilon_0} . \frac{\lambda}{R}$ where $l <<$ length of wire.

Express

Record :

CHAPTER 23 ~ ELECTRIC POTENTIAL



~ The electrostatic force is conservative

$$U_b - U_a = -W = -qEd$$

KE increases

⇒ PE decreases, and the charged particle accelerates from a to b.

⇒ electric PE is transformed into KE so total E conserved

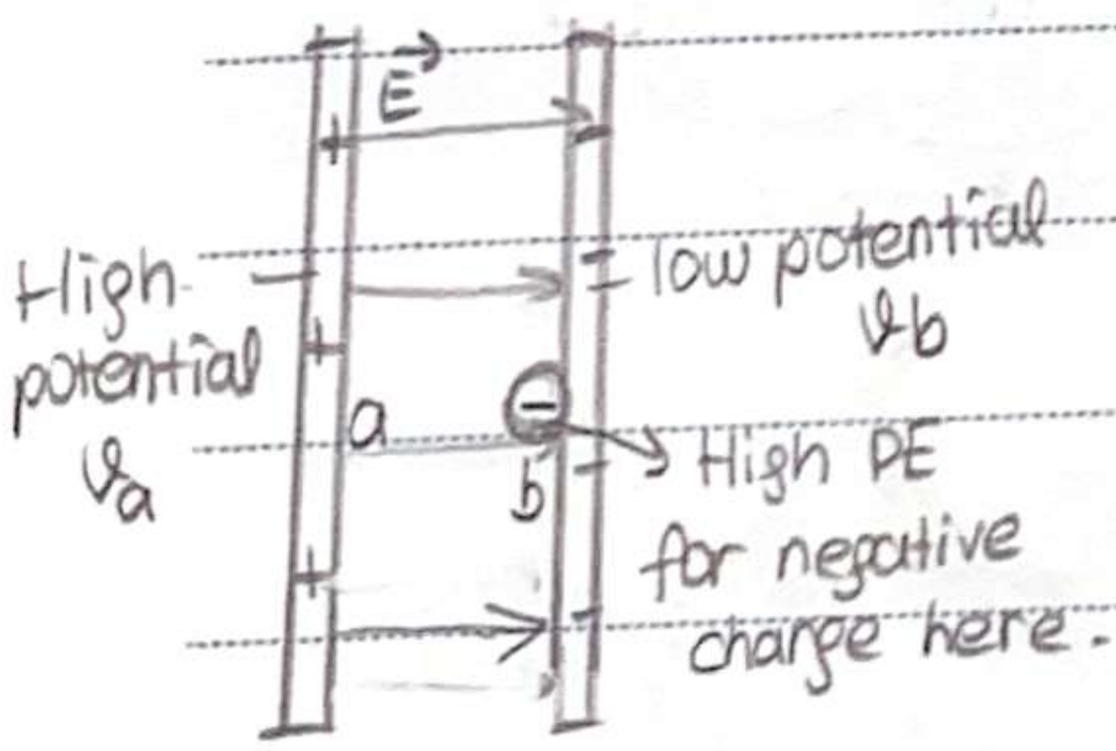
$$V_a = \frac{U_a}{q}$$ $$1 \text{ Volt} = 1 \text{ J/C}$$ $$V_{ba} = \Delta V = \frac{U_b - U_a}{q} = \frac{W_{ba}}{q}$$

$U = V \cdot q$

(-) charges move towards high electric potential

(+) " " " low "

ex 23.1 // Suppose a negative charge, such as an electron, is placed near the negative plate at point b, as shown here. If the electron is free to move, will its electric potential energy increase or decrease? How will the electric potential change?



⇒ PE decreases as its KE gets larger, so ;

$U_a < U_b$

$\Delta U = U_a - U_b < 0$ ⇒ $V_{ab} = V_a - V_b > 0$

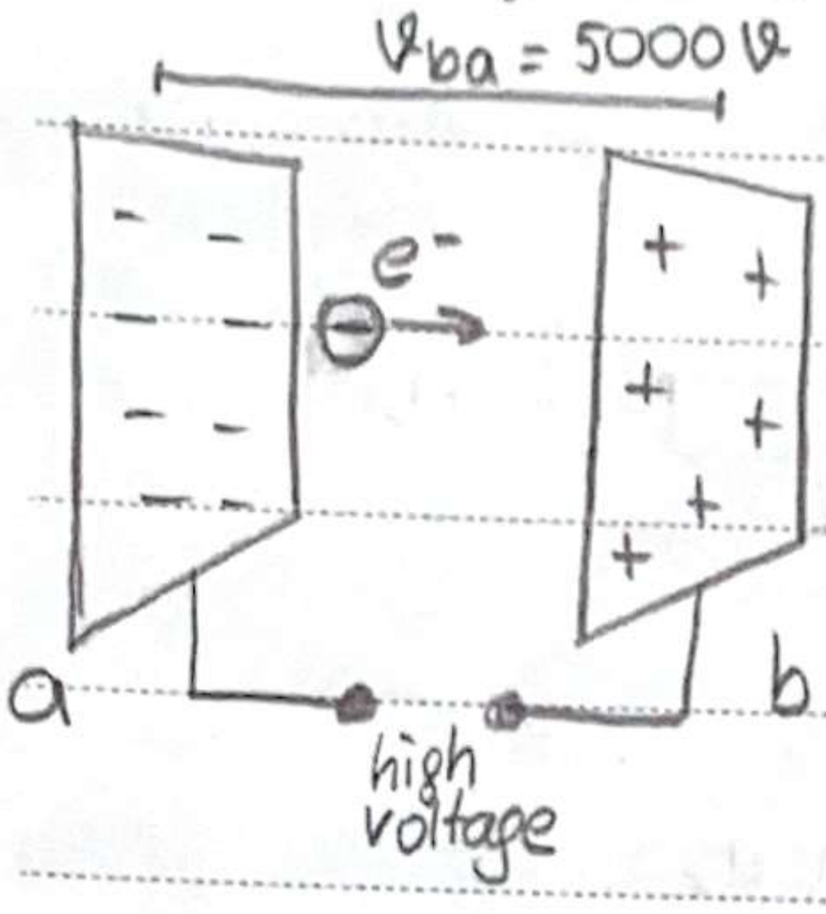
⇒ potential V_a and V_b are due to charges on the plates not due to electron.

$$\Delta U = U_b - U_a = q \cdot (V_b - V_a)$$

$$\Delta U = q \cdot V_{ba}$$ //

Express

ex 23.2 // Suppose an electron in a cathode ray tube is accelerated from rest through a potential difference $V_b - V_a = V_{ba} = +5000\,V$.



a) What is the change in electric potential energy of the electron?

$$\Delta U = q \cdot V_{ba}$$

$$\Delta U = (-1.6\times10^{-19}\,C).(+5000\,V) = -8.10^{-16}\,J$$

minus sign = PE decreases

b) $\Delta K + \Delta U = 0$
$\Delta K = -\Delta U$

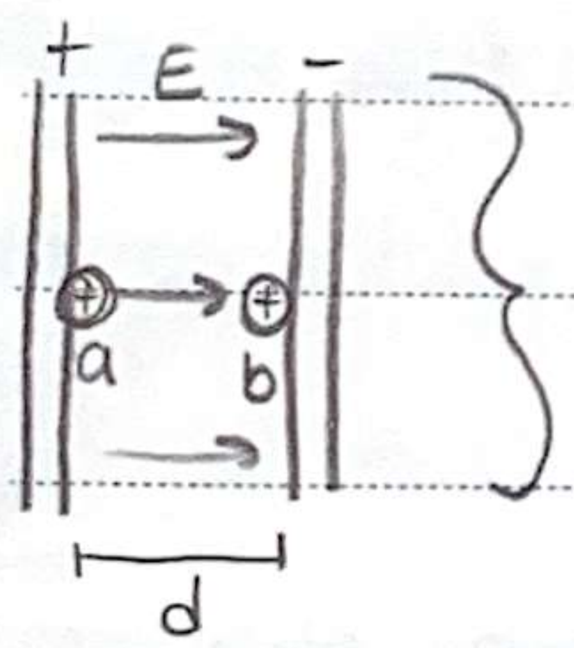
$$\frac{1}{2}mv^2 - 0 = -q.(V_b - V_a)$$
$$= -q \cdot V_{ba}$$

$$v = \sqrt{\frac{-2qV_{ba}}{m}} = 4.2\times10^{7}\,m/s$$

⇒ The difference in PE between any two points ⇒ $U_b - U_a = -\int_a^b \vec{F}.d\vec{l}$

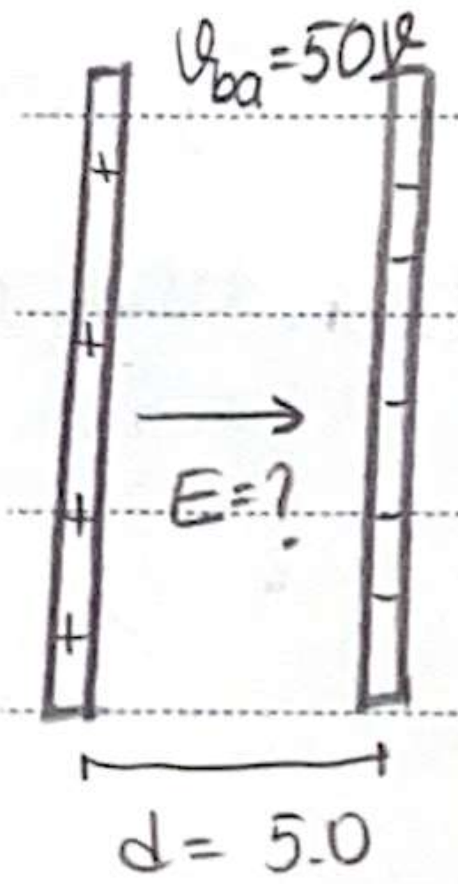
$$V_b - V_a = \frac{U_b - U_a}{q} \qquad \vec{E} = \frac{\vec{F}}{q}$$

$$\Rightarrow V_{ba} = -\int_a^b \vec{E}.d\vec{l}$$



$$V_{ba} = -E.d$$

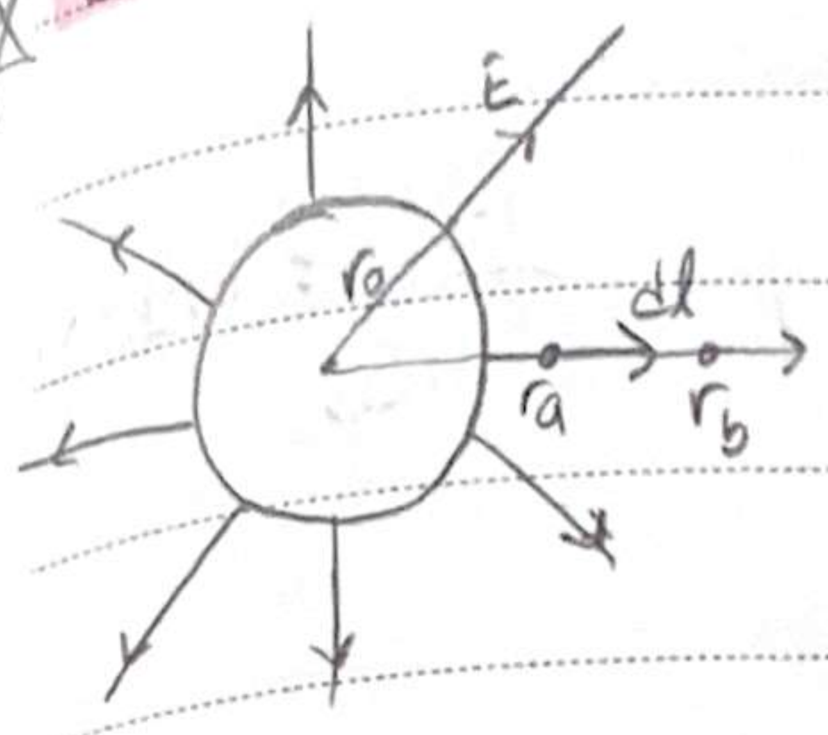
ex 23.3 // two parallel plates are charged to produce a potential difference of 50V. If the seperation between the plates is 0.050m, calculate the magnitude of the electric field in the space between the plates.



$$E = \frac{V_{ba}}{d} = \frac{50V}{0.05m} = 1000\,V/m$$

Record :

ex 23.4 // Determine the potential at a distance r from the center of a uniformly charged conducting sphere of radius r_0 for a) $r>r_0$, b) $r=r_0$ c) $r<r_0$, The total charge on the sphere is Q



$\rightarrow E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2}$ → points radially outward if $Q>0$ ↳ points radially inward if $Q<0$

$$V_b - V_a = -\int_{r_a}^{r_b} \vec{E}.d\vec{l} = -\frac{Q}{4\pi\varepsilon_0}\int_{r_a}^{r_b}\frac{dr}{r^2} \Rightarrow V_{ba} = \frac{Q}{4\pi\varepsilon_0}\cdot\left(\frac{1}{r_b}-\frac{1}{r_a}\right)$$

a) → lets choose $V_b=0$ at $r_b=\infty$ $\longrightarrow$ $V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r}$

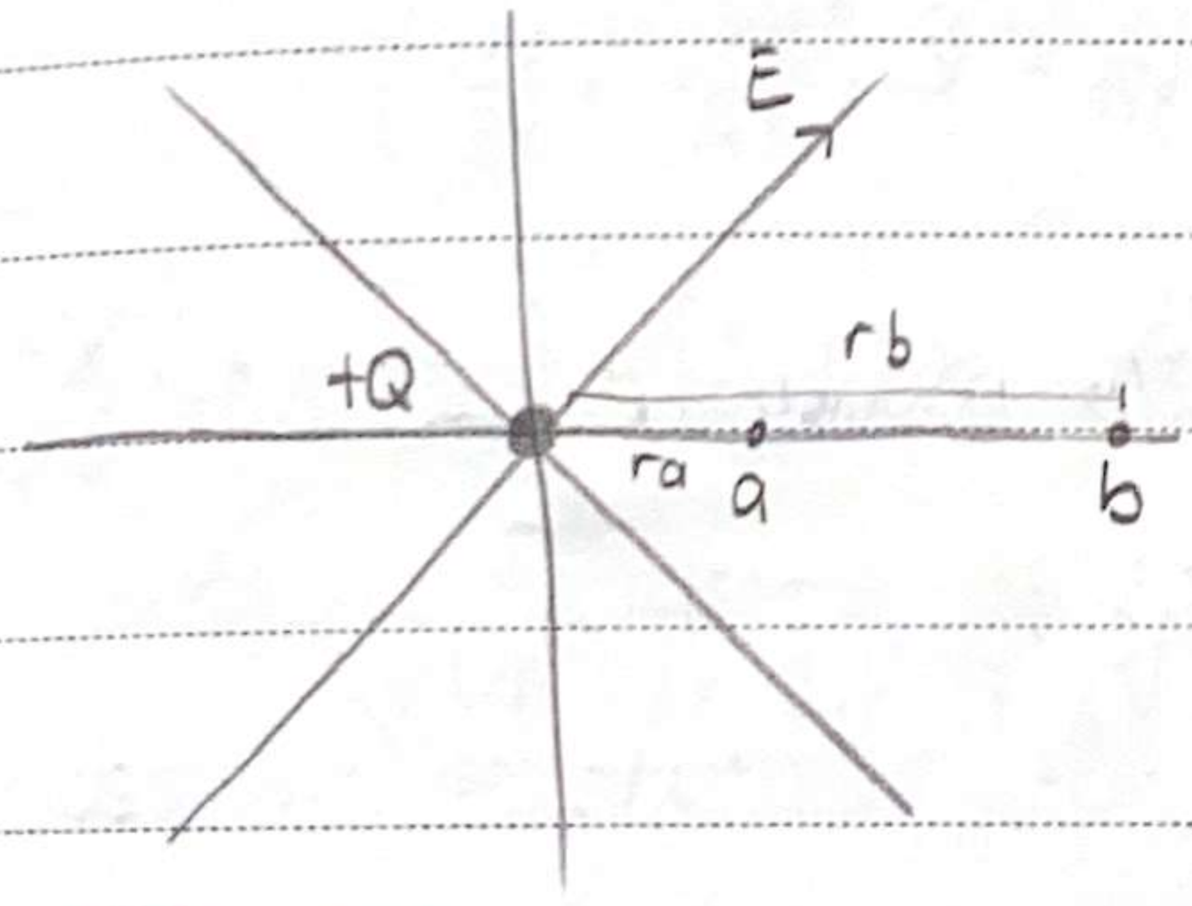
b) as r approaches r_0, the potential difference at the surface of the conductor $V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r_0}$, $r_a = r_0$

c) inside the conductor $E=0$

$\int \vec{E}' d\vec{l}' = 0$ ⇓ the change in the potential } V is constant

for $r<r_0$	
$E=0$	V= constant

for $r>r_0$	
$E \propto \frac{1}{r^2}$	$V \propto \frac{1}{r}$



$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}$ } is directed radially outward from positive charge

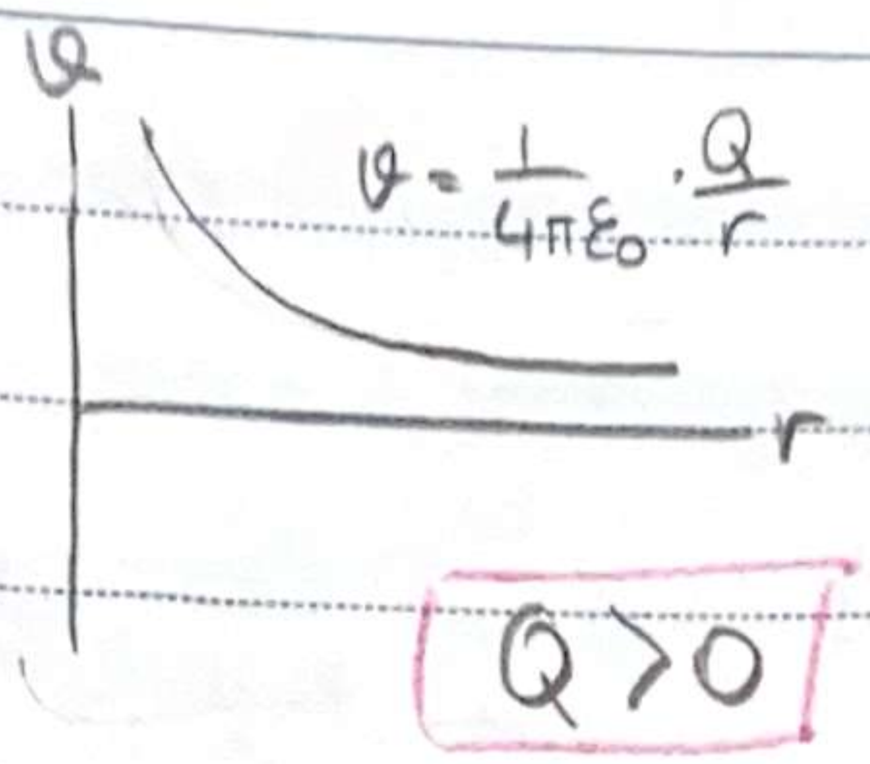
$$V_b - V_a = -\int_{r_a}^{r_b} \vec{E}'.d\vec{l}' = \frac{-Q}{4\pi\varepsilon_0}\cdot\int_{r_a}^{r_b}\frac{1}{r^2}dr$$

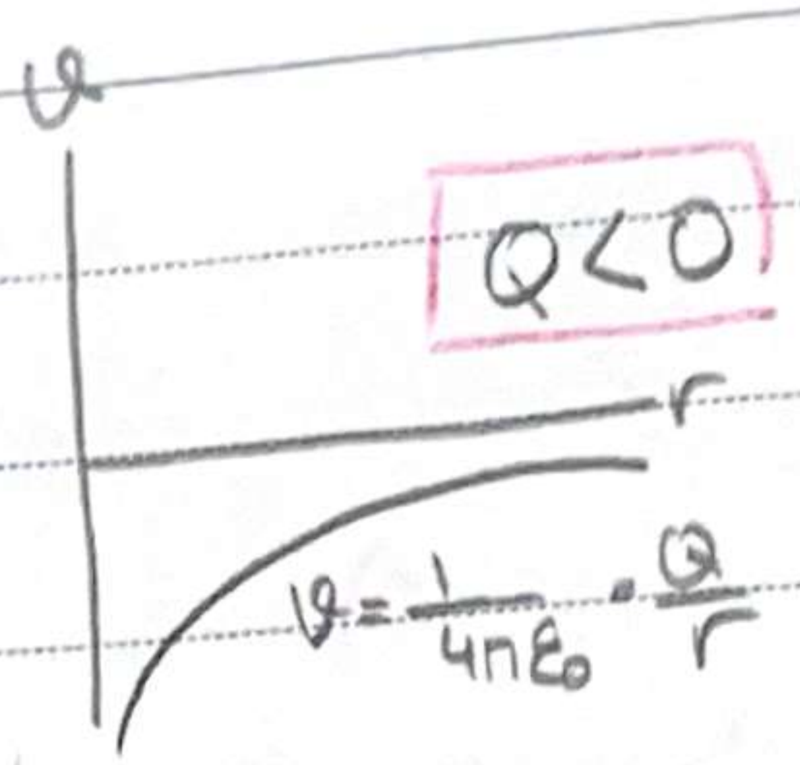
$$V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r} \qquad V_{ba} = \frac{1}{4\pi\varepsilon_0}\cdot\left(\frac{Q}{r_b}-\frac{Q}{r_a}\right)$$

↳ the electric potential expression

Express

Record :





$\frac{1}{4\pi\varepsilon_0} = (8.99\times10^9)$

ex 23.6 // What minimum work must be done by an external force to bring a charge $q = 3.00\,\mu C$ from a great distance away (take $r=\infty$) to a point 0.500 m from a charge $Q = 20.0\,\mu C$?

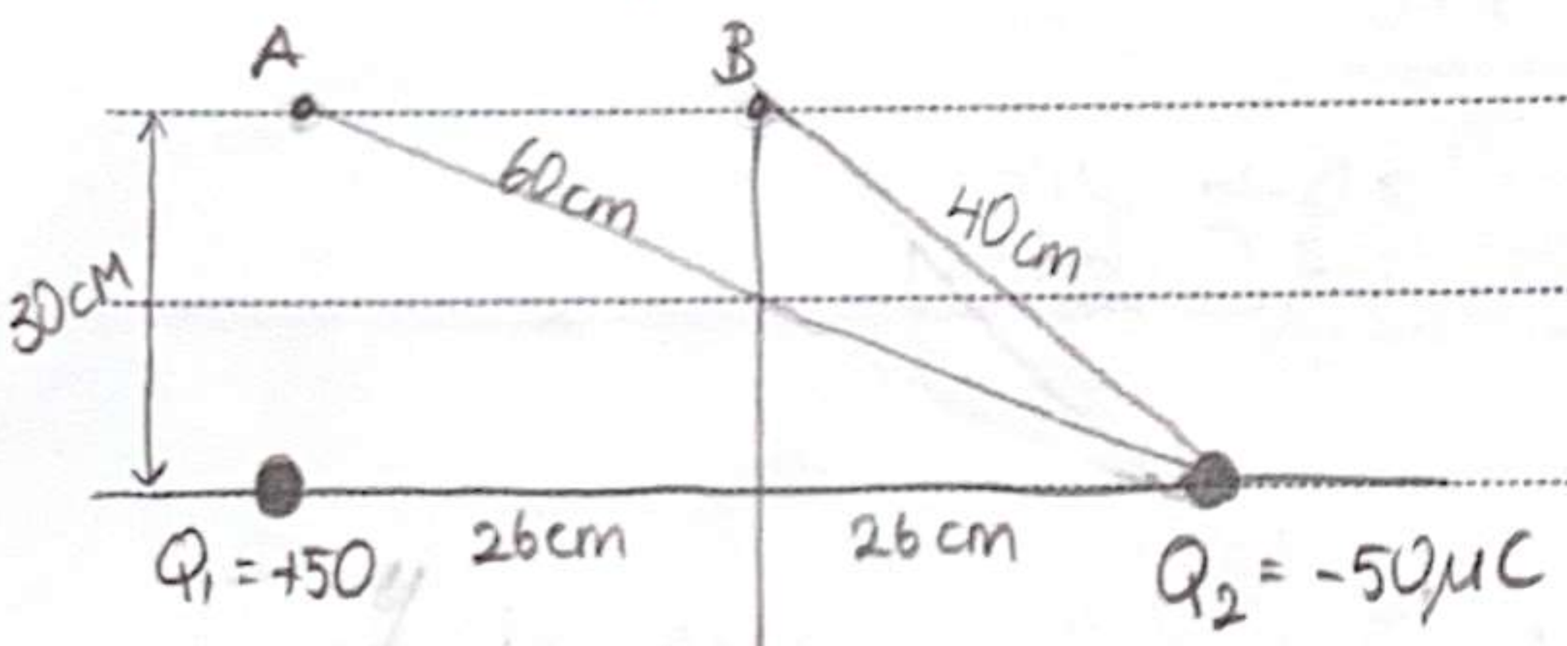
$W = q\cdot(V_b - V_a)$ → charge in PE

$W = q\cdot\left(k\cdot\frac{Q}{r_b} - k\cdot\frac{Q}{r_a}\right)$ → $r_a = \infty$, $r_b = 0.5M$ → $W = \frac{(3.10^{-6}c)(8.99\times10^9)(2\times10^{-5})}{(0.5)M}$

$\frac{1}{\infty} = 0$ //

$\boxed{W = 1.08J}$ //

ex 23.7 // Calculate the electric potential



a) at point A due to 2 charges

$V_A = V_{A_2} + V_{A_1}$

$V_A = k\cdot\left(\frac{Q_2}{r_{A_2}} + \frac{Q_1}{r_{A_1}}\right)$

$V_A = (9\times10^9\,Nm^2/c^2)\left(\frac{(5\times10^{-5}c)}{0.3M} + \frac{(-5\times10^{-5}c)}{0.6M}\right)$

$V_A = \boxed{7.5\times10^5\,N}$ //

b) at point B

$V_B = V_{B_1} + V_{B_2}$

$V_B = (9\times10^9\,Nm^2/c^2)\left(\frac{(5\times10^{-5}c)}{0.4m} + \frac{(-5\times10^{-5}c)}{0.4m}\right)$

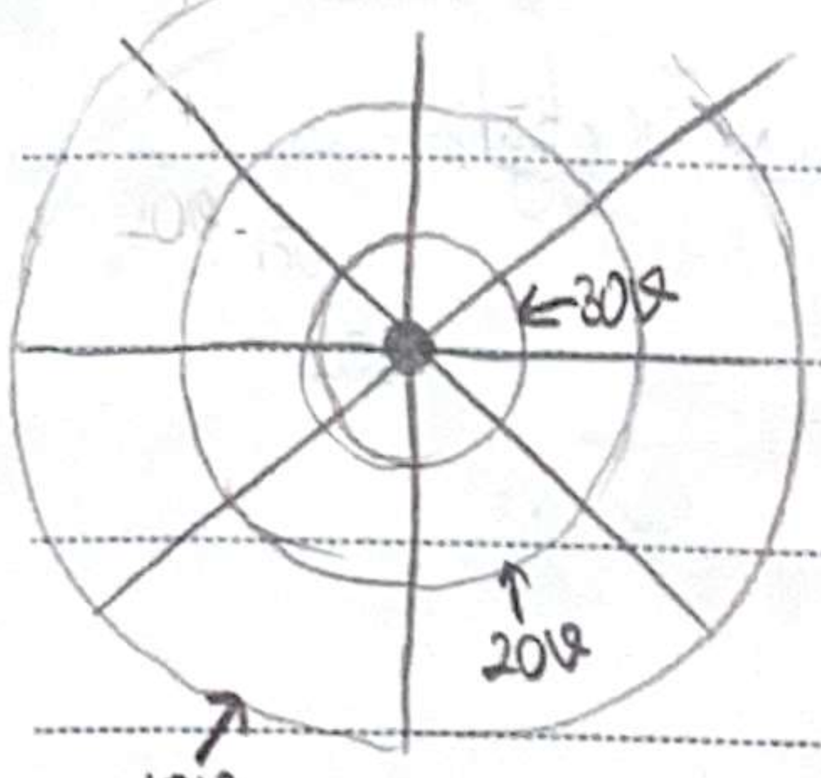
$\boxed{V_B = 0}$ //

the potential will be 0 everywhere on the plane

Express

$$V = \frac{1}{4\pi\varepsilon_0} \int \frac{dq}{r} \Rightarrow$$

ex 23.10 // For a single point charge with $Q = 4.0 \times 10^{-9} C$, sketch the equipotential surfaces (or lines in a plane containing the charge) corresponding to $V_1 = 10V$, $V_2 = 20V$ and $V_3 = 30V$



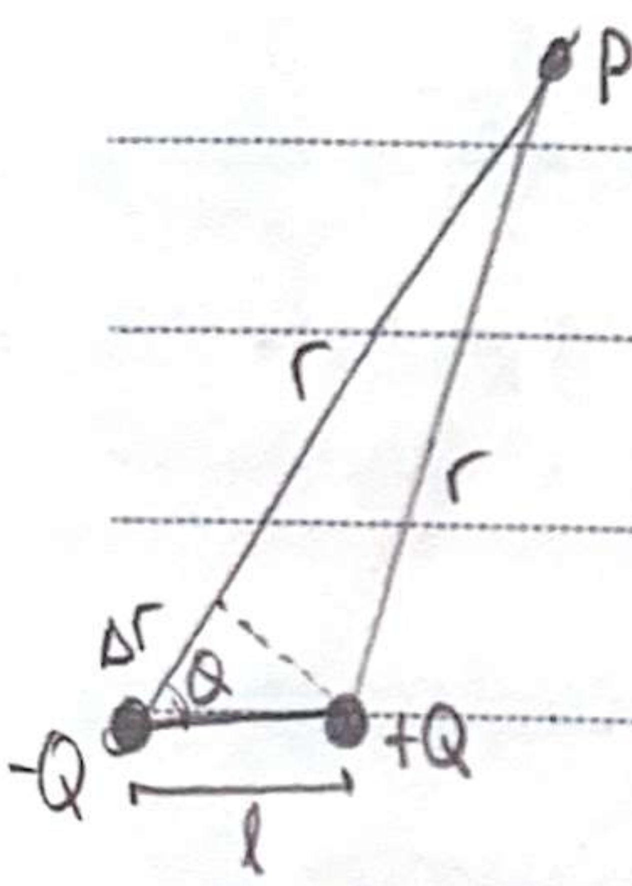
$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r} \Rightarrow r = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{V}$$

for $V_1 = 10V \rightarrow r_1 = \frac{(9.10^9 Nm^2/C^2)(4.10^{-9}C)}{10V} = \boxed{3.6M}$ //

for $V_2 = 20V \rightarrow r_2 = \frac{(9.10^9 Nm^2/C^2)(4 \times 10^{-9}C)}{20V} = \boxed{1.8M}$ //

sooo $V_3 = 30 \Rightarrow r_3 = \boxed{1.2M}$ //

electric dipole potential



$\Rightarrow$ the electric potential, point P due to a dipole ;

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-Q)}{(r + \Delta r)}$$

$$\hookrightarrow V = \frac{Q}{4\pi\varepsilon_0} \cdot \frac{\Delta r}{r.(\Delta r + r)}$$

$1eV = 1.6 \times 10^{-19} J$

$\Delta r \approx l . \cos\theta$

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P.\cos\theta}{r^2}$$

$P = Q.l$ } dipole moment

$$E_l = \frac{-dV}{dl}$$

$$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1 . Q_2}{r_{12}}$$

PROBLEM SOLUTIONS 1 ~ CHAPTER 21

Q12 -

Calculate the net force on each charge due to the other two?

$F_1 = \bullet \leftarrow\bullet \quad \bullet\rightarrow$

$\xleftarrow{147}$

$F_{12} = k.\frac{Q_1 Q_2}{r^2} = 8.988 \times 10^9 \frac{(75\times10^{-6})(48\times10^{-6})}{(0.35)^2} = 264\times10^{-3}$

$F_{13} = k.\frac{Q_1 Q_3}{r^2} = 8.988\times10^9 \frac{(75\times10^{-6})(85\times10^{-6})}{(0.7)^2} = 117\times10^{-3}$

$F_2 = \bullet\rightarrow \quad \bullet \quad \bullet\rightarrow$

$\xrightarrow{563}$

$F_{23} = k.\frac{Q_2 Q_3}{r^2} = 8.988\times10^9 \frac{(48\times10^{-6})(85\times10^{-6})}{(0.35)^2} = 299\times10^{-3}$

$F_{21} = 264\times10^{-3}$

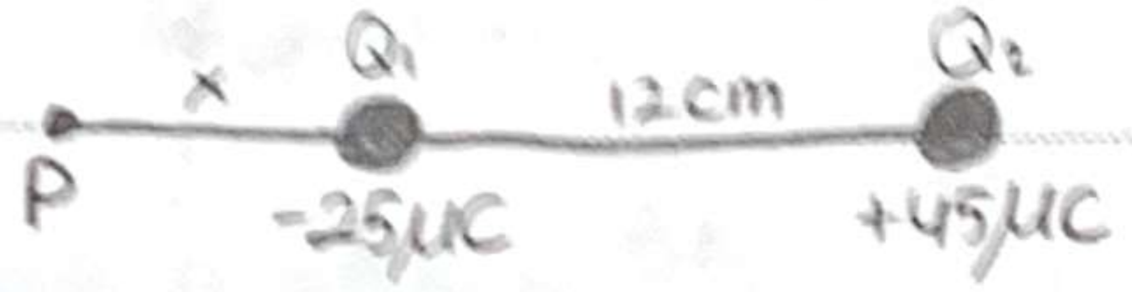
$F_3 = \leftarrow\bullet \quad \leftarrow\bullet \quad \bullet$

$F_{13} = 117\times10^{-3}$

$F_{23} = 299\times10^{-3}$

$\left.\right\}$ 417×10^{-3} $\longleftarrow$

Q36 -



electric field at the point is zero. x=?

$|\vec{E}_1| = |\vec{E}_2|$

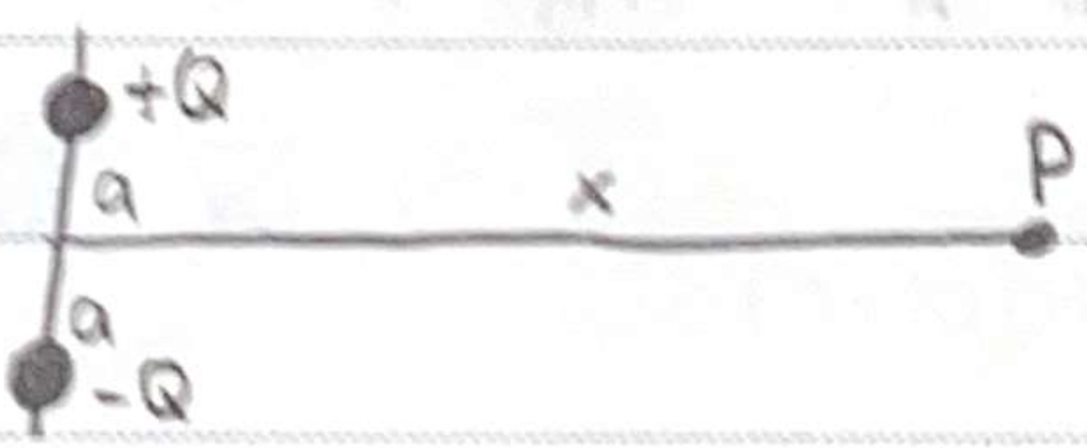
$\cancel{k}.\frac{|Q_1|}{x^2} = \cancel{k}.\frac{|Q_2|}{(x+12)^2} \Rightarrow \frac{\overset{5}{\cancel{25}}}{x^2} = \frac{\overset{9}{\cancel{45}}}{(x+12)^2}$

$9x^2 = 5x^2 + 120x + 720$

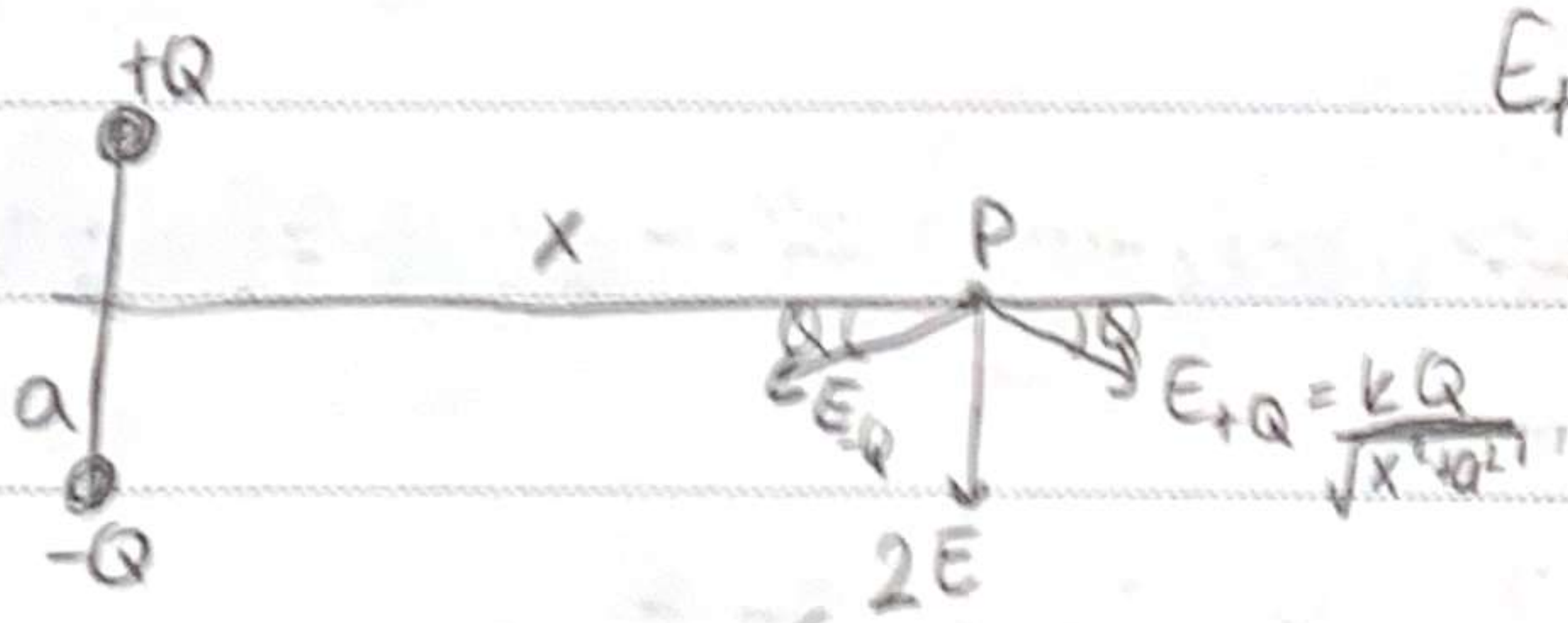
$x^2 - 30x - 180 = 0$

$\boxed{x = 35.128}$

Q48 -



determine the direction and magnitude of the electric field at the point P?



$E_{+Q} = E_{-Q} = k.\frac{Q}{\left((x^2+a^2)^{\frac{1}{2}}\right)^2}$

$2E_Q.\sin\theta = 2.k.\frac{Q}{(x^2+a^2)}.\sin\theta$

$E = E_{-q}.\sin\theta$

$2E = 2E_Q.\sin\theta$

$\sin\theta = \frac{a}{\sqrt{x^2+a^2}}$

$\frac{2kQa}{(x^2+a^2)^{3/2}}$

Record : / /

PROBLEM SOLUTIONS 21 ~ CHAPTER 23

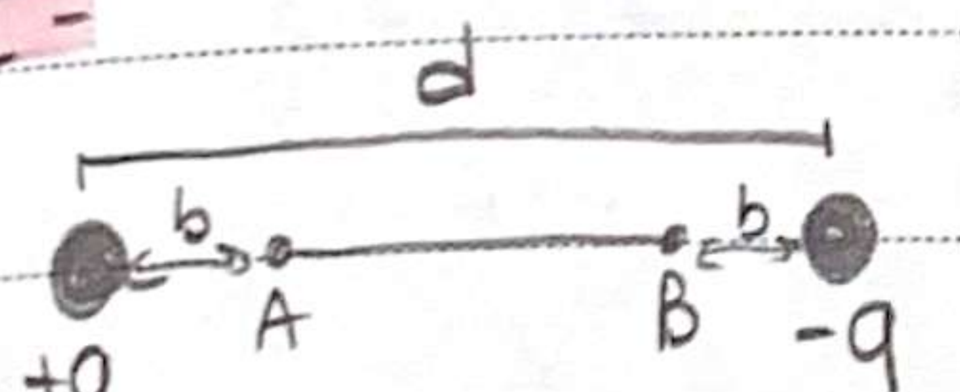
Q 10 - A manufacturer claims that a carpet will not generate more than 5.0 kV of static electricity. What magnitude of charge would have to be transferred between a carpet and a shoe for there to be a 5.0 kV potential difference between the shoe and the carpet. Approximate the shoe and the carpet as large sheets of charge separated by a distance $d = 1.0\,mm$

the area of a shoe = $30\,cm \times 8\,cm = 24 \times 10^{-3}\,m^2$

$\Rightarrow$ magnitude of electric field $\Rightarrow$ $E = \frac{V}{d} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$ $\quad \sigma = \frac{Q}{A}$

$$Q = \frac{\varepsilon_0 A V}{d} = \frac{(8.85 \times 10^{-12})(24 \times 10^{-3})(5.10^3)}{1.10^{-3}} = 1.062 \times 10^{-6}$$

Q 32 -



Determine a formula for $V_b - V_a = V_{ba}$

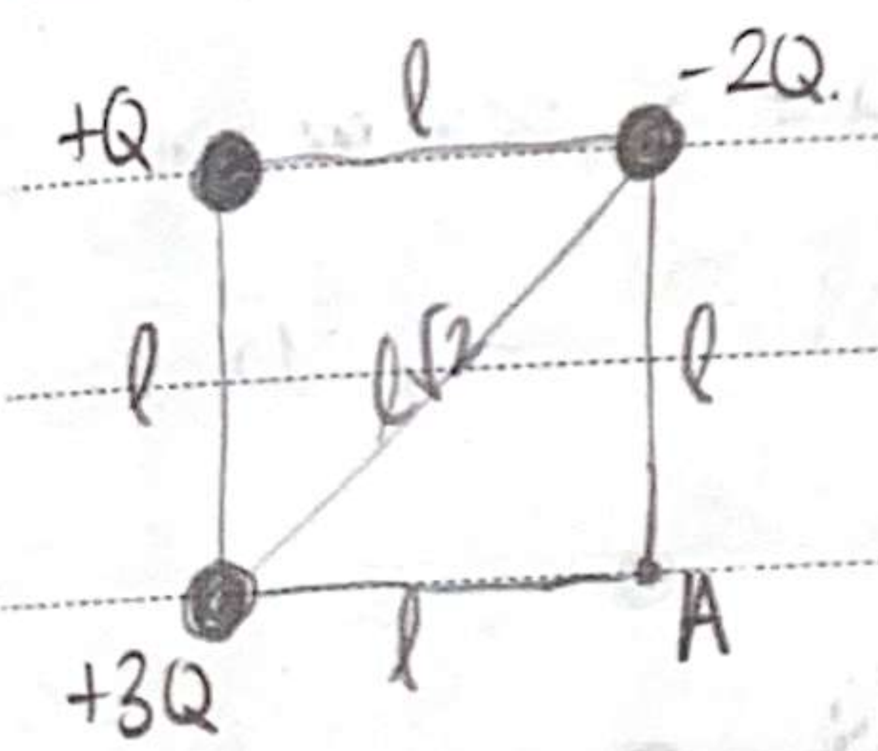
$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$$

$$V_b = \left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(d-b)} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-q)}{b}\right)$$

$$-V_a = -\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{b} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-q)}{(d-b)}\right)$$

$$V_{ba} = \frac{2q}{4\pi\varepsilon_0} \cdot \left(\frac{2b-d}{b.(d-b)}\right)$$

Q 34 -



What is the potential at point A, taking $V = 0$ at a great distance?

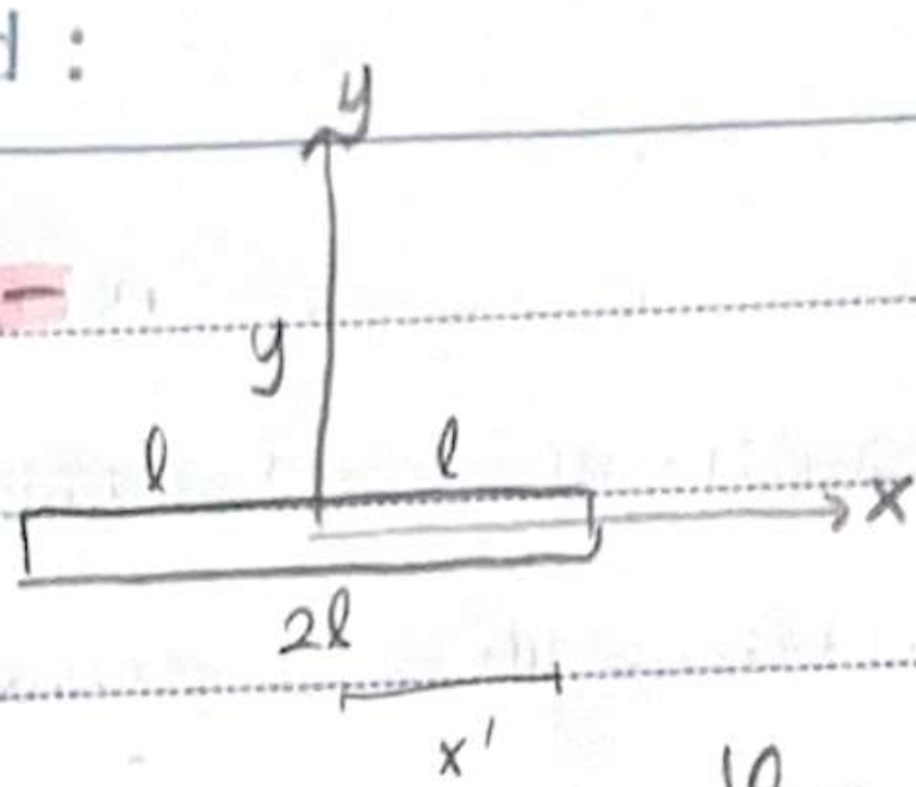
$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$$

at point A $\Rightarrow$ $V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3Q}{l} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{\sqrt{2}l} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{(-2Q)}{l}$

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{l}\left(1 + \frac{1}{\sqrt{2}}\right)$$

Express

Q 38 -



Determine the potential V as a function of y for points along the y axis. Let V=0 at infinity.

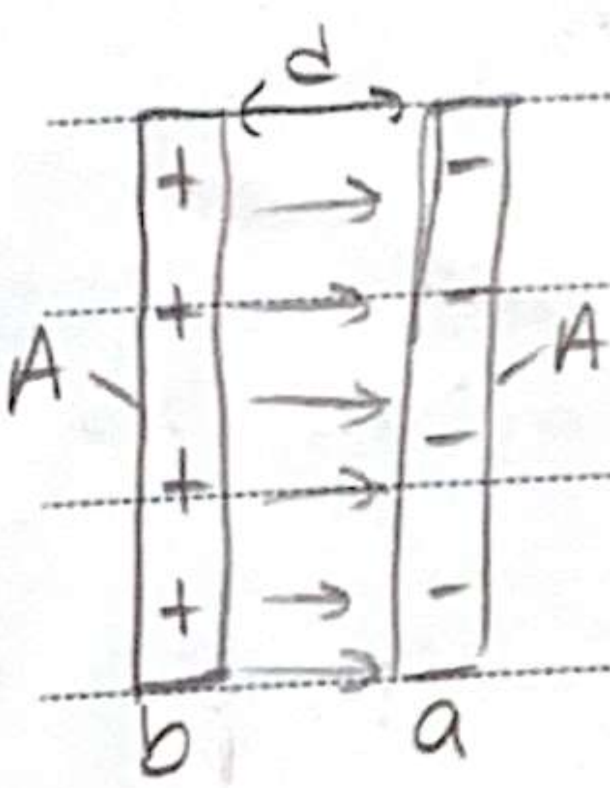
$$V = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}$$

The charge on the element is $dq = \frac{Q}{2l}dx'$

$$V_{yaxis} = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r} = \underbrace{\frac{1}{4\pi\varepsilon_0}\int_{-l}^{l}\frac{Q/2l\, dx'}{\sqrt{x'^2+y^2}}}_{\text{burası verilir}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{2l}\left[\ln\left(\sqrt{x'^2+y^2}+x'\right)\right]_{-l}^{+l}$$

CHAPTER 24 ~ Capacitance, Dielectrics, Electric Energy

direç ← capacitance = C



$$C = \frac{Q}{V} = \varepsilon_0\frac{A}{d}$$

$1F = 1\frac{C}{V}$

$E = \frac{V}{d}$

ex 24.1 a) Calculate the capacitance of a parallel-plate capacitor whose plates are 20 cm x 3.0 cm and are separated by a 1.0 mm air gap? $A = 6\times10^{-3}$, $C = \varepsilon_0\frac{A}{d} = (8.85\times10^{-12})\frac{6\times10^{-3}}{1\times10^{-3}} = \boxed{53pF}$

b) What is the charge on each plate if a 12-V battery is connected across the two plates? $Q = C.V = 53\times10^{-12}.12 = \boxed{6.4\times10^{-10}}$

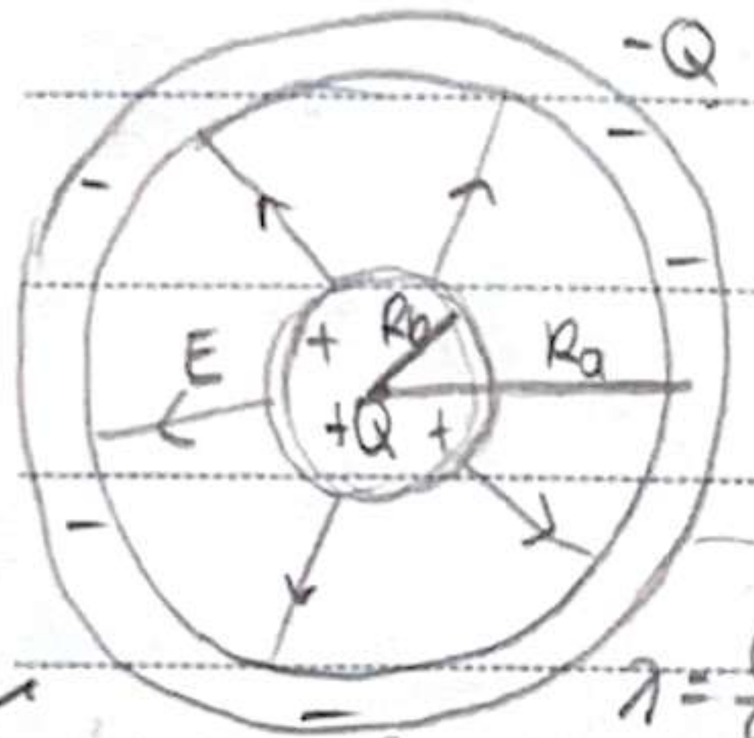
c) Electric field between the plates? $E = \frac{V}{d} = \frac{12}{1\times10^{-3}} = \boxed{1.2\times10^{4}}$

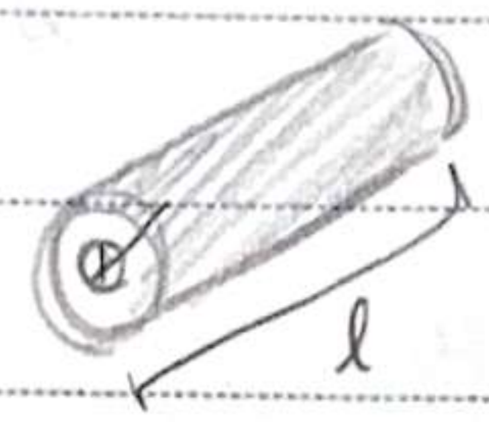
d) Estimate the area of the plates needed to achieve a capacitance of 1 F, given the same air gap d?

$$C = \varepsilon_0.\frac{A}{d} \rightarrow A = \frac{Cd}{\varepsilon_0} \approx \frac{(1F)(1\times10^{-3})}{(9\times10^{-12})} = \boxed{10^8 m^2}$$

$C = \frac{3\times10^{-8}}{3,4}$ $\quad V = \frac{Q}{C}$ $\quad$ / /

ex 24.2 // A cylindrical capacitor consists of a cylinder (or wire) of radius R_b, surrounded by a coaxial cylindrical shell of inner radius R_a. Both cylinders have length ℓ. Determine a formula for the capacitance.





$$V = V_b - V_a = -\int_a^b \vec{E}\,d\vec{\ell} = \frac{-Q}{2\pi\varepsilon_0 \ell} \cdot \int_{R_a}^{R_b} \frac{dr}{r} \qquad \lambda = \frac{Q}{\ell}$$

$$= -\frac{Q}{2\pi\varepsilon_0 \ell} \ln\frac{R_b}{R_a} = \frac{Q}{2\pi\varepsilon_0 \ell} \ln\frac{R_a}{R_b} = V$$

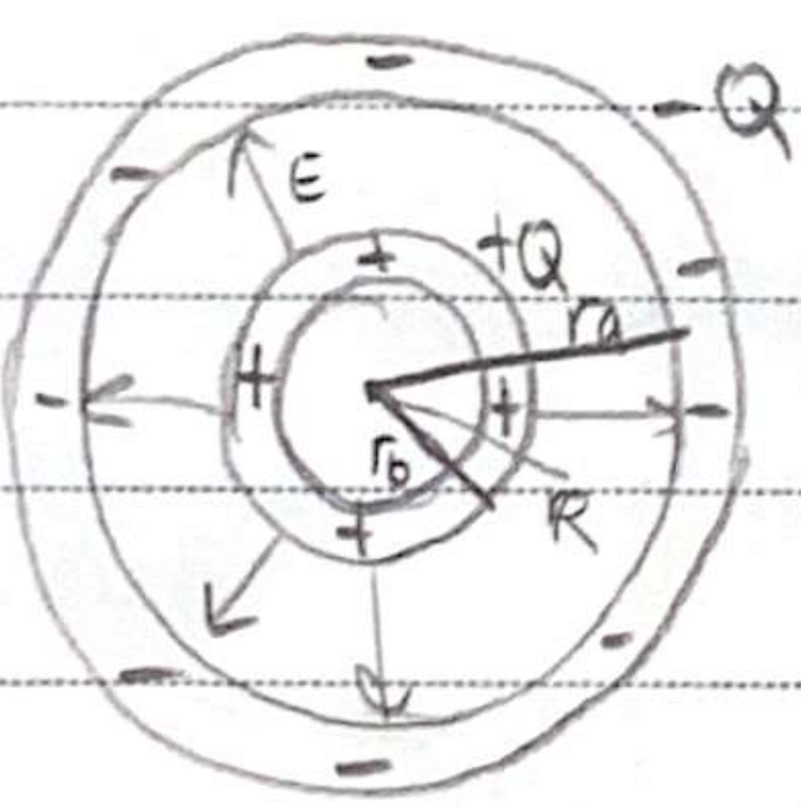
NOT

$$\oint E\,dA = \frac{Q_{encl}}{\varepsilon_0} \qquad \lambda = \frac{Q}{\ell}$$

$$E \cdot 2\pi r\ell = \frac{\lambda \cdot \ell}{\varepsilon_0} \rightarrow E = \frac{1}{2\pi\varepsilon_0} \cdot \frac{\lambda}{r}$$

$$C = \frac{Q}{V} = \boxed{\frac{2\pi\varepsilon_0 \ell}{\ln(R_a/R_b)}}$$

ex 24.3 // A spherical capacitor consists of two thin concentric spherical conducting shells of radius r_a and r_b as shown. The inner shell carries a uniformly distributed charge Q on its surface. Determine the capacitance of the two shells.



$$\oint E\,dA = \frac{Q_{encl}}{\varepsilon_0} \Rightarrow E \cdot 4\pi R^2 = \frac{Q}{\varepsilon_0} \Rightarrow E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R^2}$$

$$V = -\int_b^a \vec{E}\,d\vec{\ell} = -\int_{r_b}^{r_a} \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R^2} \cdot dR = \frac{-Q}{4\pi\varepsilon_0} \int_{r_b}^{r_a} \frac{dR}{R^2}$$

$$V = \frac{-Q}{4\pi\varepsilon_0} \cdot \left(-\frac{1}{R}\right)\Bigg|_{R_B}^{R_A} = \frac{Q}{4\pi\varepsilon_0} \cdot \left(\frac{1}{R_B} - \frac{1}{R_A}\right) = V$$

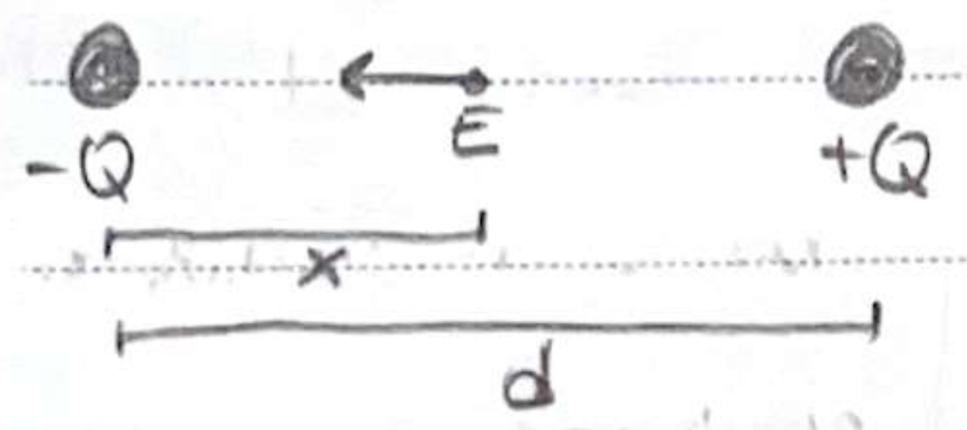
→ pozitif olsun diye işaret değişti

$$C = \frac{Q}{V} = \frac{\cancel{Q}}{\frac{\cancel{Q}}{4\pi\varepsilon_0}\left(\frac{1}{R_b} - \frac{1}{R_A}\right)} = \frac{4\pi\varepsilon_0}{\frac{1}{R_b} - \frac{1}{R_A}} = \boxed{4\pi\varepsilon_0 \left(\frac{R_a R_b}{R_a - R_b}\right)}$$

ex 24.4

$\to \frac{C}{\ell}$

Estimate the capacitance per unit length of two very long straight parallel wires, each of radius R, carrying uniform charges -Q and +Q $(d >> R)$ $V \to E \to Q$



$$C = \frac{Q}{V} \qquad E = \frac{1}{2\pi\varepsilon_0}\left(\frac{\overbrace{Q/\ell}^{\lambda}}{x} + \frac{\overbrace{Q/\ell}^{\lambda}}{d-x}\right) \Rightarrow$$

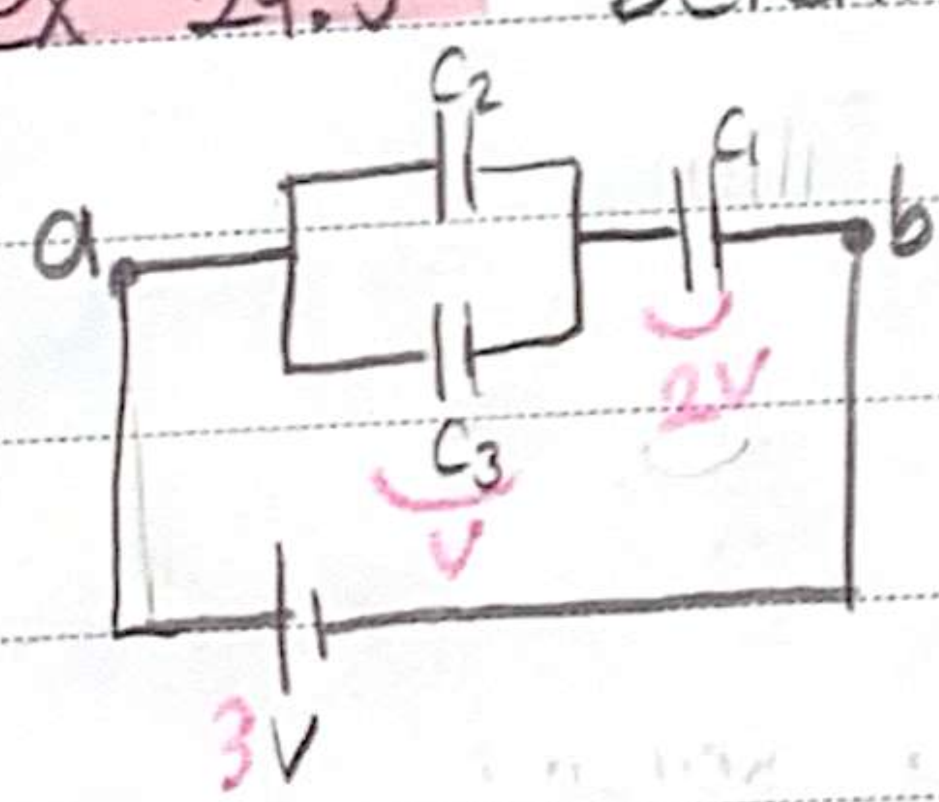
$$V = V_b - V_a = -\int_a^b E\,d\ell = \left(\frac{-Q}{2\pi\varepsilon_0 \ell}\right)\int_R^{d-R}\left(\frac{1}{x} + \frac{1}{d-x}\right)dx = \frac{-Q}{2\pi\varepsilon_0\ell}\left[\ln x - \ln(d-x)\right]\Big|_R^{d-R}$$

$$= -\frac{Q}{2\pi\varepsilon_0\ell}\left[\ln(d-R) - \ln R - \ln R + \ln(d-R)\right] = \frac{Q}{\pi\varepsilon_0\ell}\left(\ln(d-R) - \ln R\right)$$

$$V \approx \frac{Q}{\pi\varepsilon_0\ell}\left(\ln d - \ln R\right)$$

$$\frac{C}{\ell} = \frac{Q}{V.\ell} = \frac{\cancel{Q} \cdot \pi\varepsilon_0\cancel{\ell}}{\cancel{Q}(\ln d - \ln R)\cancel{\ell}} = \boxed{\frac{\varepsilon_0 \pi}{\ln\left(\frac{d}{R}\right)}}$$

ex 24.5 Determine the capacitance of a single capacitor that will have the same effect as the combination shown.



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

$$C_{23} = C_2 + C_3 = 2C$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{23}} = \frac{1}{C} + \frac{1}{2C} = \frac{3}{2C}$$

$$C_{eq} = 2/3\,C$$

ex 24.6 // assume $C = 3.0\mu F$ and $V = 4.0V$

$$C_{eq} = \frac{2C}{3} = \frac{2}{3}\cdot(3.0) \Rightarrow C_{eq} = 2.0\mu F$$

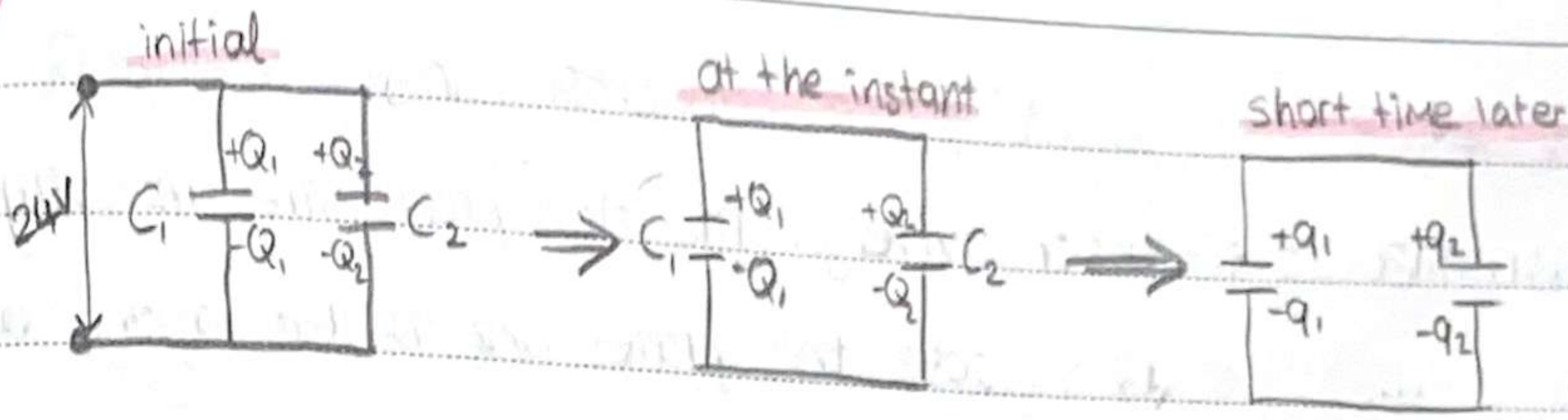
$$Q = CV = (2.0\mu F)\cdot(4.0V) = 8.0\mu C$$

$$V_1 = \frac{Q_1}{C_1} = \frac{8}{3} = 2.7V$$

$$V_2 = \frac{Q_2}{C_2} = \frac{4}{3} = 1.3V$$

$$V_3 = \frac{Q_3}{C_3} = \frac{4}{3} = 1.3V$$

ex 24.7 //



Two capacitors, $C_1 = 2.2\,\mu F$ and $C_2 = 1.2\,\mu F$ are connected in parallel to a 24 V source. After they are charged they disconnected and then reconnected to each other. Find the charge on each capacitor and the potential across each after equilibrium is established.

$Q_1 = C_1 . V = (2.2\,\mu F)(24V) = 52.8\,\mu C \Rightarrow q_1 = C_1 V'$

$Q_2 = C_2 . V = (1.2\,\mu F)(24V) = 28.8\,\mu C \qquad q_2 = C_2 V'$

potansiyel fark eşitlenir, nötrlenir yani $\Longleftrightarrow q_1 + q_2 = Q_1 - Q_2 = 24.0\,\mu C$

$V' = \frac{Q}{C} = \frac{(q_1+q_2)}{(C_1+C_2)} = \frac{24\,\mu C}{3.4\,\mu F} = 7.06\,V$ $\qquad q_1 = C_1 V' = (2.2)(7.06) = 16\,\mu C$

$q_2 = C_2 V' = (1.2)(7.06) = 8.5\,\mu C$

$$U = \frac{QV}{2} = \frac{CV^2}{2} = \frac{Q^2}{2C}$$

ex 24.8 // A camera flash unit stores energy in a $150\,\mu F$ capacitor at 200 V a) How much electric energy can be stored?

$\Rightarrow U = \frac{1}{2} C V^2 = \frac{1}{2} . (150 \times 10^{-6}\,F)(200\,V)^2 = 3.0\,J$

b) What is the power output if nearly all this energy is released in 1.0 ms?

$1.0\,ms = \frac{1}{1000}$ of a second

$P = \frac{U}{t} = \frac{(3.0\,J)}{(1 \times 10^{-3}\,s)} = \boxed{3000\,W}$