VISUAL PHYSICS

SHORT NOTES

CHAPTER

Conductors

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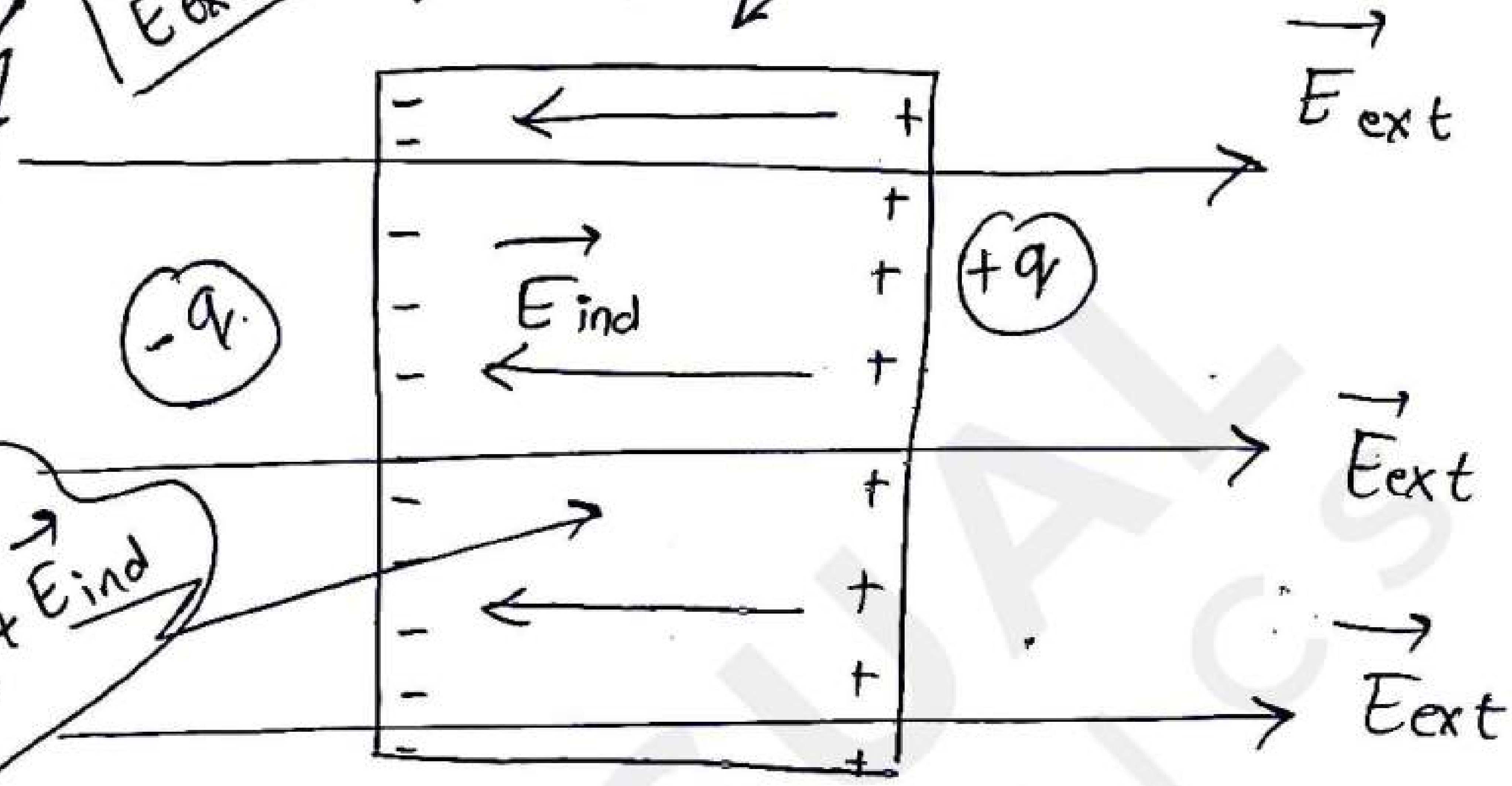
CONDUCTORS

$\vec{E}_{net} = 0$ distribution is such $\vec{E}_{ext} = -\vec{E}_{ind}$ due to free electron

conductor



$\vec{E}_{net} = \vec{E}_{ext} + \vec{E}_{ind}$

free electrons because of for any shape charge distribute in conductor, such that $\vec{E}_{net} = 0$

conductors have free electrons

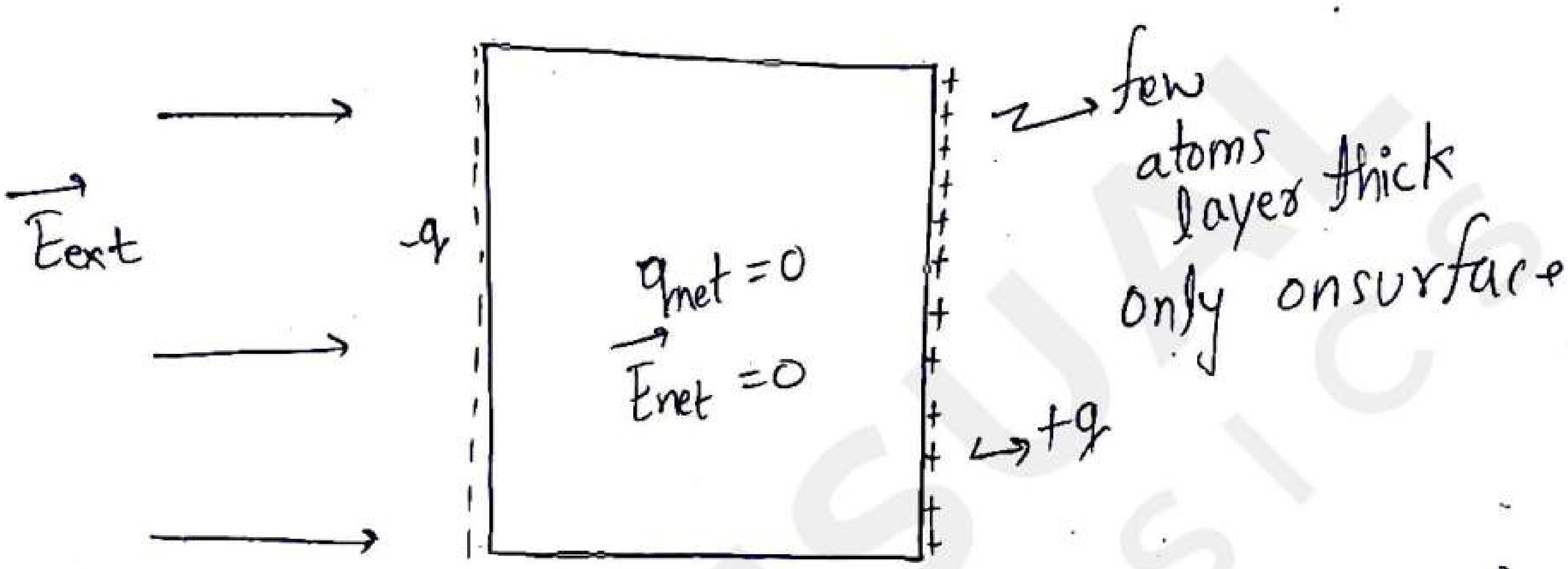
As charge is distributed, so $|-q_1| = |q_1|$ as net charge on conductor $= 0$

distribution, may or may not be uniform

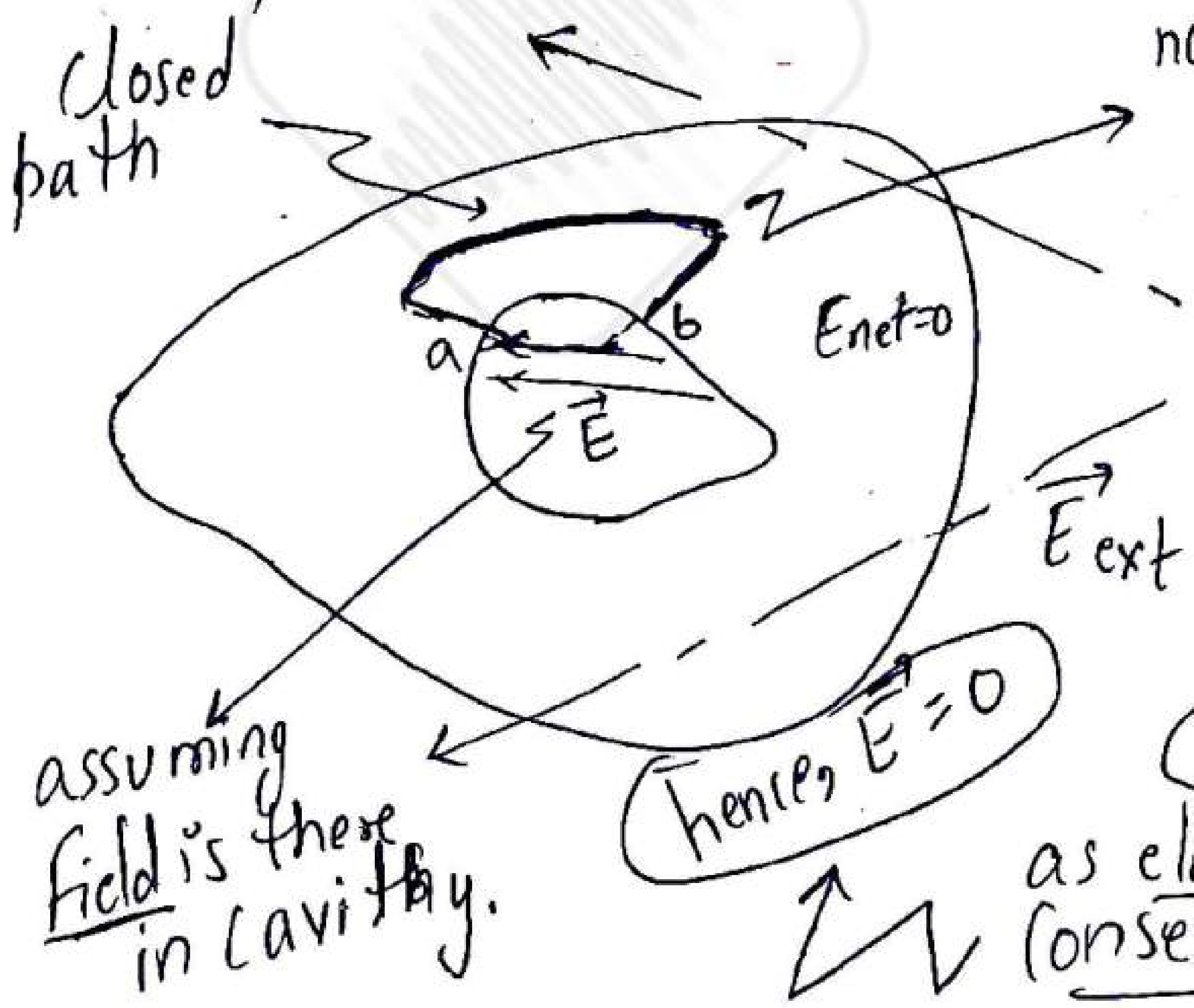
★ Field inside the conductor in electrostatic must be zero.

Induce charge will always be on the surface so that q_{net} inside $=0$, hence $\vec{E}_{net}=0$

as $\boxed{|\vec{E}_{net}| = \dfrac{q_{net}}{A\,\epsilon_0}}$



charge will distribute such that, $\vec{E}_{net}=0$ inside the conductor. And that distribution may or may not be Uniform.



now, as field is there from $a \to b$, so $W_{a\to b} \neq 0$

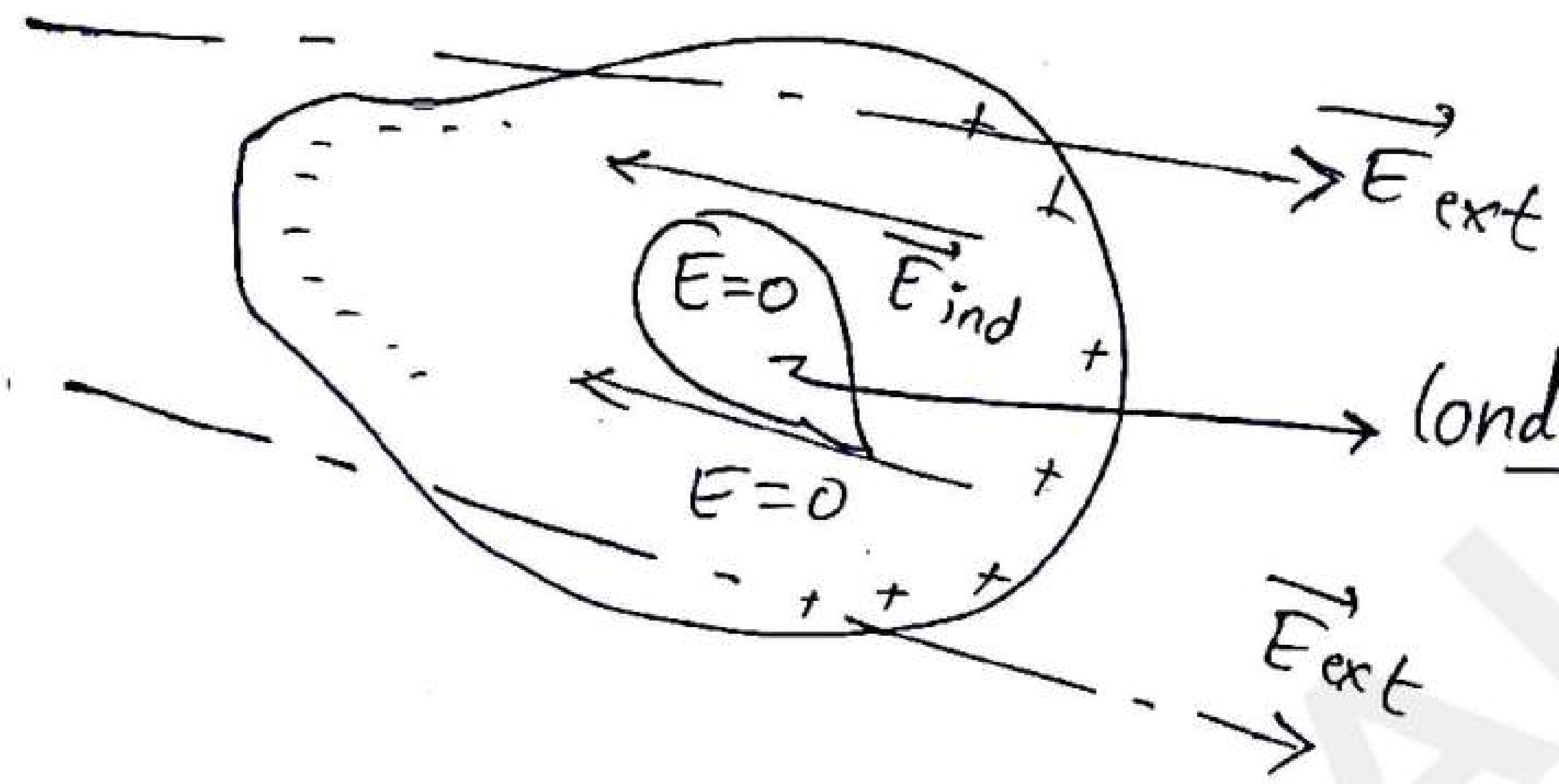
from $b \to a$, $W=0$ as no field inside conductor

so, $\oint W \neq 0$

not possible

as electrostatic field is conservative

Hence, $\vec{E} = 0$ inside cavity of conductor

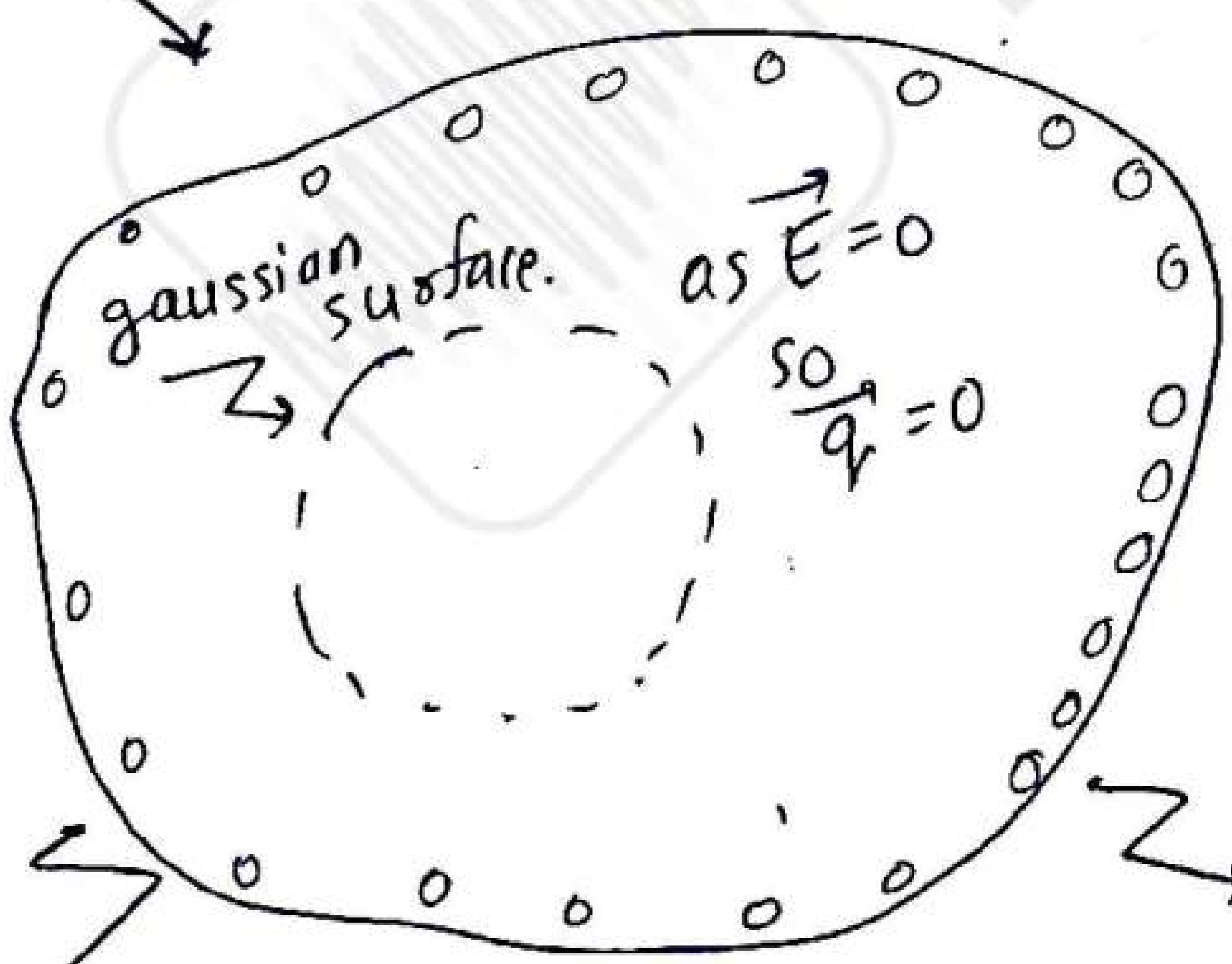


conductor shields → Electrostatic shielding

★ Field inside an empty cavity $=0$.

So inside a metal cage, in case of lighting as car.

placed on conductor

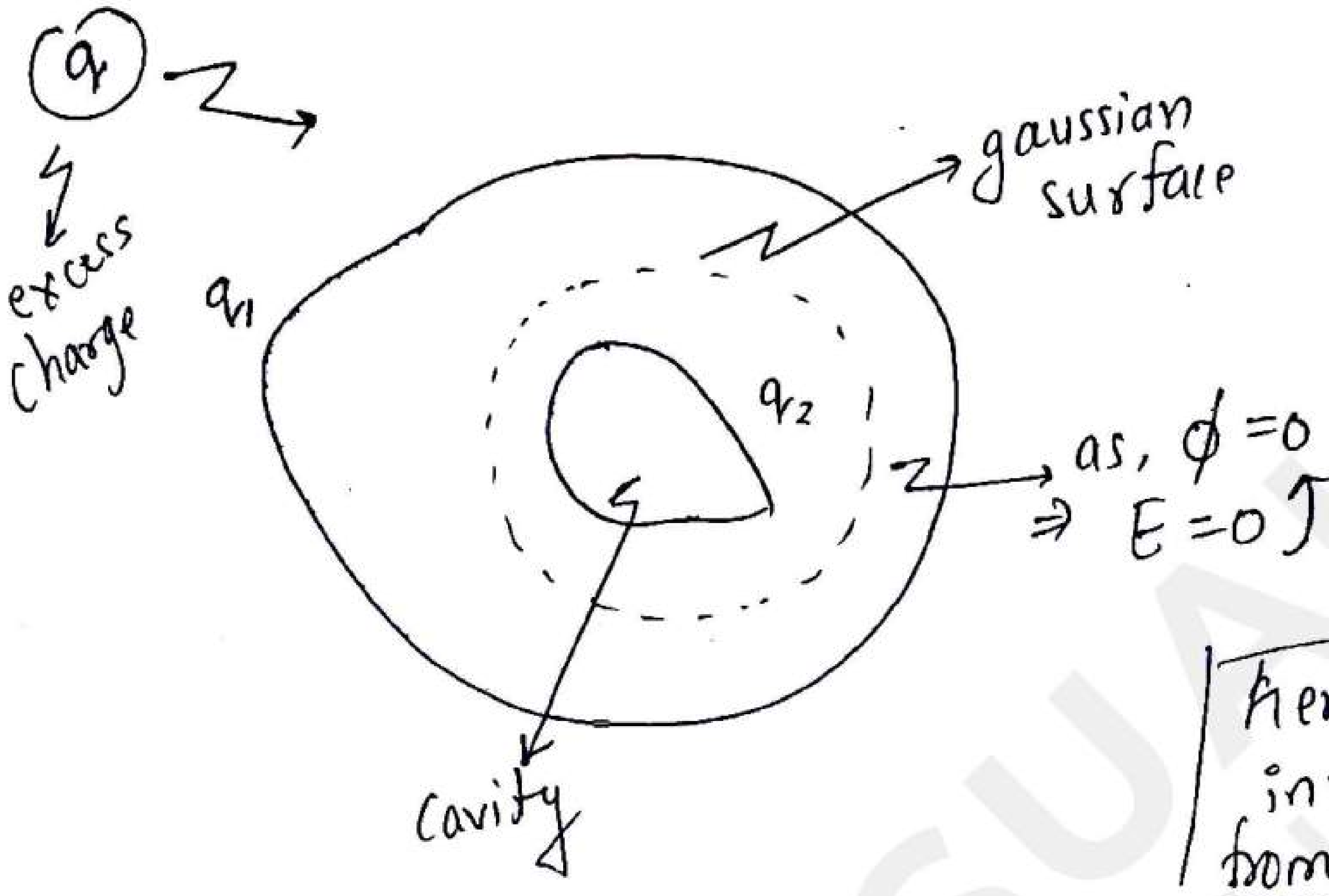


→ charge distribute such that $\boxed{\vec{E}_{inside} = 0}$

→ may or may not be uniform

always distribute on surface.

if there is cavity ?



as, $\phi = 0 \Rightarrow \boxed{q_{net} = 0}$

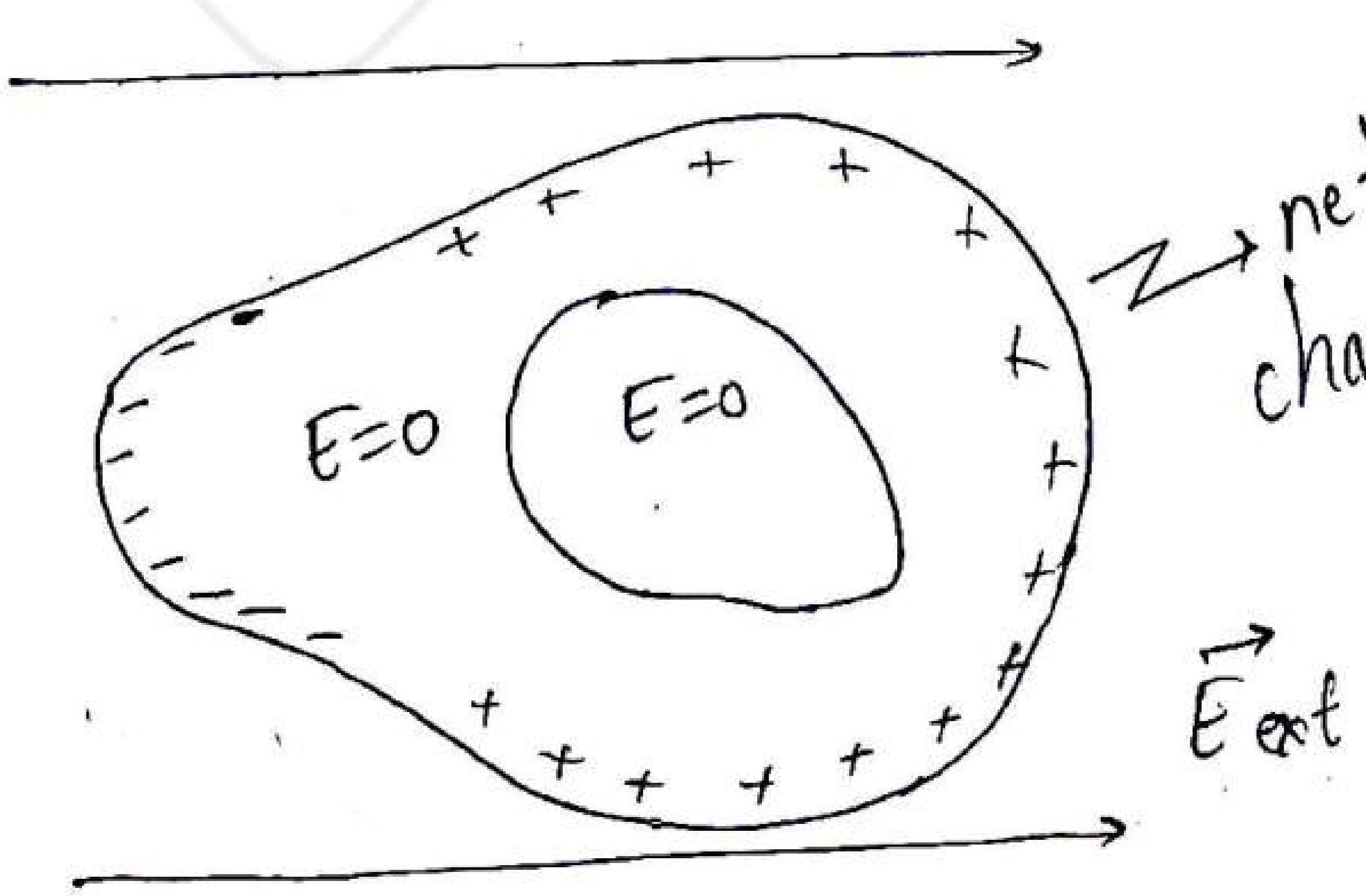
$\Rightarrow E = 0$

Hence no charge inside the cavity from excess charge

★ (i) Cannot be field inside the cavity
(ii) Net charge inside the cavity

⟷ from the excess charge given over the conductor

If a charged conductor placed inside the field:



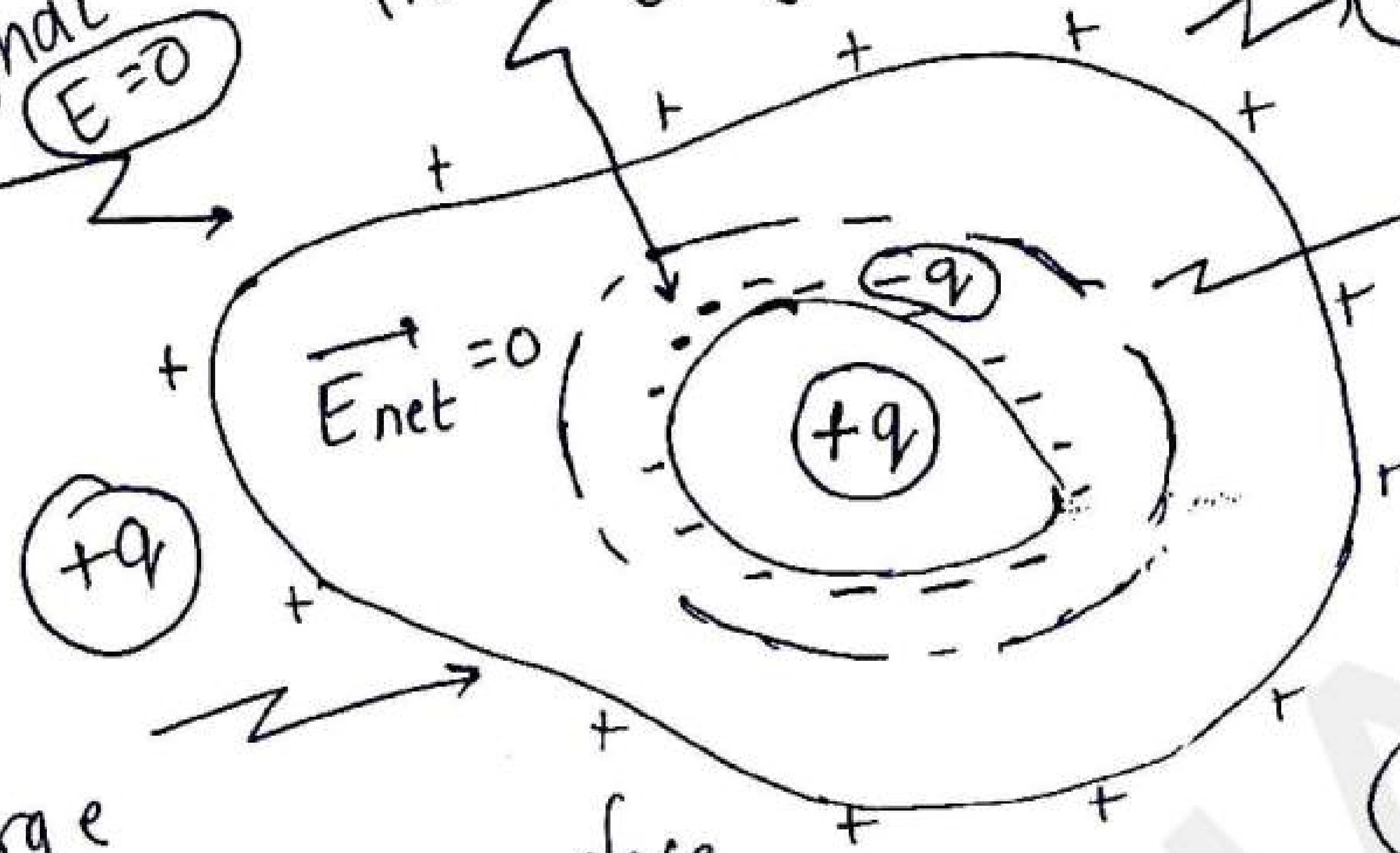
net charge +q
charge distribute such that, $\vec{E}_{net} = 0$

Charge Inside the Cavity

distribute such that $E=0$

Induced charge

charge distribution independent of inside charge cavity



gaussian surface

$\phi=0$ as $\vec{E}=0$

$\Rightarrow q_{net}=0$

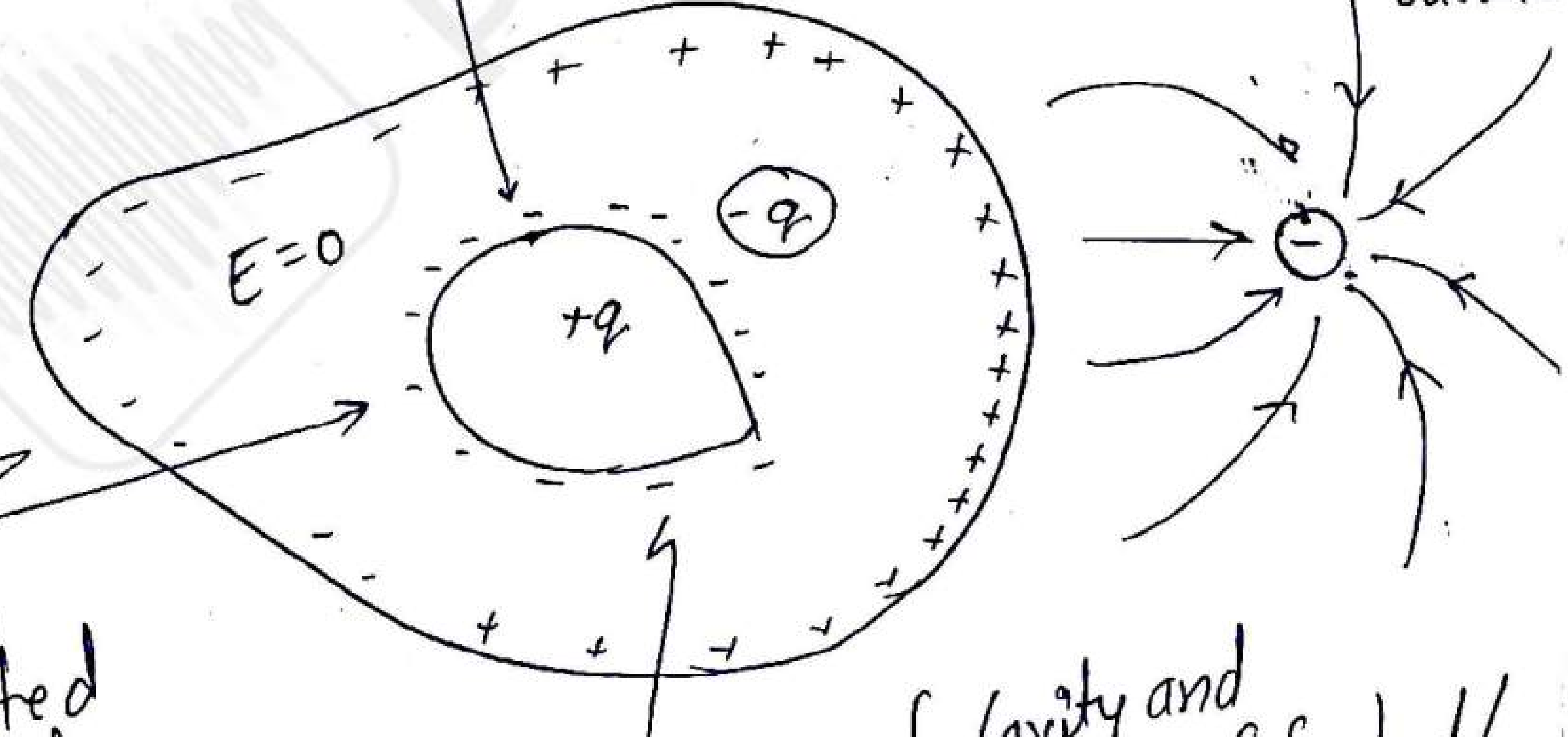
means, equal & opposite charge must Induce over surface.

charge will come over the surface of conductor, due to Induce charge over the cavite

Inside charge distribution effected only by charge inside cavity

Now,

External field can only change charge distribution over surface

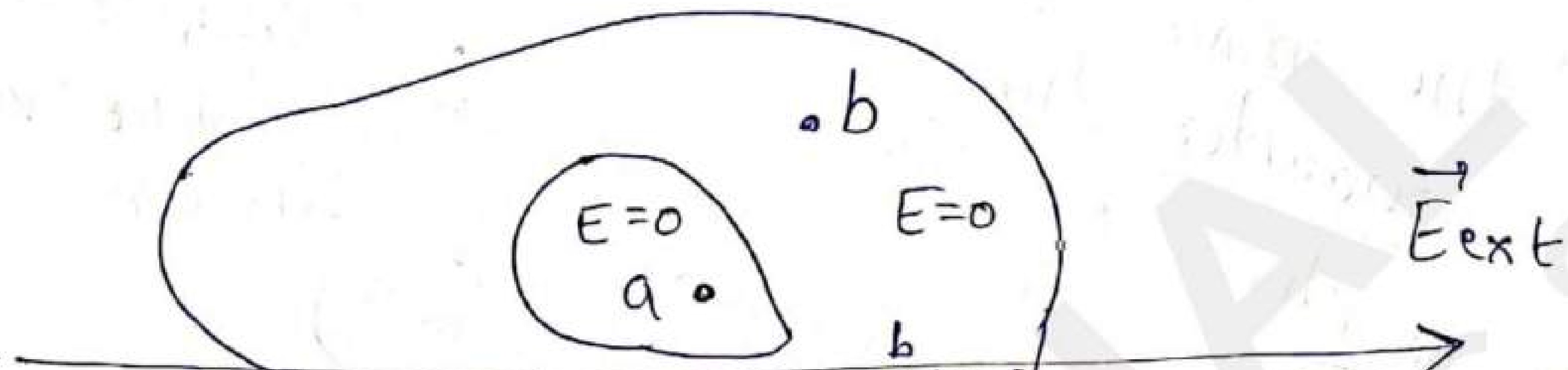


* Inside charge distribution is uneffected by external field presence

system of cavity and charge is unaware/uneffected by external field.

Potential of Conductor :

$\longrightarrow \vec{E}_{ext}$



$$\Delta V = -\int_a^b \vec{E}\cdot\vec{dl} = 0 \text{ as } , E=0$$

$$\Rightarrow \boxed{\Delta V = 0}$$

between a & b, no potential difference.

potential at every point inside a conductor is same, even inside empty cavity.

$V \neq 0 \rightarrow V = \text{Constant}$

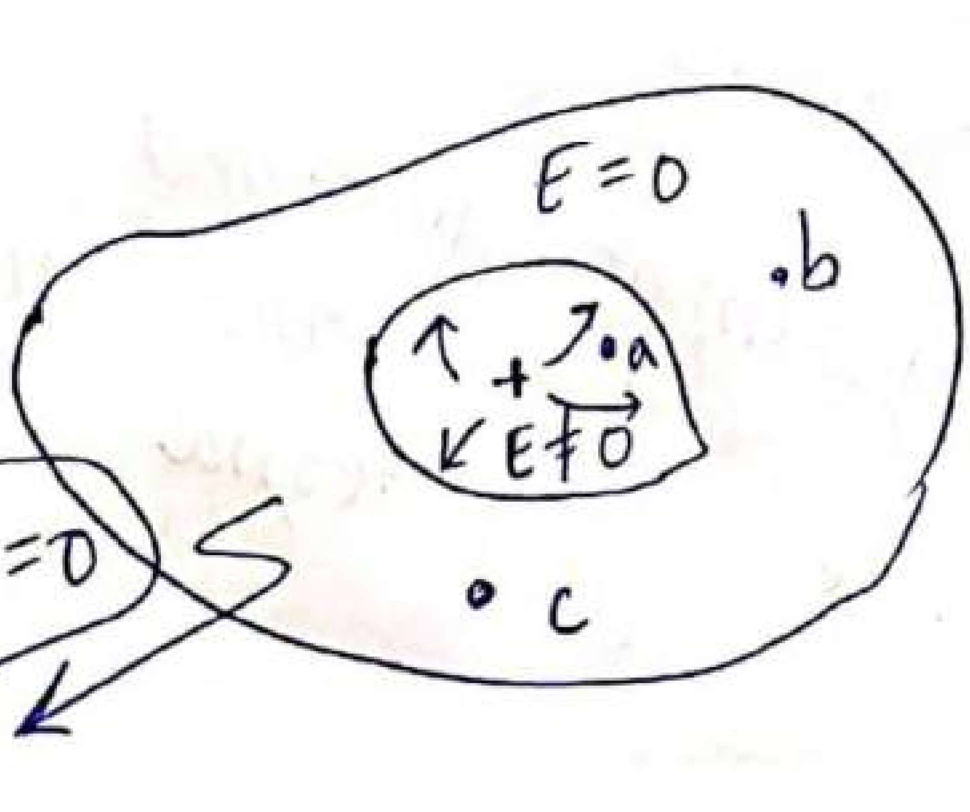
potential is not zero, potential difference is zero

if charge Inside Cavity?

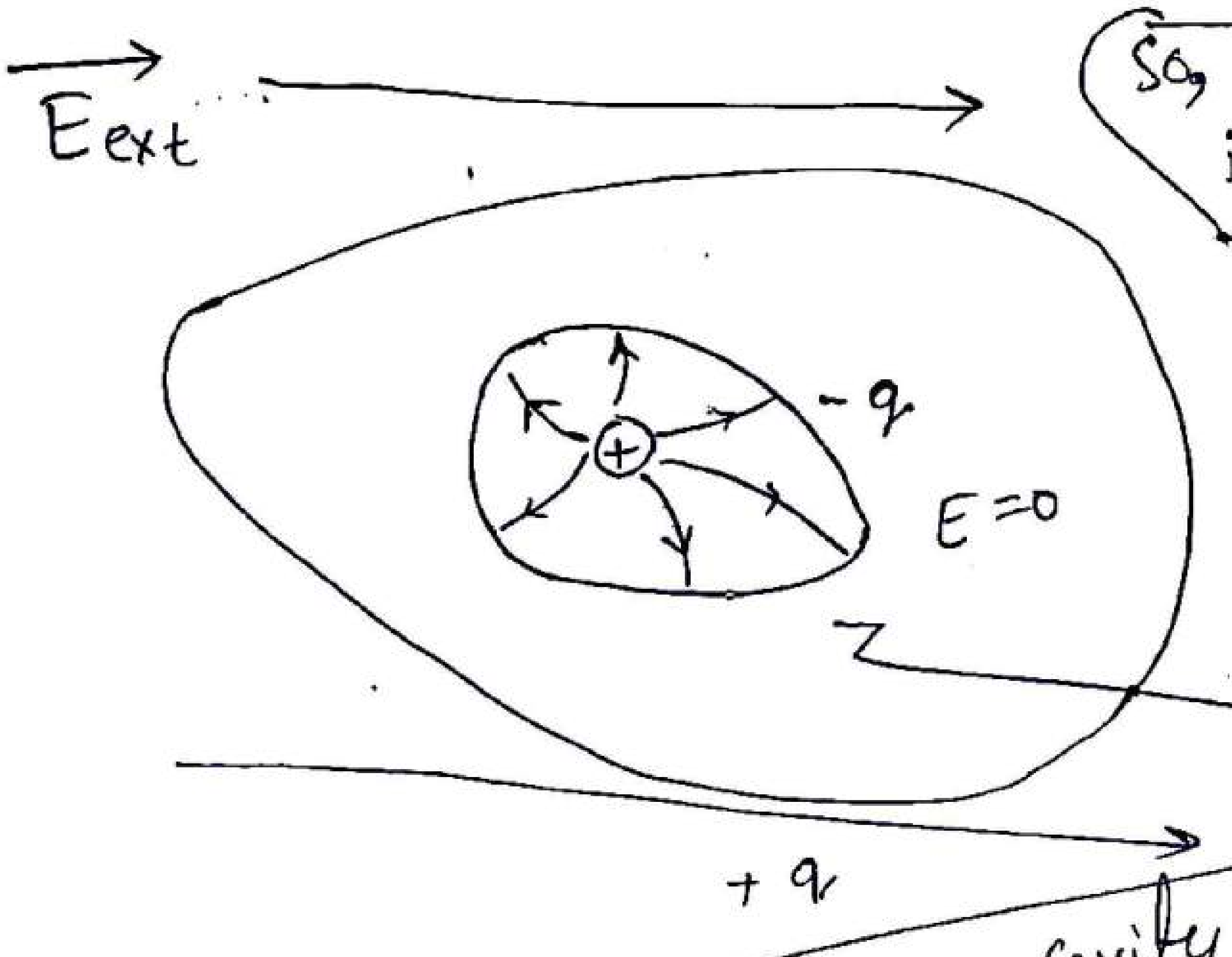
$V_a \neq V_b \Rightarrow V_a - V_b \neq 0$

as $E \neq 0$ inside cavity

but, throughout the body of conductor potential is same.



$V_b - V_c = 0$



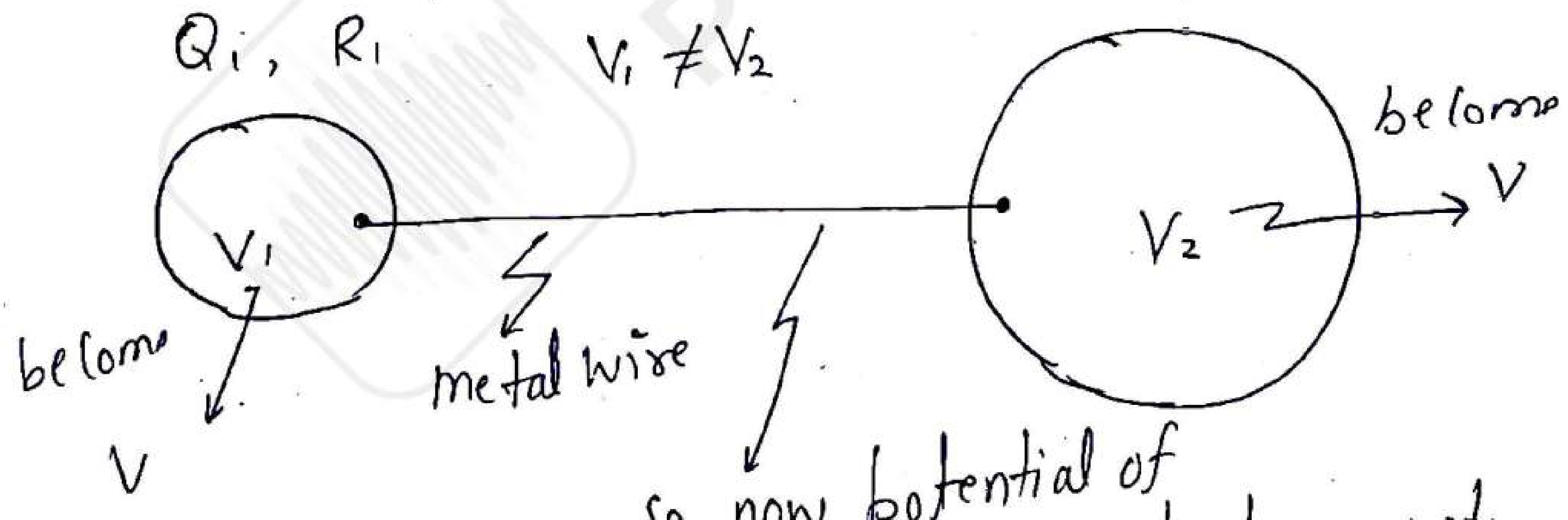
So, the potential change is only by external field and the charge on surface of conductor

for cavity and charge system net $E=0$, outside the cavity

hence, charge & cavity system do not effecet potential distribution.

Earthing:

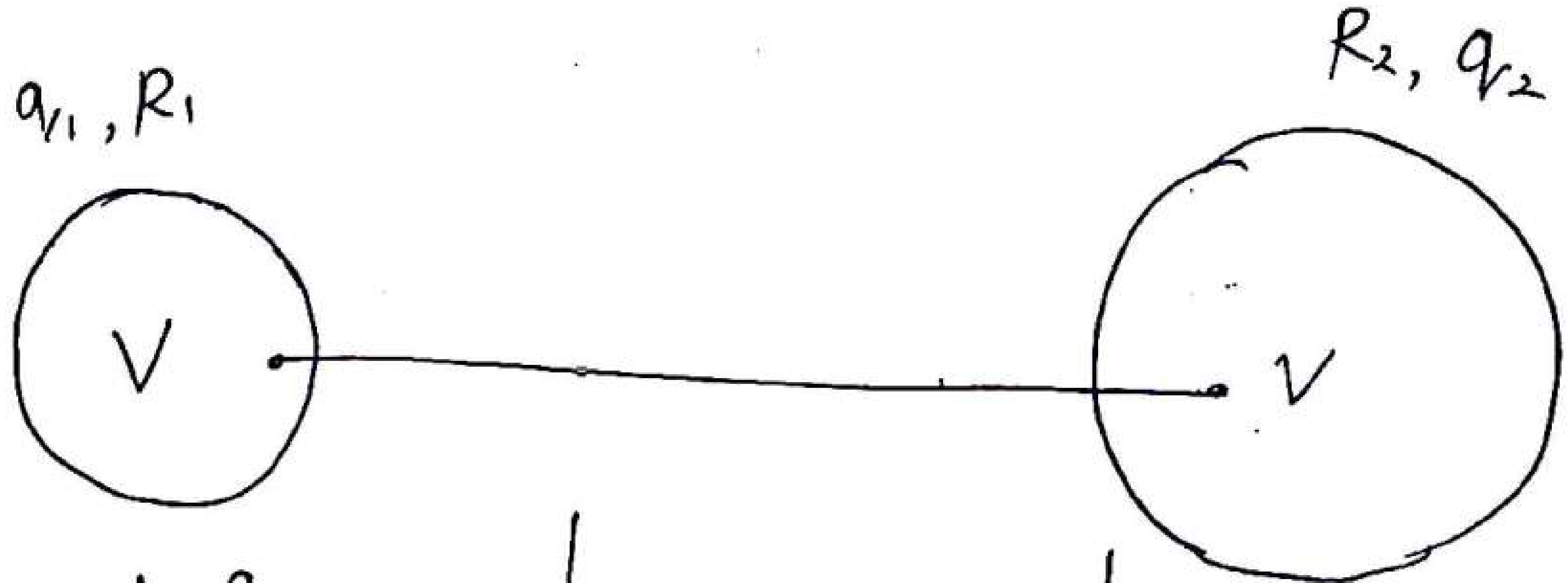
As potential inside the conductor = potential on the conductor



so now potential of both the conductors must be same.

Hence must be charge transfer.

so, $Q_1 \rightarrow q_1$ $\quad Q_2 \rightarrow q_2$



$V = \frac{kq_1}{R_1}$ $\quad \left| \frac{kq_1}{R_1} = \frac{kq_2}{R_2} \right|$ $\quad V = \frac{kq_2}{R_2}$

if $R_2 \rightarrow \infty$ $\Rightarrow$ $\frac{kq_2}{R_2}$ belome zero

so that means, $\frac{kq_1}{R_1} \rightarrow 0$

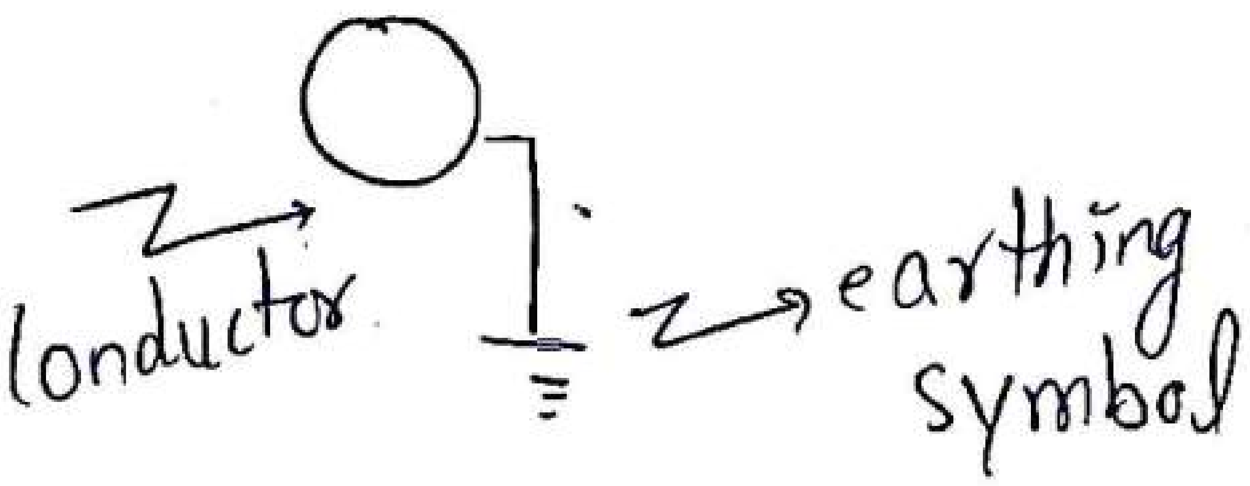
only possible when $q_1 \xrightarrow{\text{tends}} 0$

same case with when we connect with earth

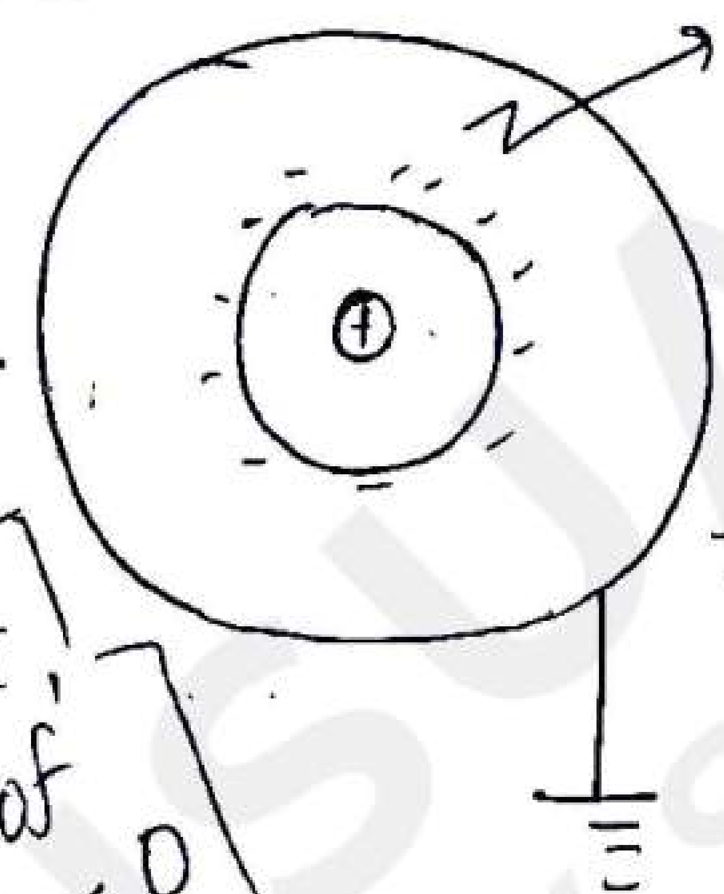
$R_2 \rightarrow \infty$, $V \rightarrow 0$, but $q \rightarrow$ high for earth

but $V = \frac{kq}{R_2} \rightarrow 0$ (Not exactly zero)

so, When we connect a conductor to earth $V \rightarrow 0$, $\Rightarrow q_1 \rightarrow 0$, all charge of conductor Flows into earth.



so, for the case



but still net charge $\neq 0$

charge of surface flows Into earth

Key point of earthing is that Net ~~cha~~ potential of conductor surface $= 0$

net charge may or may not be zero. Depending on condition.

$\vec{E}$-field outside the Conductor:

At surface of conductor,

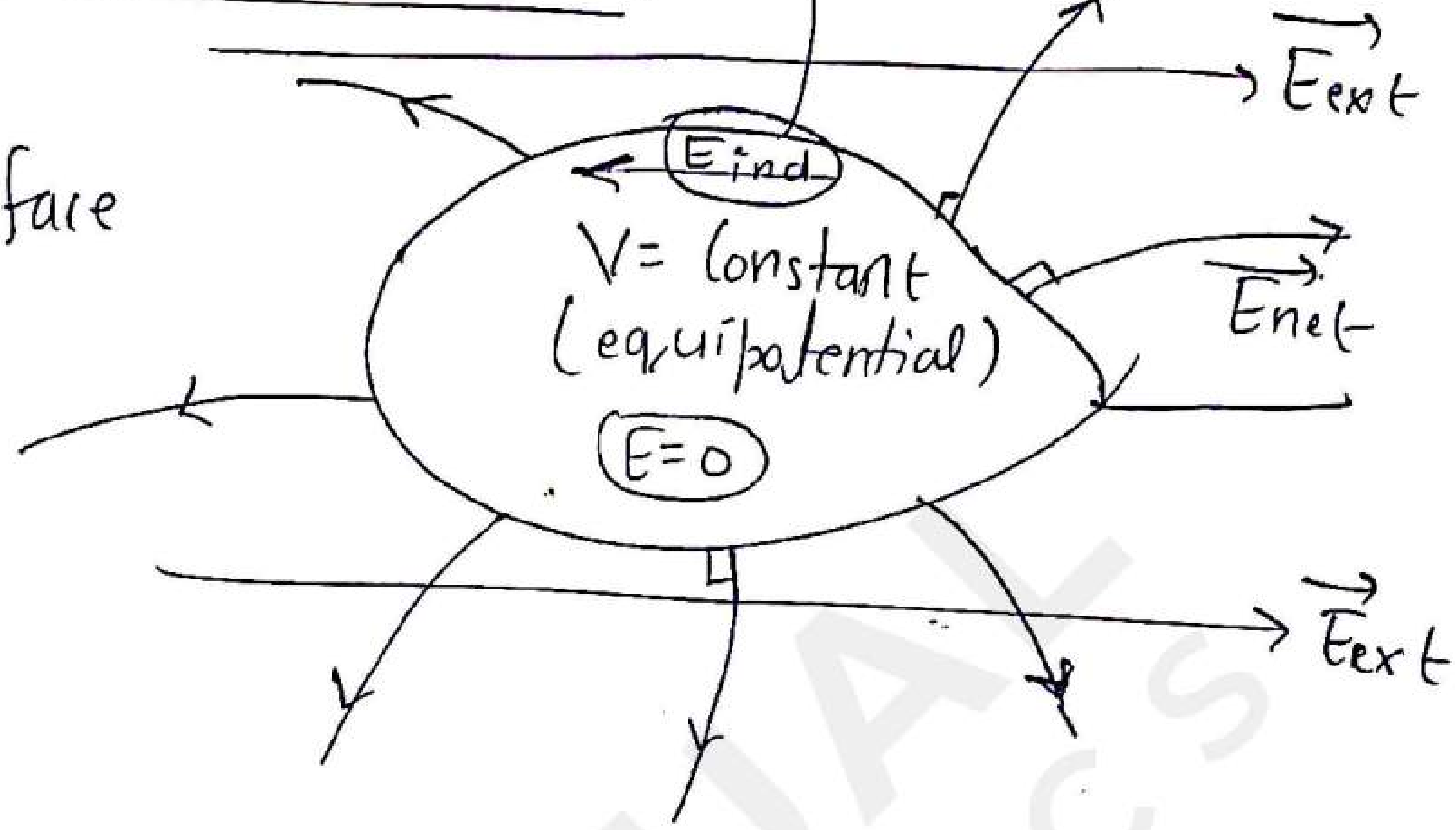
$\vec{E} \perp$ to surface, so no component along surface.

As if $\vec{E}$ is along surface charge starts to move

$$\boxed{\vec{E}_{net} = \vec{E}_{ext} + \vec{E}_{ind}}$$

Induced field Inside

$\perp$ to surface



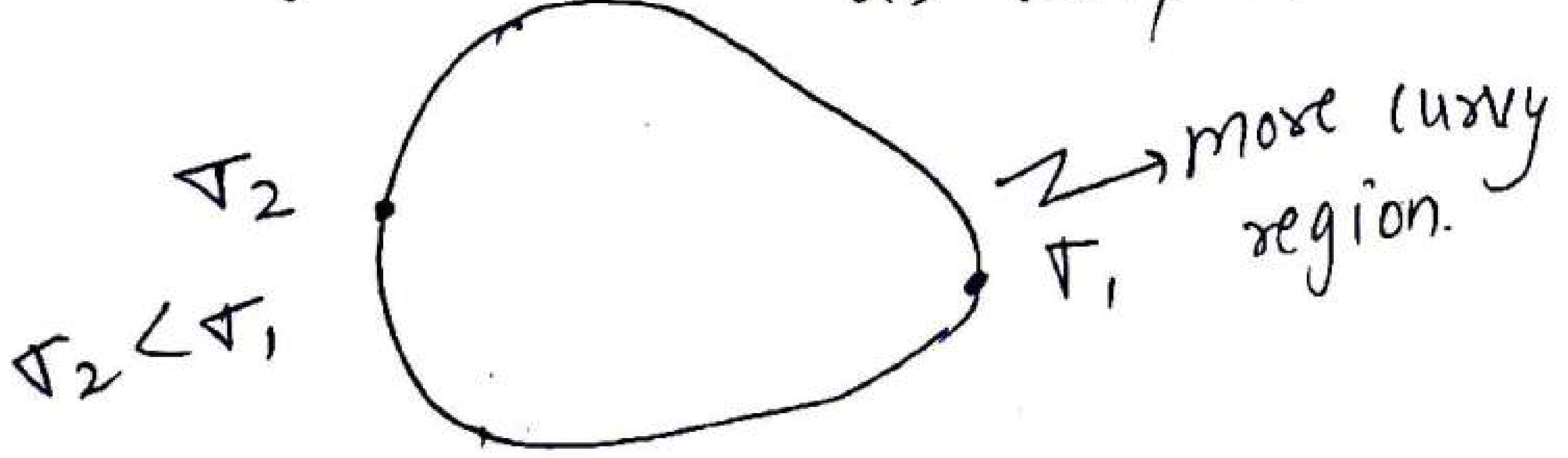
if $\vec{E}_{ext} = 0$, $\vec{E}_{net}$ = due to charge on surface.

★ $\boxed{\text{Net field is always perpendicular to conductor surface at every point}}$

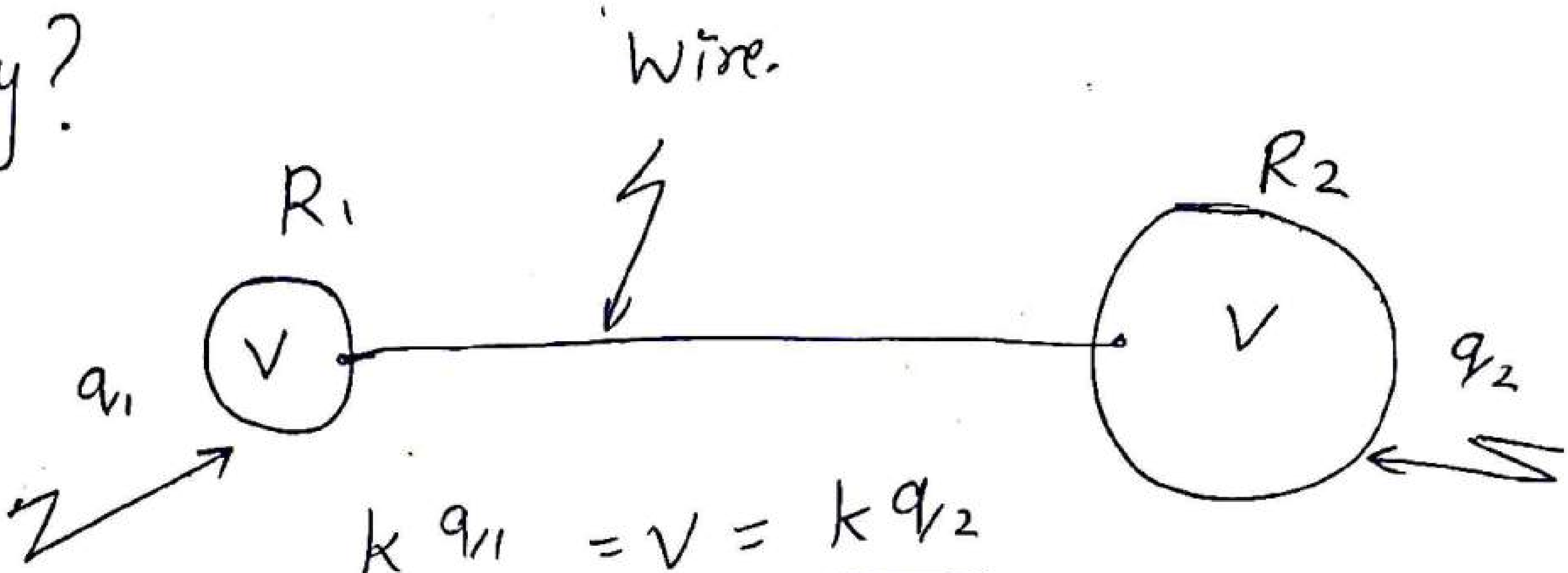
But, not necessarly, charge density is equal.

★ $\boxed{\text{charge distribution, depends on condition}}$

In general, σ is more near more curvy regions as compared with less curvy one.



Why?



$$\frac{k q_1}{R_1} = V = \frac{k q_2}{R_2}$$

$$\Rightarrow \boxed{q_1 = \frac{q_2 R_1}{R_2}}$$

$$\sigma_1 = \frac{q_1}{4\pi R_1^2} \quad \& \quad \sigma_2 = \frac{q_2}{4\pi R_2^2} \Rightarrow \underline{\sigma_2 < \sigma_1}$$

$$\Rightarrow \boxed{\sigma \propto \frac{1}{R}}$$

from this if R is less σ is high

means R is less $\longrightarrow$ more curvy nature..

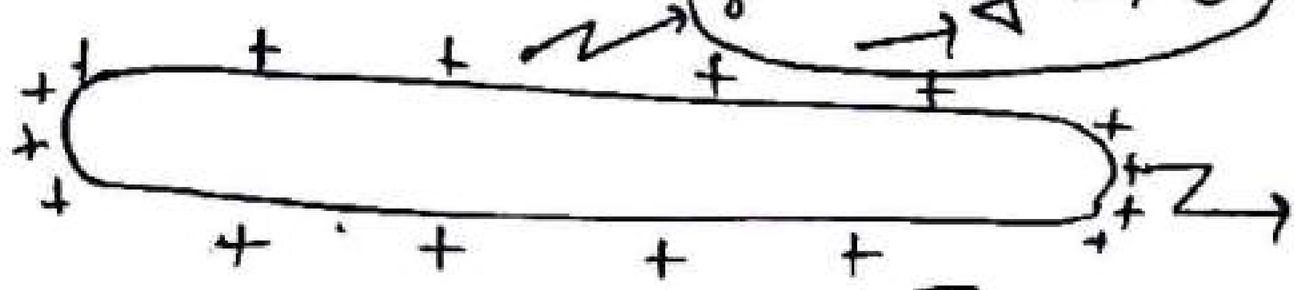
more σ $\hookrightarrow$ charge density.

Now, for plane surface, $r \longrightarrow \infty$

$\sigma \longrightarrow 0$ $\longrightarrow$ This is not the case.

as we know for plane sheets charge is also over the surface not only in corners.

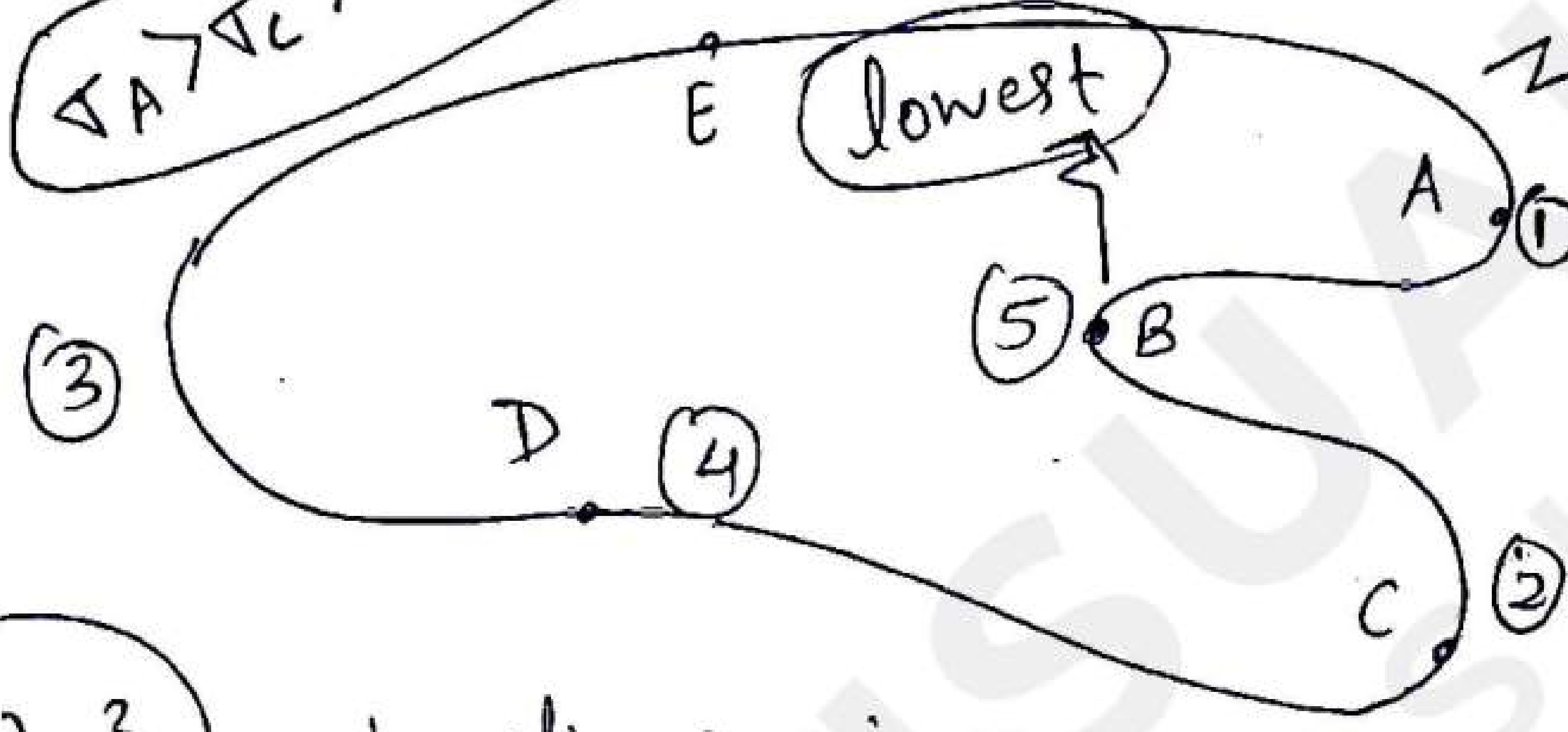
$\sigma \propto \frac{1}{R}$ is just relation between two curvy regions



$r \to \infty$, $\sigma \to 0$ not possible.

charge density is high

but, charge is also on plane surface



Now, $\sigma_A > \sigma_C > \sigma_E > \sigma_D$

bulging inwards

bulging outwards → highest

5 & 4 → negative curviness → bulging Inwards.

1, 2, 3 → positive curviness → bulging outwards

★ σ is high at more curvy regions holds only for bulging outwards surface.

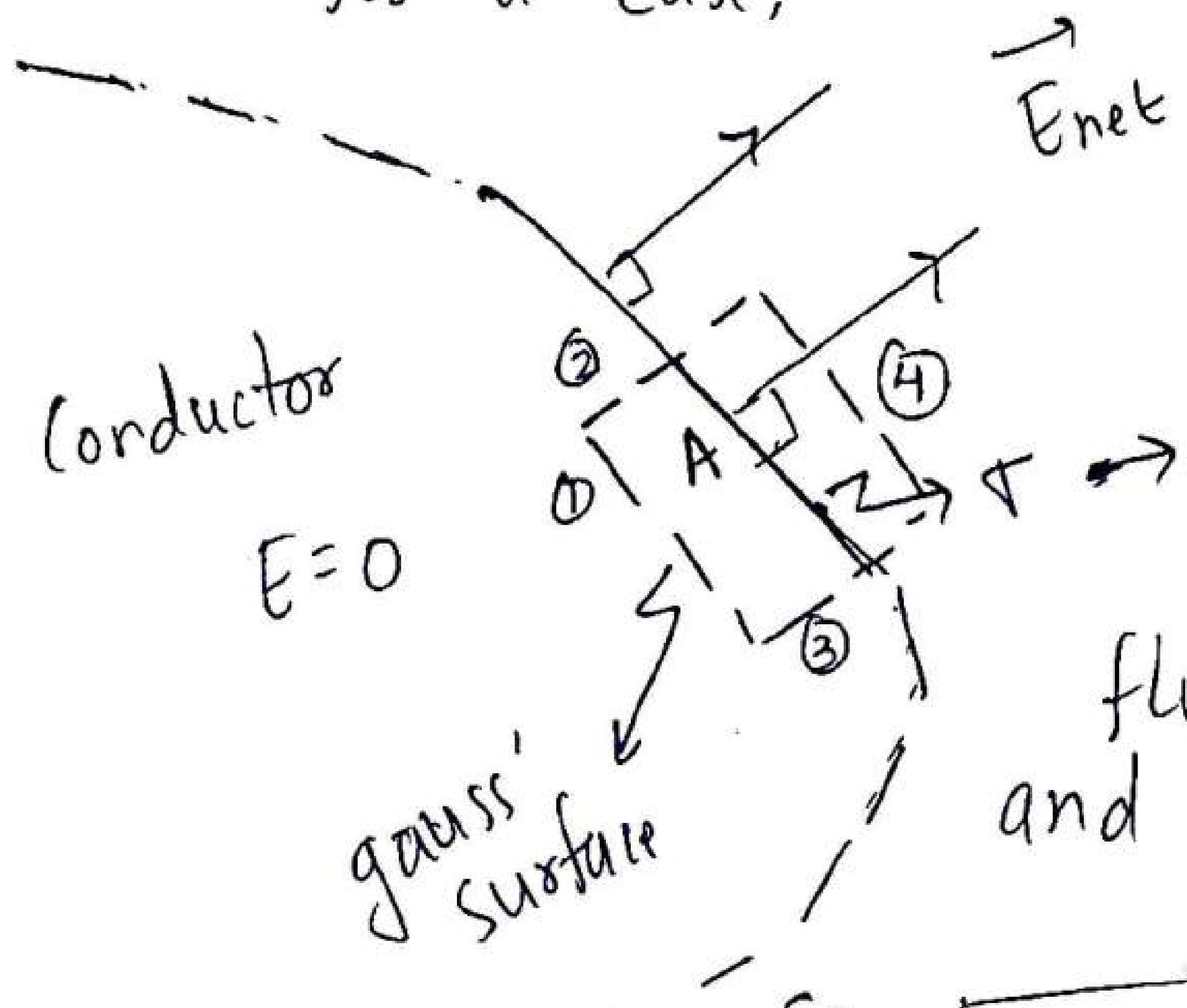
★ σ is less at more curvy regions for bulging Inwards surfaces.

$\boxed{\text{This holds till } \vec{E}_{ext} = 0}$

So this relation only valid for Isolated charged conductors.

Now for a case,

(small section of conductor)



flux through ① = 0

and throug ② & ③ = 0 as $\vec{E} \perp$ to surface ② & ③

so, $\boxed{\dfrac{q_{net}}{\epsilon_0} = EA}$ → Area of part considered

gauss law

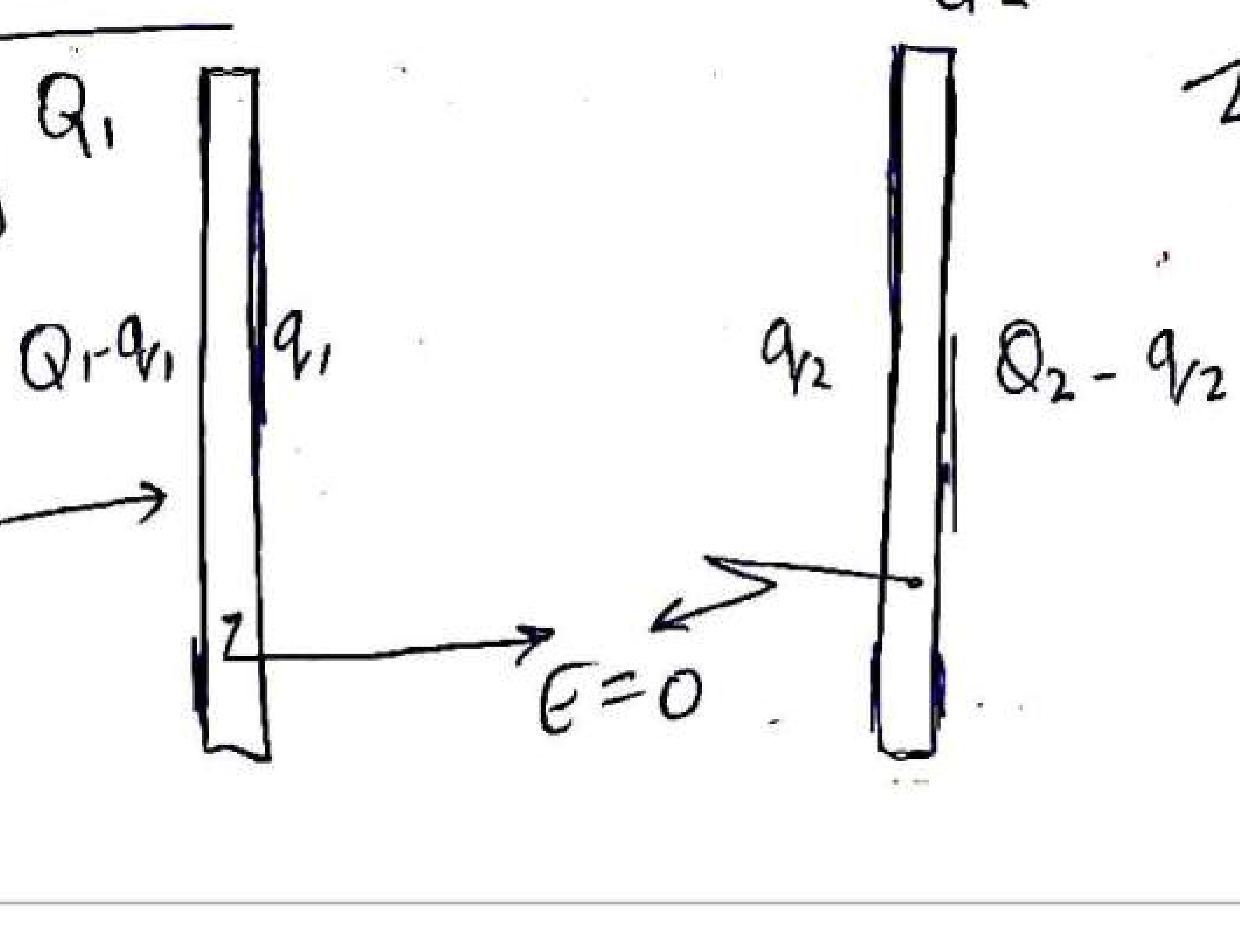
$q_{net} = \sigma A$

so, $\boxed{E = \dfrac{\sigma}{\epsilon_0}}$

σ high for high curvy so E will be high and vise-versa

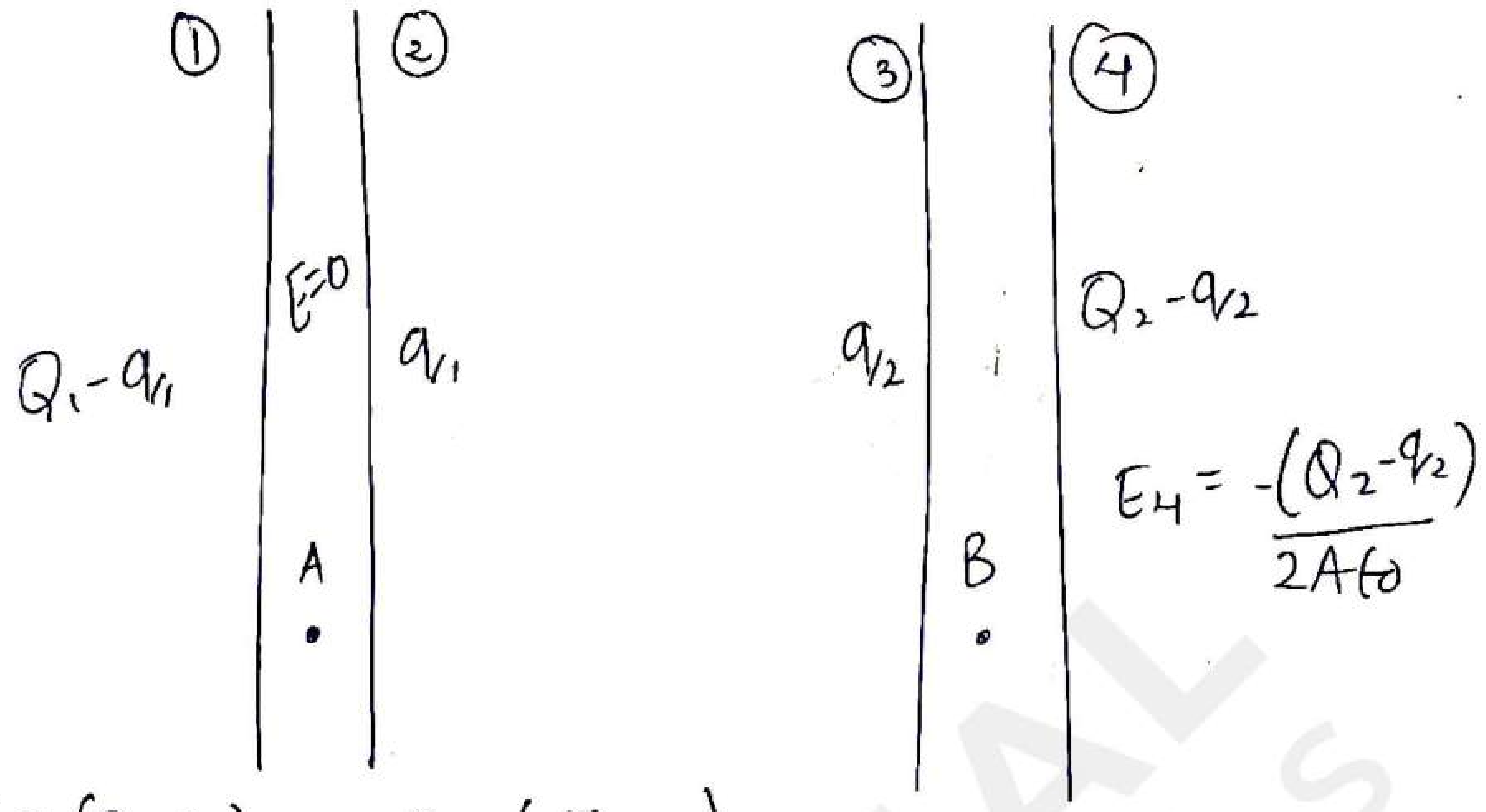
so, E is different at different points, as σ is different for different points.

Conducting Sheets:



→ Now here we have four sheets

charge distribute such that $\vec{E} = 0$ inside



$$E_1 = \frac{(Q_1 - q_1)}{A2\epsilon_0} \qquad E_2 = \left(\frac{-q_1}{A2\epsilon_0}\right) \qquad E_3 = -\frac{q_2/A}{2\epsilon_0}$$

E_1, E_2, E_3, E_4 are field by 1, 2, 3 & 4 at point A

now, $\boxed{E_1 + E_2 + E_3 + E_4 = E_A = E = 0}$

on solving we get

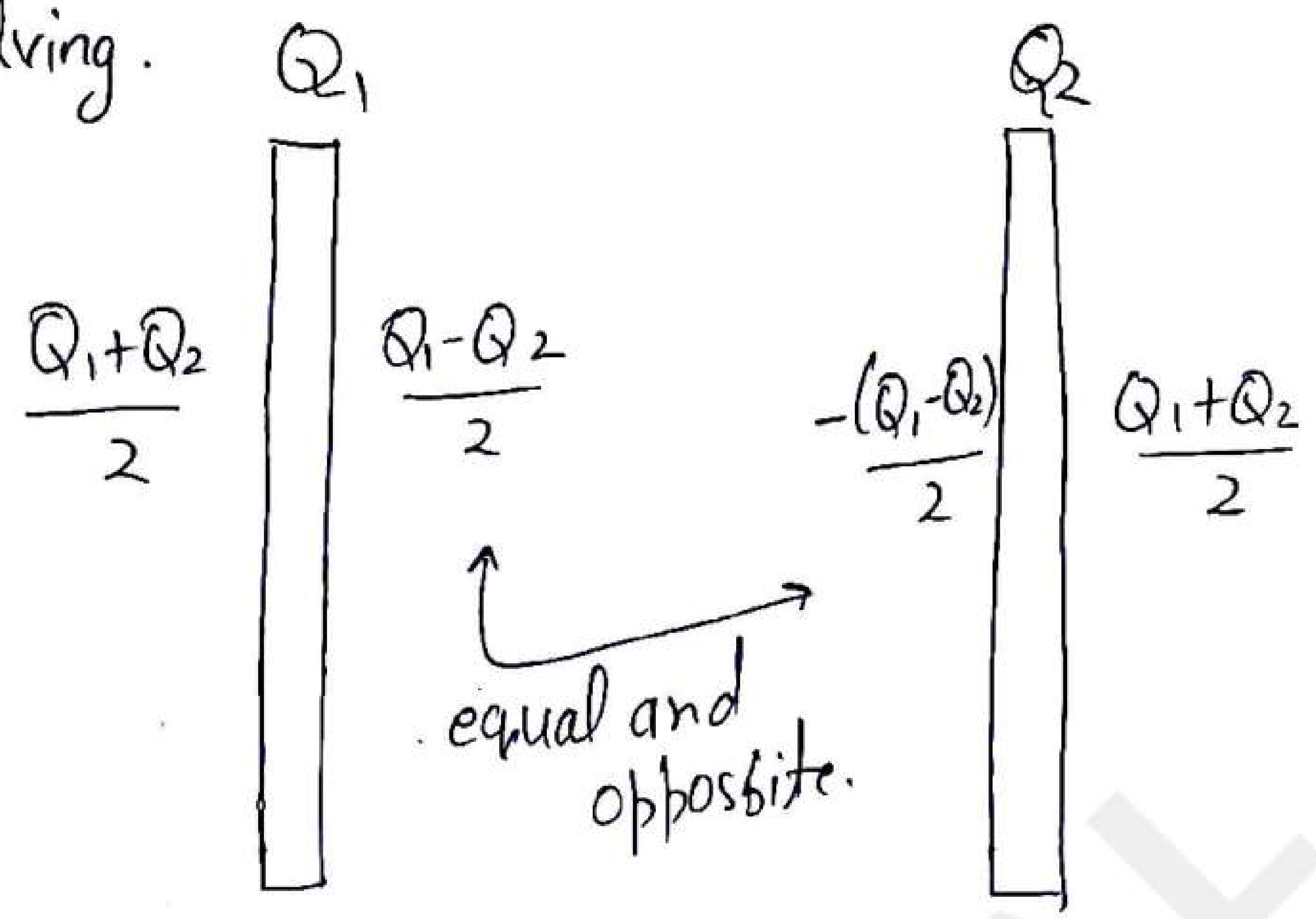
$$\boxed{q_1 = \frac{Q_1 - Q_2}{2}}$$

similarly, if we solve for point B

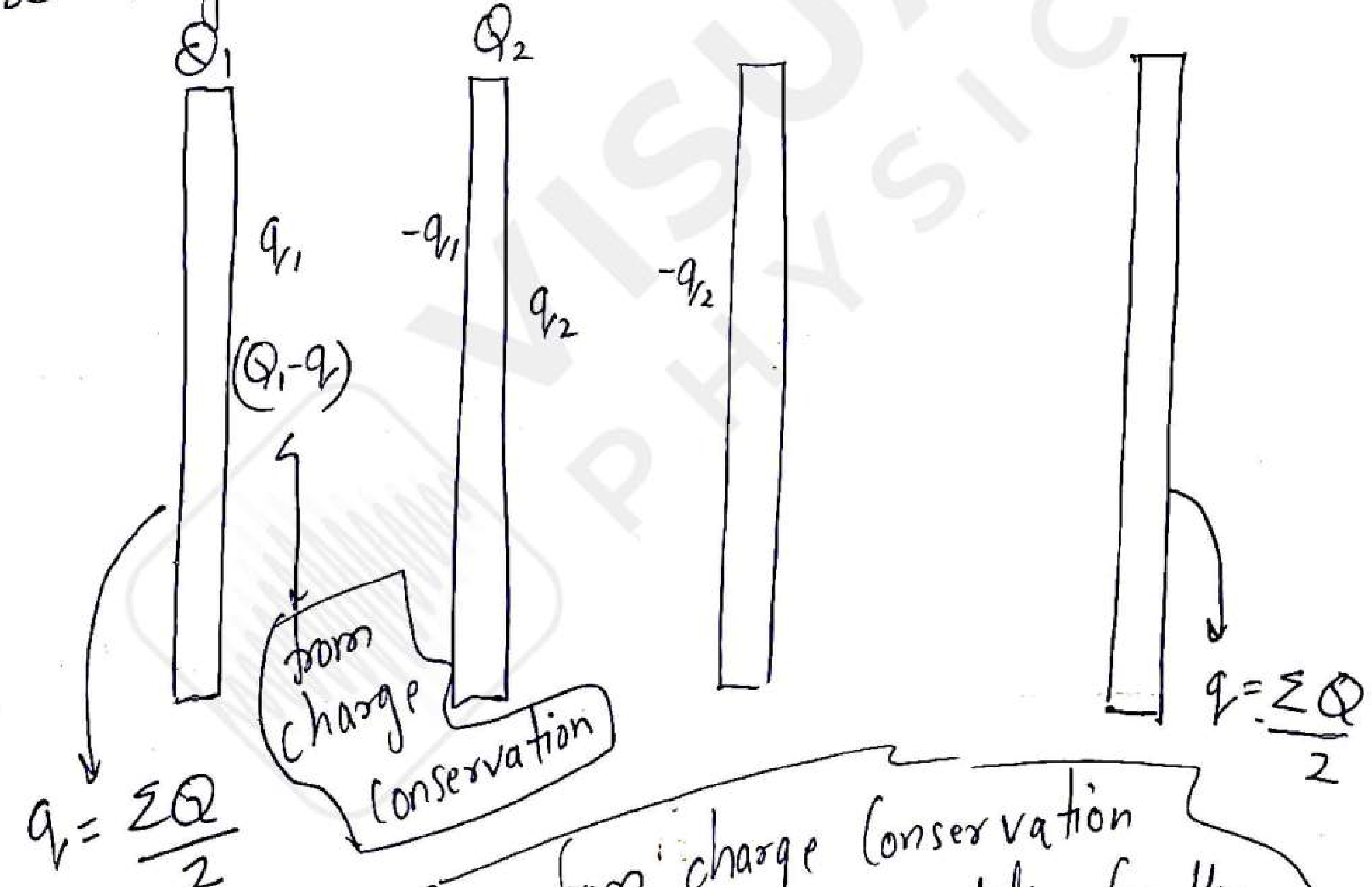
we get, $q_2 = -\frac{(Q_1 - Q_2)}{2}$

★ So we can have net charge on each surface from, q_1 & q_2.

on solving.



so In general.



★ So, from charge conservation and using the condition for the charge outside the surface of system we can have charge on each plate.

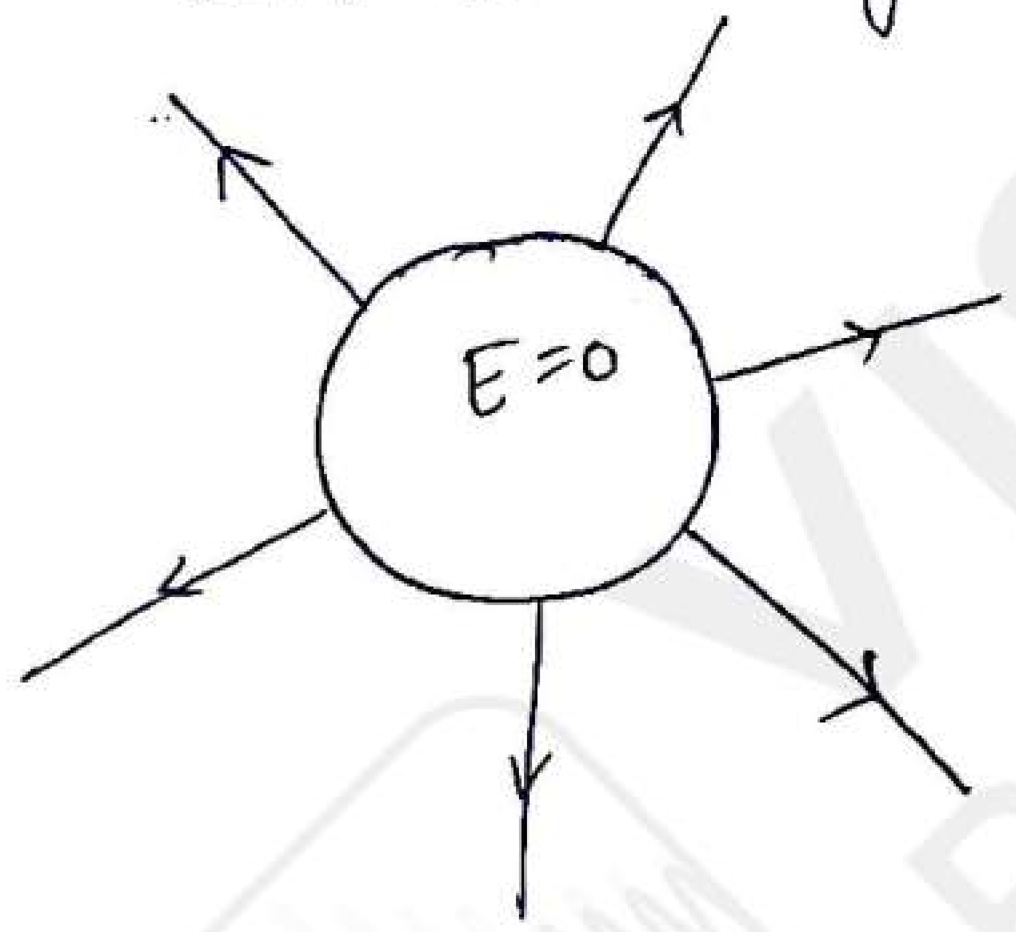
Electrostatic pressure.

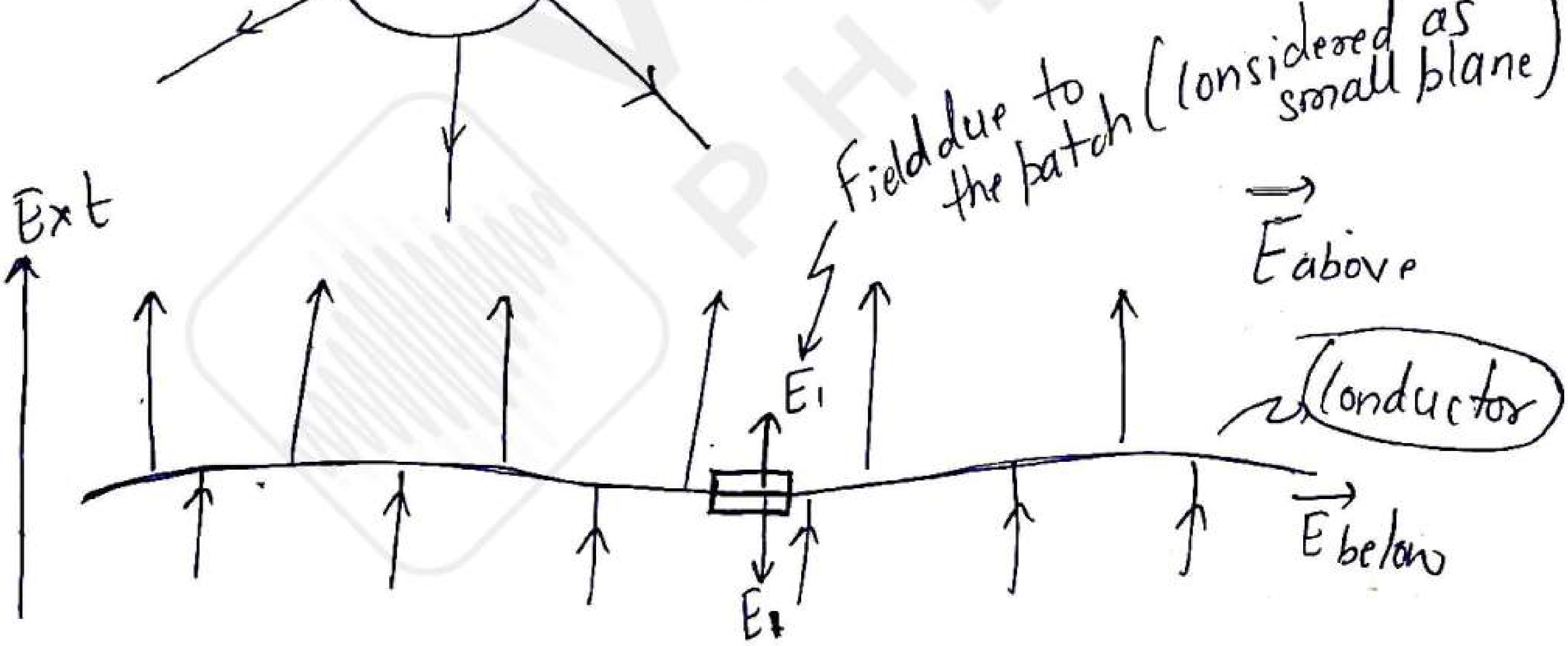
as, $\boxed{\vec{F} = q\vec{E}_2}$ → field due to rest of charge

charge free

(i) $\vec{E}$ field in space is continous.

(ii) Field distribution is discontinous at a surface charge density, distribution





now $E_{net} = E_{other} + E_{patch} = E_{above}$

$E_{net} = E_{other} - E_{patch} \Rightarrow E_{below}$

field due to the surface except the considered patch

so, $E_{above} + E_{below} = 2E_{other}$

$\Rightarrow \boxed{E_{other} = \dfrac{E_{above} + E_{below}}{2}}$

So, Field at patch $= \frac{1}{2}(E_{above} + E_{below})$

if path Area $\rightarrow dA$

$\hookrightarrow \sigma$

So, $\boxed{dq = \sigma dA}$

$\Rightarrow dF = dq\, E_{other}$

$\Rightarrow \frac{dF}{dA} = \sigma\left[\frac{1}{2}(E_{above} + E_{below})\right]$

P = electrostatic pressure

$\Rightarrow \boxed{p = \sigma\left[\frac{1}{2}[E_{above} + E_{below}]\right]}$

for Conductor,

$E_{below} = 0$

$E_{above} = \frac{\sigma}{\epsilon_0}$

so, $\boxed{P = \frac{\sigma^2}{2\epsilon_0}}$ → Electrostatic pressure on the surface of Conductor