Book section

ohm's law →

$$V = IR \quad \text{or} \quad J = \sigma E$$

good Conductor have Conductivity of order $10^{7}/\Omega m$

low Conductivity 10^{-10} and $10^{-20}/\Omega m$
Insulators.

semiconductors have Conductivity order = 10^{-6} to $10^{4}/\Omega m$

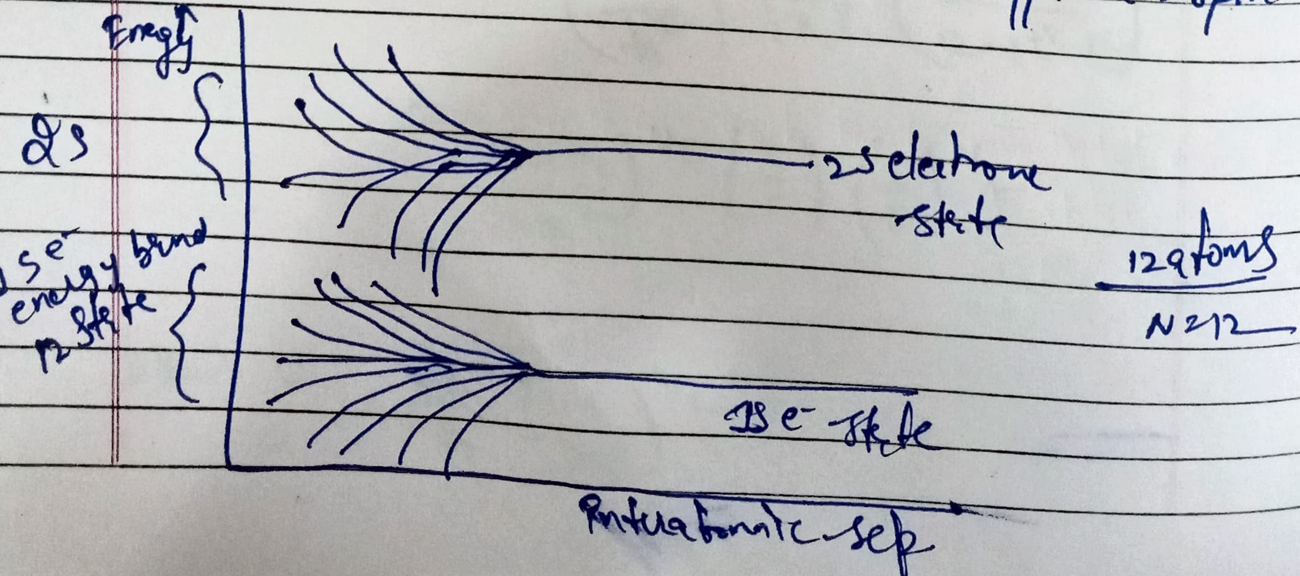
~~pauli exclu~~

Energy band structures in Solids →

electrical conductance in any material is related to these (states (conduction band) are occupied by electrons.

pauli exclusion principle →

any two electrons Can exist in any state of subshell in opposite spin.



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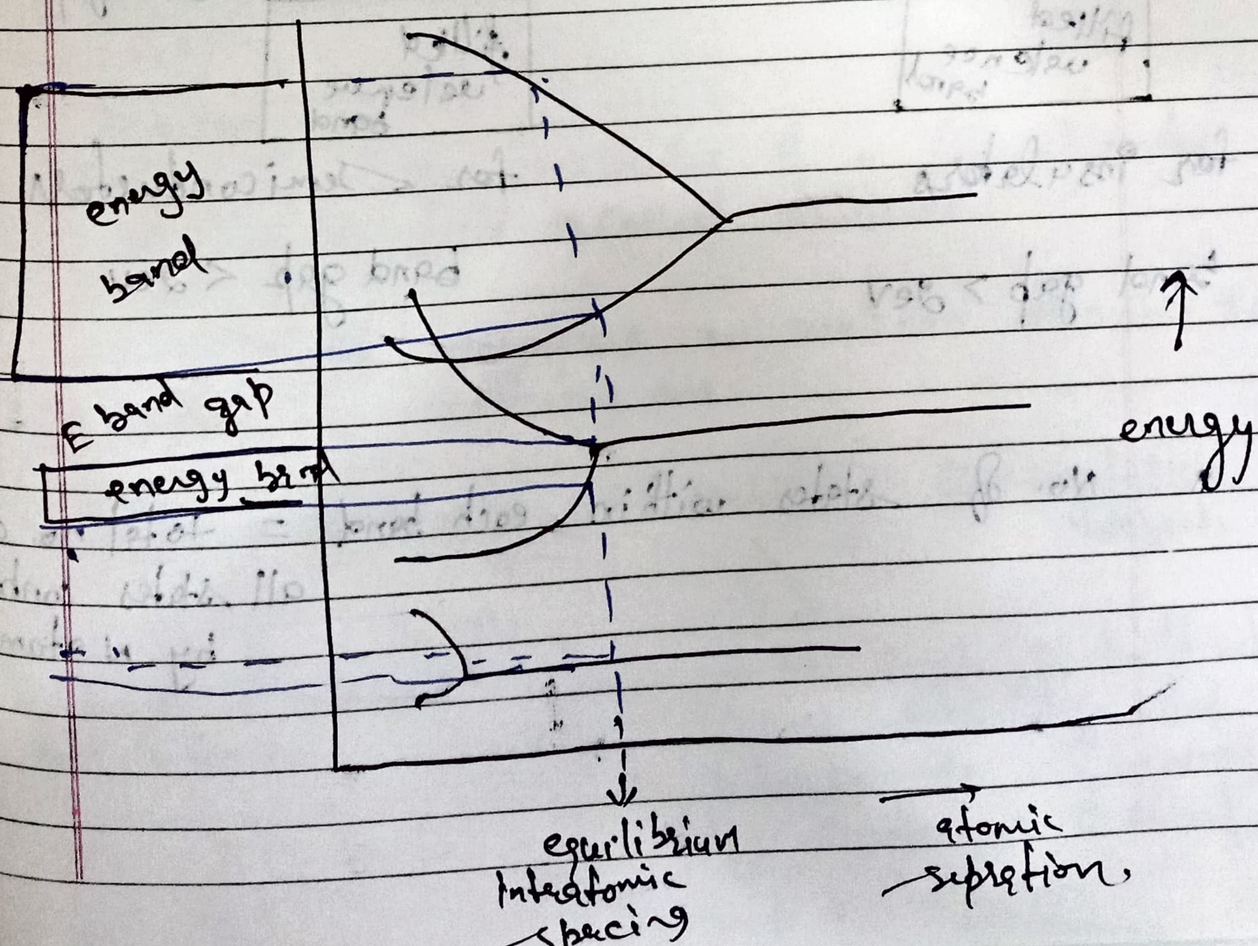
electrone energy band →

each distinct atomic state may split into a series of closely spaced electron states in the solid to form what is termed an electron energy band.

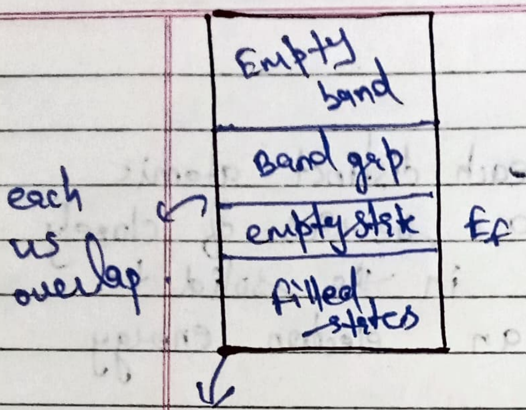
the extent of spliting depends on interatomic separation.

within each band, the energy states are discrete, yet the difference b/w adjacent state is exceeding small.

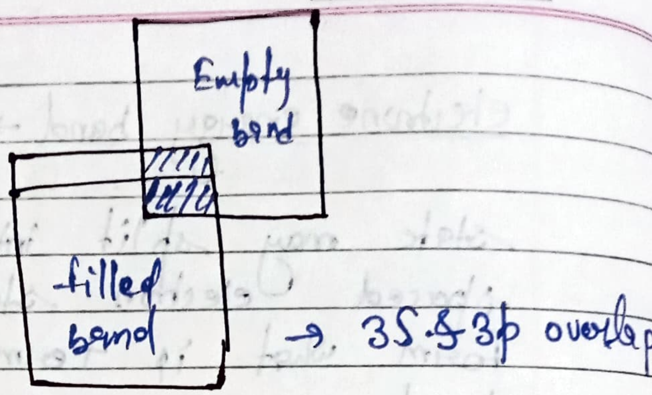
at equilibrium state, band formation may not form.



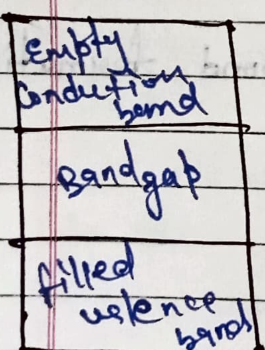
4 different types of ~~various~~ e^- band structure at 0K.



in metals such as Cu

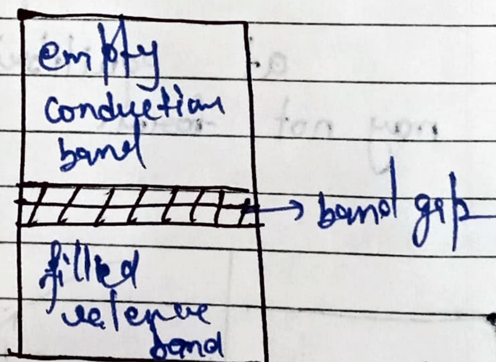


for, Mg like metals (overlapping of filled & unfilled band)



for insulators

band gap > 2eV



for semiconductors

band gap < 2eV

- No. of states within each band = total no. of all states contributed by N atoms.

Fermi energy →

The energy corresponding to the highest filled state at 0K is called ~. denoted by E_f.

fermi Energy is taken as that energy below which, for N atoms, N states are filled, two electrons per states.

fermi energy for these two bands (conduction band & valence band) structures lies with in the band gap - near its center.

- holes have energy less than E_f.

Resistance →

the scattering of e⁻ (phonon) under the electric field is called resistence.

the parameters are used to describle the extent of scattering are.

i) drift velocity (ii) Mobility (iii) Crystalline defects.

avg. velocity of e⁻ in the dir of force imposed by applied force.

$\boxed{V_d = \mu E}$

$V_d = \frac{eE\tau}{m}$

μ is const in drift velocity called mobility and indicate the frequency of scattering events.

unit = $m^2/V.sec$.

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Electrical Conductivity →

$$\sigma = \frac{1}{\rho} = \mu n e$$

n → no. density (unit/m³)

e → 1.6×10^{-19} C

μ → mobility

⇒ Conductivity ∝ mobility & free e⁻s.

Matthiessen's rule →

for a metal, total electrical resistivity equals the sum of thermal, impurity, and deformation contributions.

(2)

$$\rho_{Total} = \rho_t + \rho_I + \rho_d$$

ρ_t → thermal vibration

ρ_I → impurities

ρ_d → deformation.

← factor affecting resistivity →

(i) Temperature →

for pure metal and all the Cu-Ni alloys resistivity rise linearly above about -200°C

$$\rho_t = \rho_0 + aT$$

with ↑ in temp. thermal vibration and lattic irregularities (which serve scattering) rises

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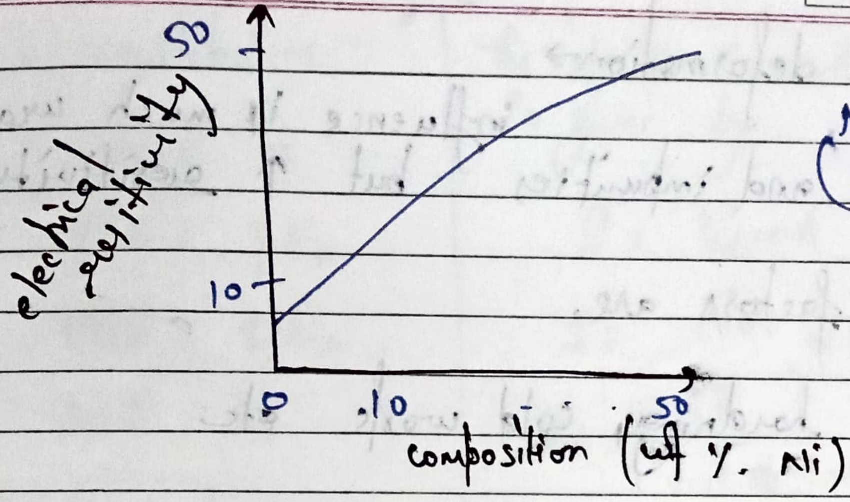

~~Ni — Cu~~

(Cu – Ni) Alloy.

(2) impurities →

imputies is related to the impurity concentration c_i

$$\rho_i = A c_i (1 - c_i)$$

A = composition independent constant. that is a function of both impurity and host metals.

imputy act as scattering center

↑ imputy : ↑ resitivity

Ni - in Cu graph given above.

- for two phase alloys consisting of α and β phases.

rule of resistivity follows

$$\rho_i = \rho_\alpha V_\alpha + \rho_\beta V_\beta$$

{ V_α & V_β are vol. fraction of individual phase

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plastic deformation →

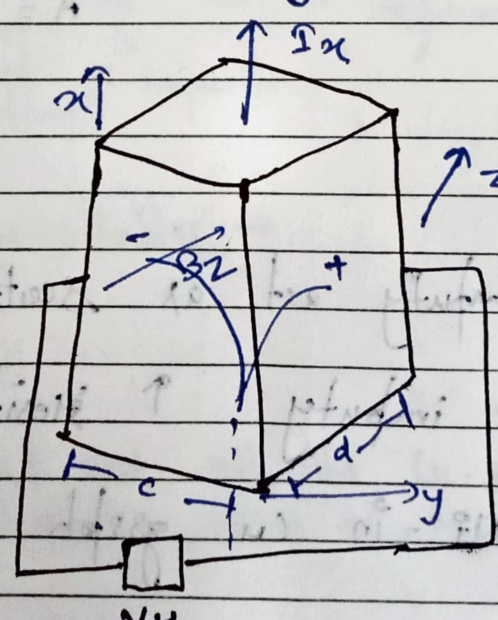
temp and impurities influence is much weaker than but ↑ resistivity.

other factors are.

Age hardning, cold work etc.

The hall effect →

Hall effect is a result of the phenomenon by which a magnetic field applied perpendicular to the direction of motion of charged particle exerts a force on the particle perpendicular to both the mag. field and particle motion direction.



magnitude of force due to mag. field

$F_B = qvB$

$= e v_d B$

Mag. of force due to electric force

$f_E = e E_H \Rightarrow E = \frac{F}{q}$

In equilibrium

$f_B = f_E$

$qvB = qE_H$

$ev_dB = eE_H$

$v_dB = E_H$

or $\boxed{v_d = \frac{E_H}{B}}$ —(1)

the electric current in slab is given by

$I = v_d e n A$

$I = c \cdot d \cdot v_d e n \quad \{A = cd\}$

$v_d = \frac{I}{c \cdot d \cdot e \cdot n}$ —(2)

Now on comparing eq (1) & (2), we get

$$\frac{E_H}{B} = \frac{I}{c \cdot d \, e n}$$

we also know that $\left\{E_H = \frac{V_H}{d}\right\}$

$$E_H = \frac{V_H}{c}$$

$$\Rightarrow \frac{V_H}{\cancel{c} \cdot B} = \frac{I}{d \cdot \cancel{c} \cdot \cancel{v_d} \cdot e \cdot n}$$

$$V_H = \frac{B \cdot I}{d \cdot \cancel{c} \cdot e \cdot n} \Rightarrow \left(\frac{1}{n \cdot e}\right) \cdot \frac{BI}{d}$$

$$\boxed{V_H = \left(\frac{1}{ne}\right) \cdot \frac{BI}{d}} \rightarrow \text{Hall voltage}$$

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$$\boxed{R_H = \frac{1}{n|e|}}$$ → Hall Coefficient

Const for a given material.

$$\boxed{\mu_e = \frac{\sigma}{n|e|}}$$ → electron mobility.

or

$$\boxed{\mu_e = |R_H|\sigma}$$

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Capacitance →

is related to the quantity of charge stored on either plate.

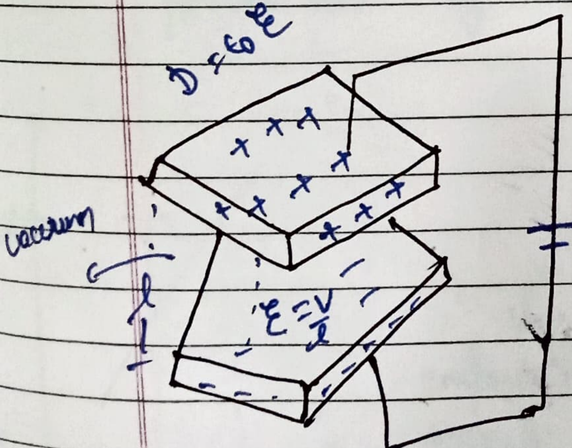
$C = \frac{Q}{V}$ ← +ve or -ve charge stored on plate.
→ applied voltage

unit = Coulombs/volt or farads (f).

Capacitance of for parallel plate Capacitor, in vacuum

$C = \frac{\epsilon_0 A}{l}$ → area of plate
→ dis. b/w them

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



if a dielectric material is inserted into the region within the plates then

$C = \epsilon \frac{A}{l}$

$\epsilon = \epsilon_r \epsilon_0$
relative permittivity

$\epsilon_r = \frac{\epsilon}{\epsilon_0}$

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if $\epsilon_r > 1$, then it mean ↑ in charge storing capacity upon inserting of dielectric medium b/w plates.

Electric dipole moment → dis. of sep. b/w two charges.

$p = q \times d$

vector quantity dir. -ve to +ve charge

polarization →

A torque (or force) come to bear on charges on an electric dipole to orient it with the applied field, this phenomenon is called polarization.

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class.

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Conduction and space charges →

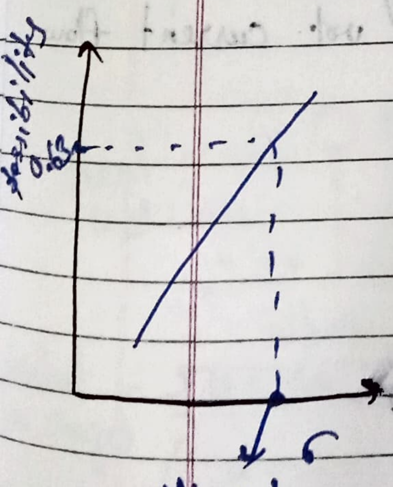
Source of Contamination : → Conducting particle
→ fibers
→ structural defect.

for dielectric materials.

σ is not const. , it is a static variable if we perform an experiment to calculate it from two samples of same material they always gives different result.

→ that why, we choose avg. result

possible val. of σ may around 63 % of σ

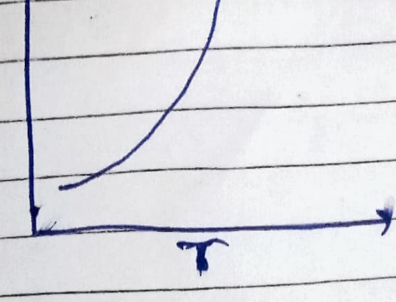


this val. taken as σ val.

$$\sigma = \sigma_0 \, e^{aE} \, e^{-b/T} \quad (1)$$

↓
emperial result

a = stress Cofficient
b = temp. Cofficient



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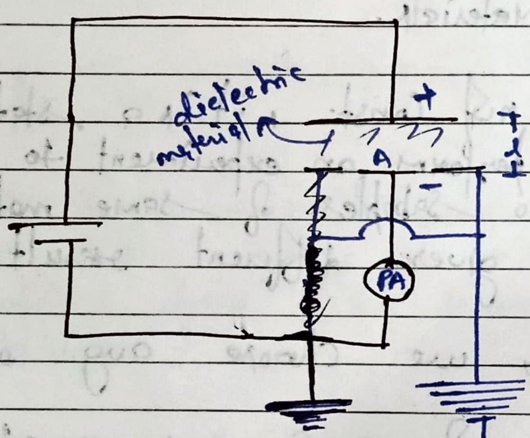
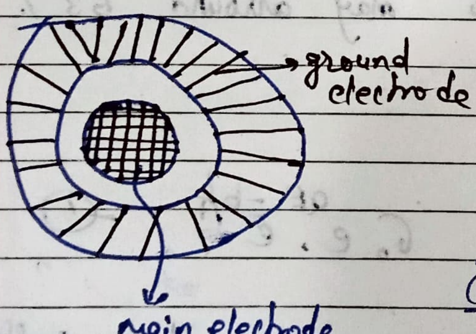
formula (2) is valid only for dielectric material, and 63% of σ is representative vol. when we consider T & E constant

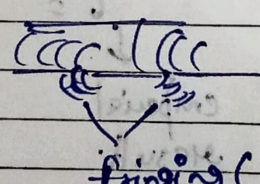
• lowest continuous current vol. = 10^{-18} A
or sometime PA → pico



$$R = \frac{\rho l}{A} = \frac{1}{\sigma}\frac{l}{A}$$



we grounded it so that only vol. current flow



space ch

the cond
state (o

there

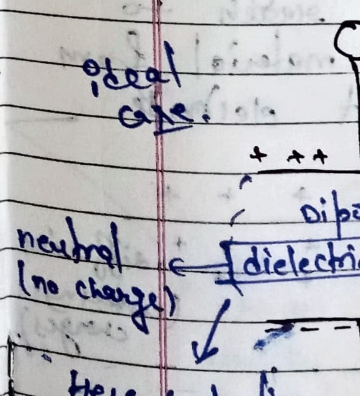
1. homo ch
2. hetro ch
3. pocket c

homo char

hetro ch

pocket

ideal case.



Here conduction current = 0

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space charge formation →

space charge are not the conducting charge. they exist in steady state (or fixed at a perticular position).

there are 3 types of space charge formation.

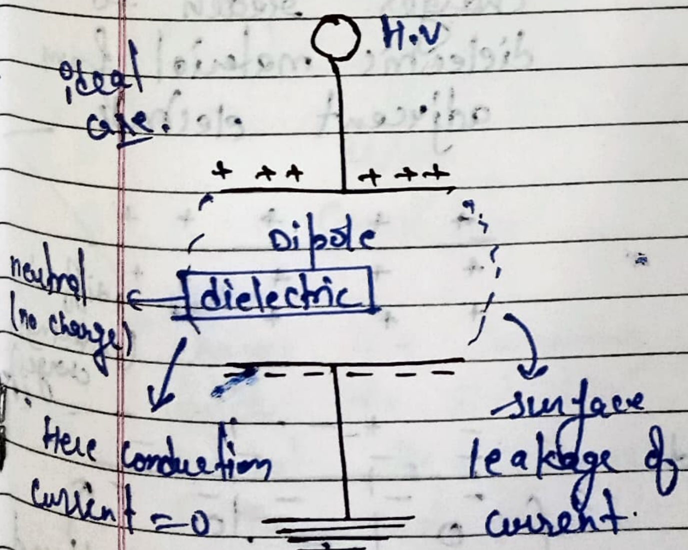
1. homo charge formation (also called charge injection).
2. hetro charge formation
3. pocket charge

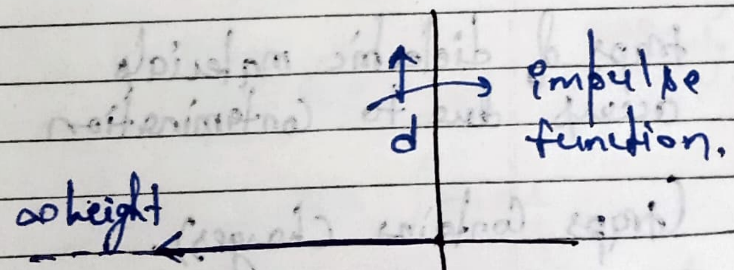
homo charge formation occur at more then ~~100~~ 80 kv/mm

hetro charge formation → operating stress 10-25 kv/mm

pocket charge formation > 100 kv/mm.

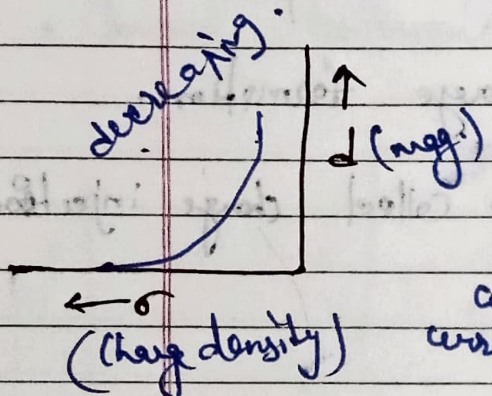
ideal case.

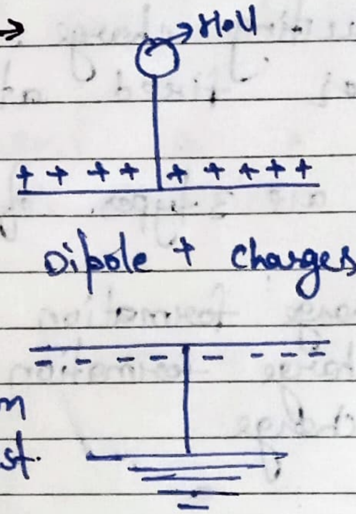




practical Case:→

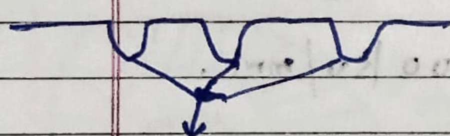
Homo charge formation→





these charges are rigidly connected with material and traped located in some traped of material

①

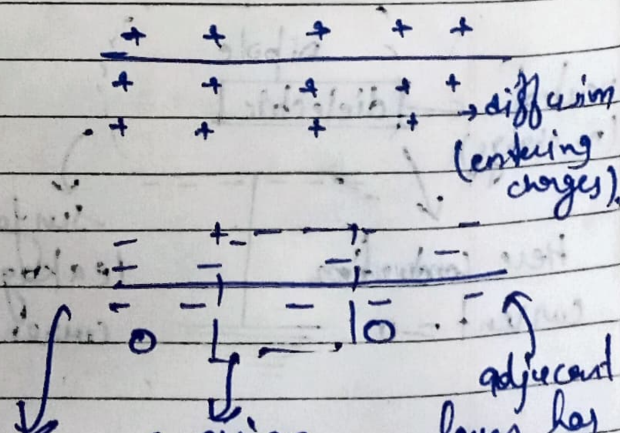


traps of dielectric materials occurs due to Contamination

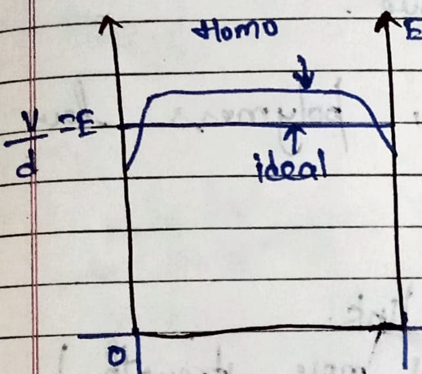
(traps Contains charges).

if these charges will disturbed then material will disturbed.

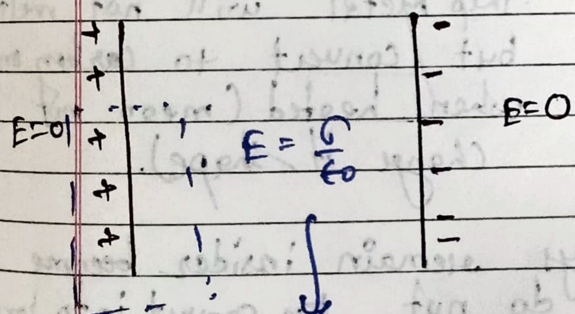
in homo charge formation charges reach to dielectric material from adjacent electrode



in fig. 1. we take Guassian surface and every time, we increase it so charge inside the surface increase that's why electric field increase. and then become constant (saturated) will be equal to ideal one.



area under ideal = area under homo.



using Guass low.

to calculate voltage V or E, we use.

$E \cdot dr = dv$ (considering mag. only)

$\int E \cdot dr = \int dv$

$V = \int E \cdot dr$

area under E & r.

charges are comming inside the dielectric material dis ↓ it mean E ↑ and we are given V const

so $\frac{V}{d} \neq E$ i.e $E > \frac{V}{d}$

Not valid

if a material continuously subjected at H.V & H.T then its bond b/w molecule will break, and will degrate fast, equipment may fail

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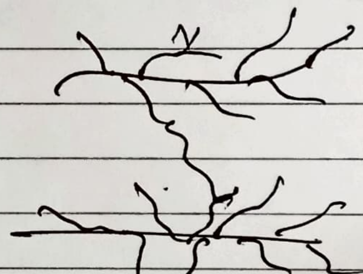
at edges voltage low but inside it will accelerate.

~~Hert~~ charge formation → In ionic metal, ion can be formed and move.

plastic materials, rubbers, polymers have cross link.



cross link.
(for more strength)

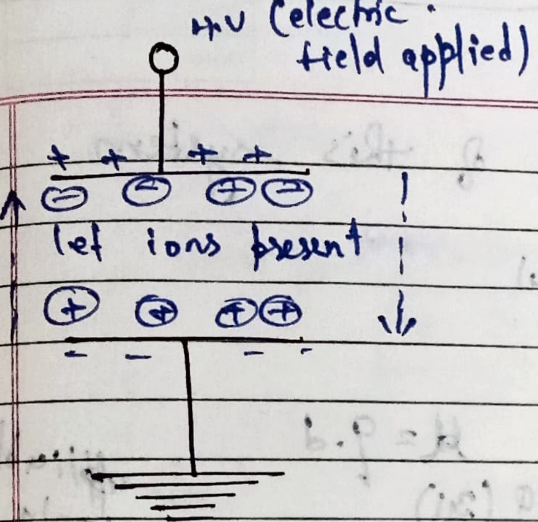
thin metal will not melt but convert to carbon only when heated (mean not change it shape).

cross linked always remain insider become because all of them do not convert into ion (cross linked agent).

used for cables. LDPE $\xrightarrow{\text{cross link}}$ $\frac{XLPE}{\Delta}$ → will not loose shape (above 90° it become liquid) → condution rise upto 90°

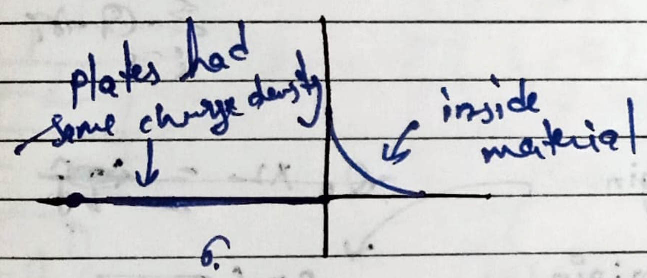
these are used as dielectric material.

HDPE → used for pipe over cover.



ions will migrates towards opposite side, electrode but they will not cross dielectric material

it mean electrodes no not get neutral.



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tut.

tsodiku, william hayatt

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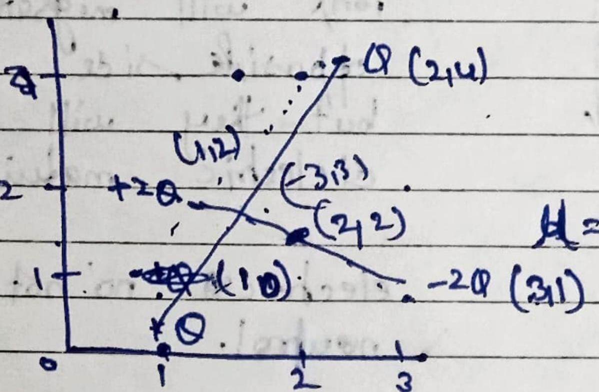
(1) find dipole moment of this system



$\mu = q.d$

qx

applicable only when over all system is neutral

$\sum_{i=1}^{n} Q \cdot r_i$

a). (2,2) → new origin

(b) (-3,3) → new origin.

~~Q. X2 = 2Q j~~

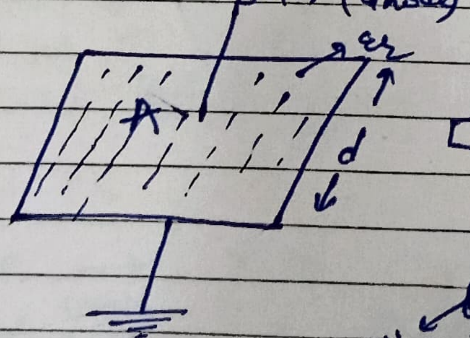
$2Q(\sqrt{1+0} = 2Q\hat{i}$

Q "

Ans. $7\hat{i} - 2\hat{j}$.

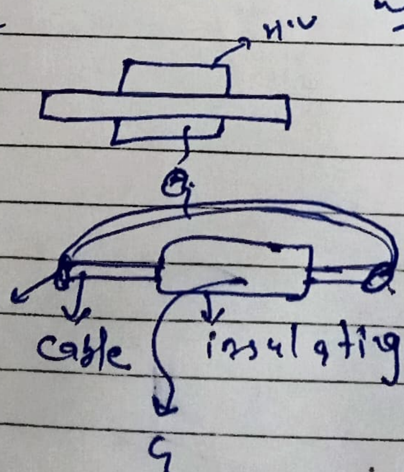
(2)

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

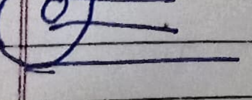


plane - plane

ans.



cylinderical systems



Maxwell equations

Electrostatics

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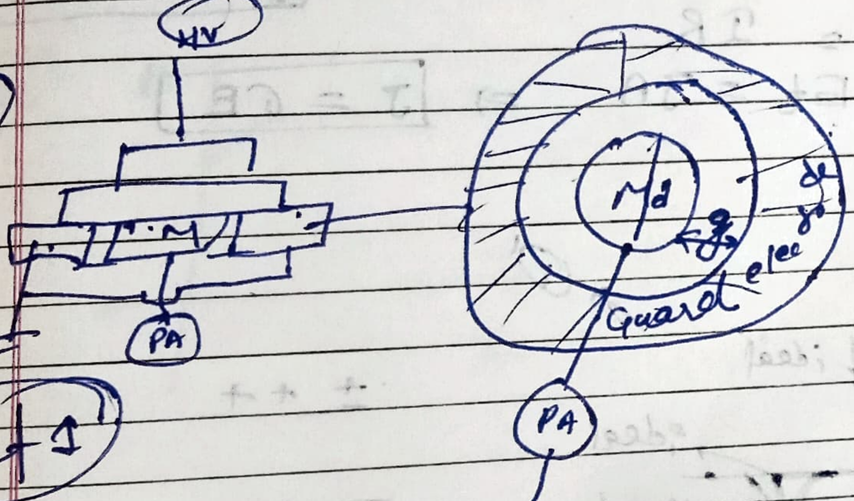
$\phi = -Q * t$

Gauss law, columb law

$\boxed{\nabla \cdot D = \rho_v}$

(3.)



used to find out resistance

for I

dielectric material thickness = 100 μm

E = 20 kV/mm, 303.15 K

d = 5 mm

(annular gap) g = 1 mm (gap)

~~e = 100V~~

$i = 10^{-11} A$

$\boxed{\sigma = \sigma e^{-bT} \cdot e^{qE}}$

constant

$\boxed{\sigma = \sigma_0 e^{bT}}$

use log-log method

(graphical method)

(approximate)

Case II

T	i(A)
303.15 K	10^{-11}
323.15	9×10^{-11}
343.15	5×10^{-10}

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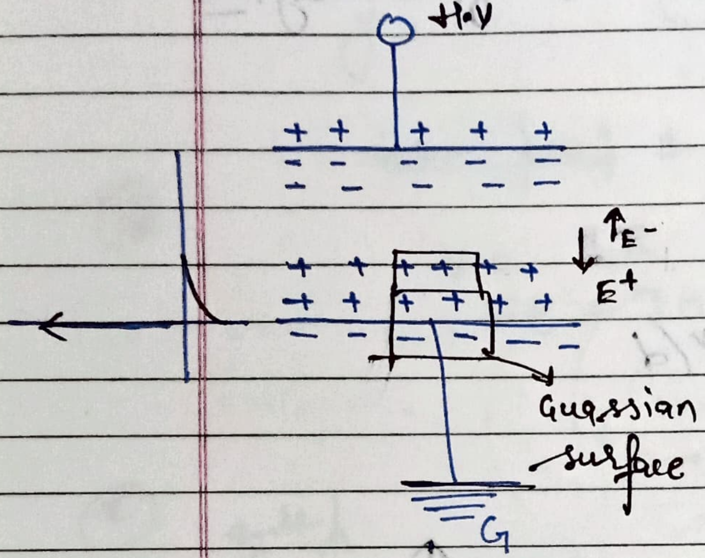
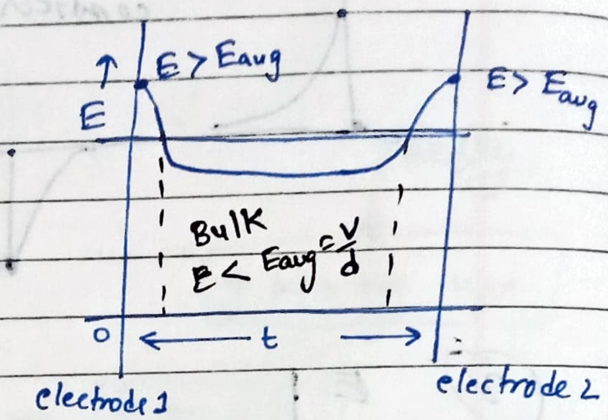
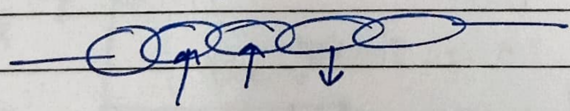
Hetro space charge →





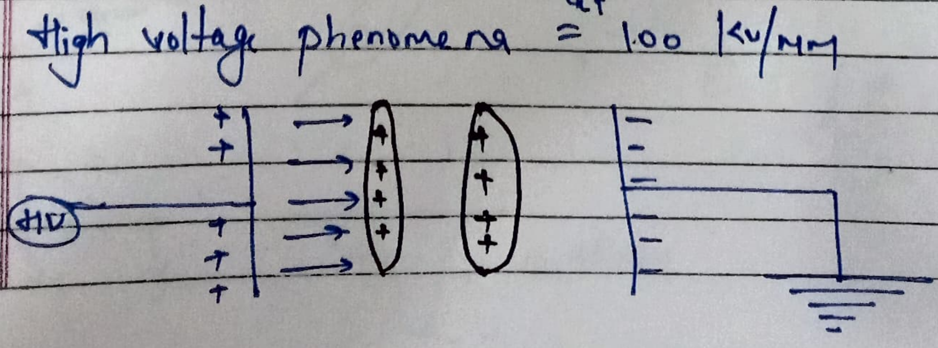
Electric field should be uniform every where to use any dielectric.

if it is weak at any where the decrement take place and equipment will fail easily.



at electrode electric field due to surface charge $= \frac{\sigma}{\epsilon}$

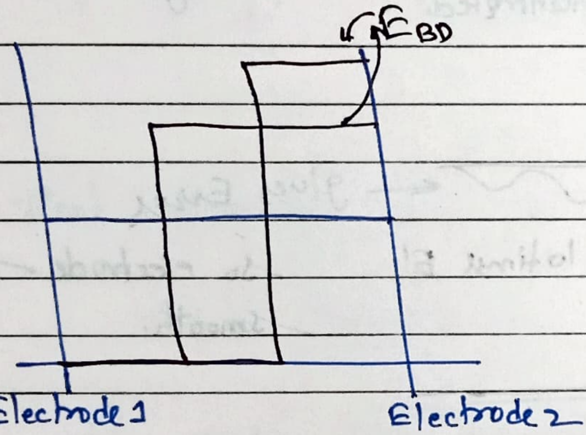
High voltage phenomena $\overset{at}{=}$ 100 Kv/mm



sudden movement (shifting) of electrode charge at which H.V. applied towards opposite charged electrode. and stop at a certain position.

this is known as poket charge.

charge pocket effect on Electric field →



Electric break down strength →

the electric field after which a material cause break.
it causes failer of material.
it is static (constant).

V_{BD} →

Voltage Breakdown has no meaning unless thickness is not mension.

Reason of breakdown →

air breakdown voltage = 3 kv/mm.

let voltage V is given to a spherical dielectric

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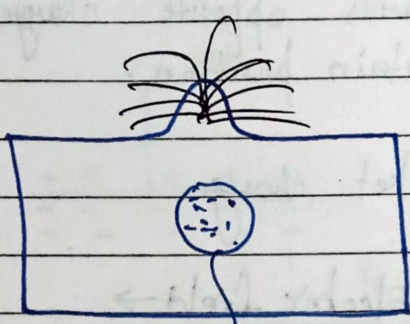
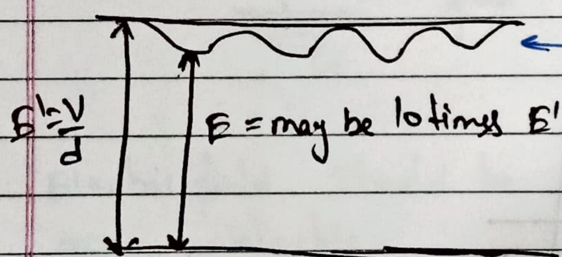
and radius r. $E \propto \frac{1}{r}$.



electron push away that's why, it got at higher at sharper edges.



← gives Error

so electrode should be ultra smooth.

Intermensic breakdown →

when a dielectric materials, an ideal electrode, no structural deffect the breakdown at and this breakdown is Called Internensic breakdown.

Electrod thermal break down →

Heat loss

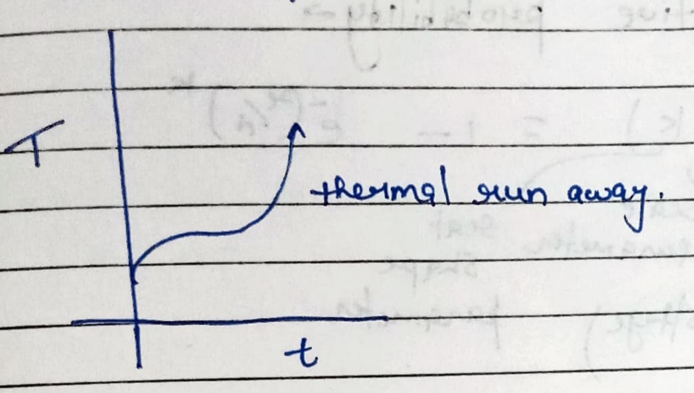
$H = \sigma E^2$

↓

temp ↑ then σ↑, H↑, again T↑, again σ↑ and so on.

if material seal thermally insulated (Can be done using glass wool) then Heat ↑

whatever voltage applied and break down occur.
because temp. ↑ exp.



if Heat generated inside material > Heat taken away

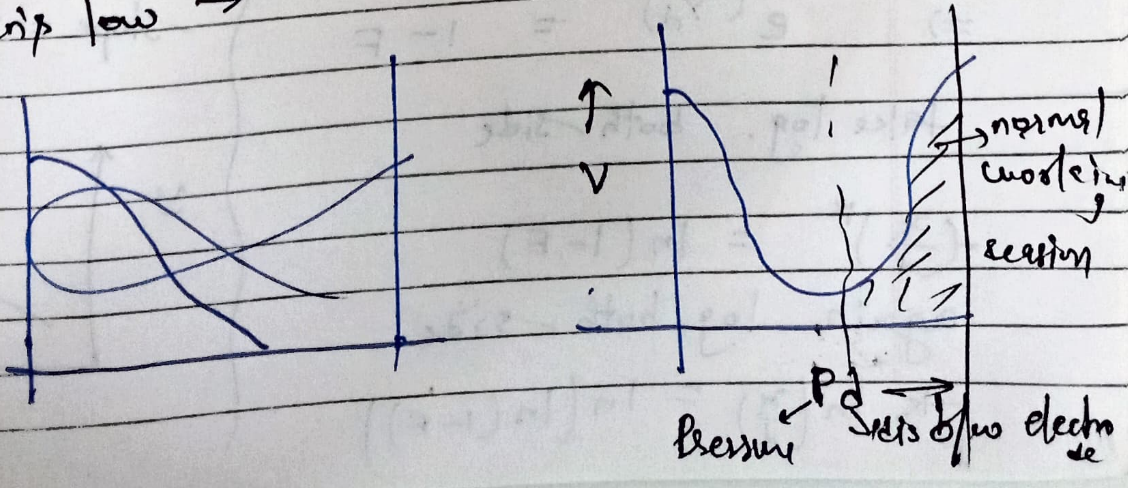
then breakdown.

if Heat gen < Heat taken away
cooling case.

if Heat gen = Heat taken away → equlibrium

break down of gases depends upon → pressure, Humidity

paschen's law →



Break down strength is statical.

Commulative probability →

$$F(x, \lambda, k) = 1 - e^{-(x/\lambda)^k}$$

x → Random variable (breakdown voltage or time)

λ → scale parameter

k → stat shape parameter

actual probability → PDF $= \frac{dF}{dx} = p(x) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^k} = f(x)$

at $x = \lambda$, Correspond to 63% possibility of breakdown

it mean if I have 100 sample that 63 sample fail.

Que. Solving Skill.

$$F(x, \lambda, k) = 1 - e^{-\left(\frac{x}{\lambda}\right)^k}$$

$$\Rightarrow \quad e^{-(x/\lambda)^k} = 1 - F$$

take log. both side

$$-\left(\frac{x}{\lambda}\right)^k = \ln(1-F)$$

again log both side

$$-k.\ln\left(\frac{x}{\lambda}\right) = \ln(\ln(1-F))$$

$$-k\left(\underbrace{\ln x}_{x} - \ln\lambda\right) = \underbrace{\ln(\ln(1-F))}_{y}$$

slope $= -k$