ESO205P : Nature and Properties of the Materials

Module 6

- **Part A: Magnetic Hysteresis of a Material (Nickel)**
- **Part B: Electrical Characterization of Semiconductors**

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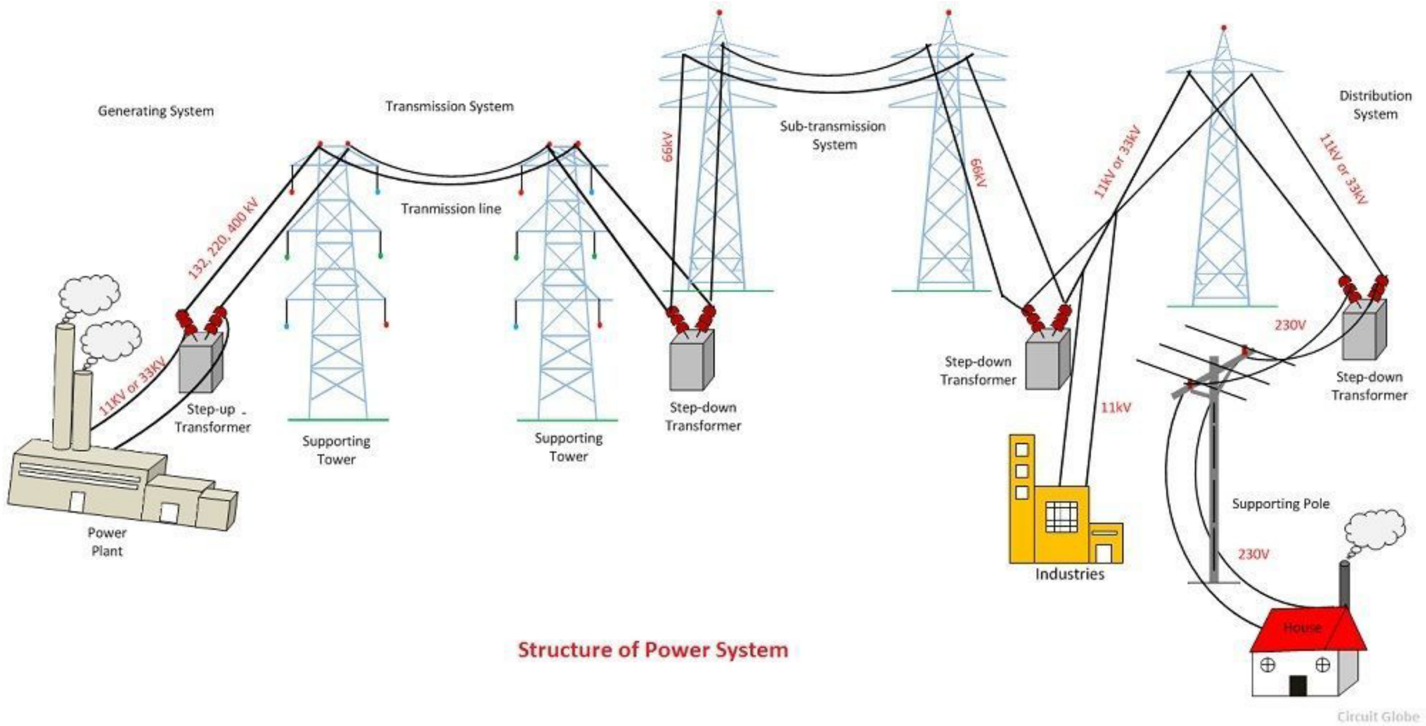
Part A: Magnetic Hysteresis of a Material (Nickel)

Transformers

- Why started with a transformer?
- Transformers do have Hysteresis losses.
- Since they are many number of transformers from generating end to consumer end these losses play a crucial role.

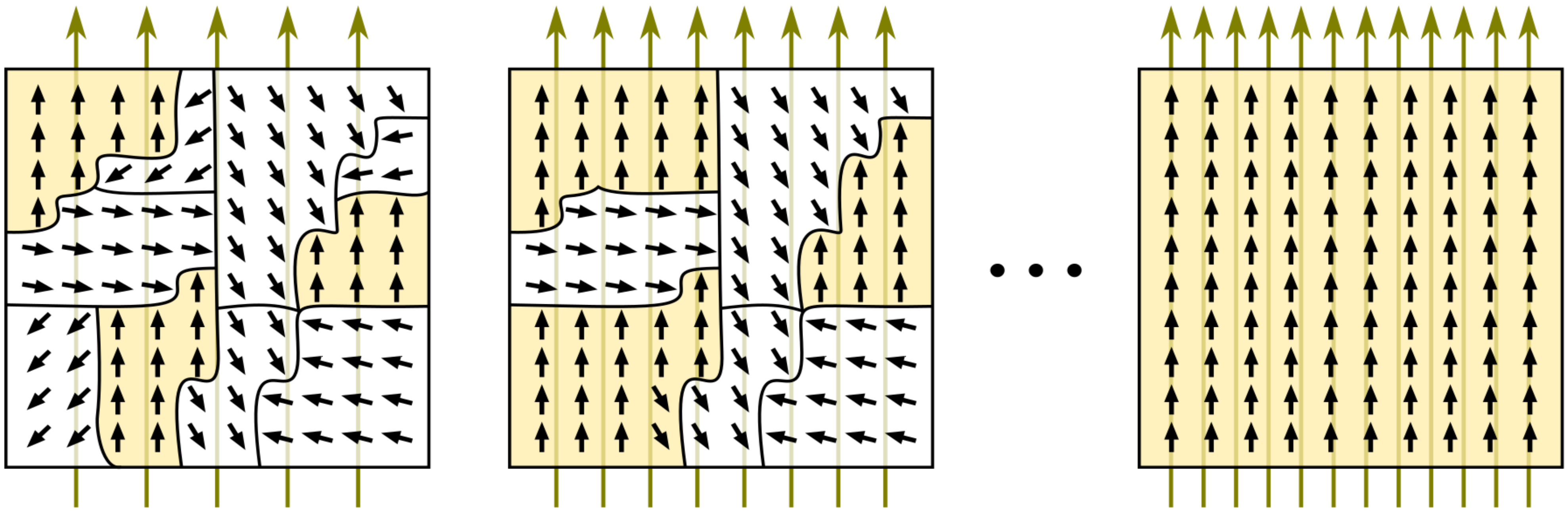


Structure of Power System

Part A: Magnetic Hysteresis of a Material (Nickel)

Domain Theory

- A domain is a small region in a magnetic material, within which the local magnetization is saturated, i.e. spins on all the atoms are parallel.
- In below figure: Number of lines indicates the strength of magnetic field.



Source: https://en.wikipedia.org/wiki/Magnetic_domain

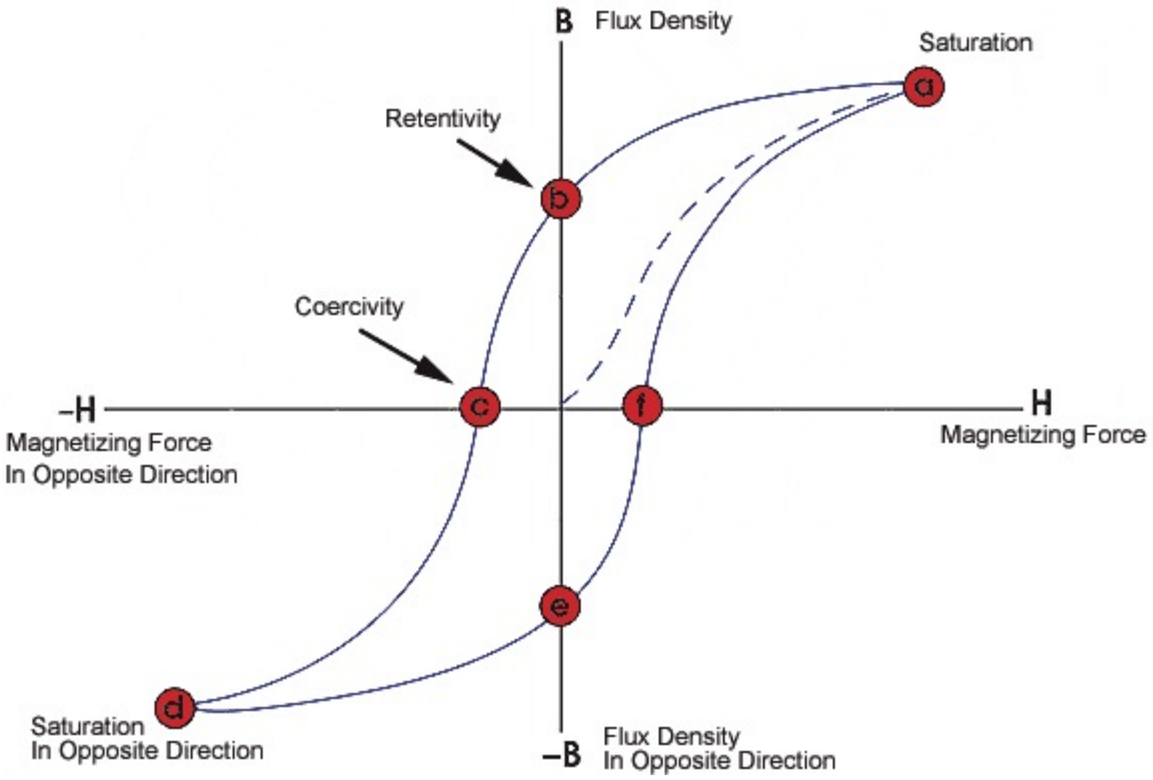
Part A: Magnetic Hysteresis of a Material (Nickel)

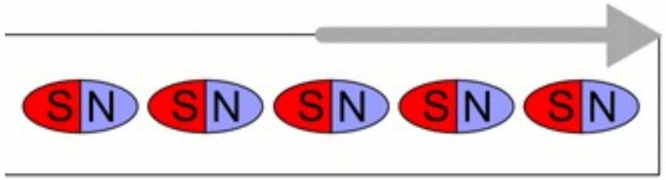
Parameters related to Hysteresis

- Saturation(B_s)
- Coercivity (H_c)
- Retentivity (B_r)

- Permeability (μ) = B/H

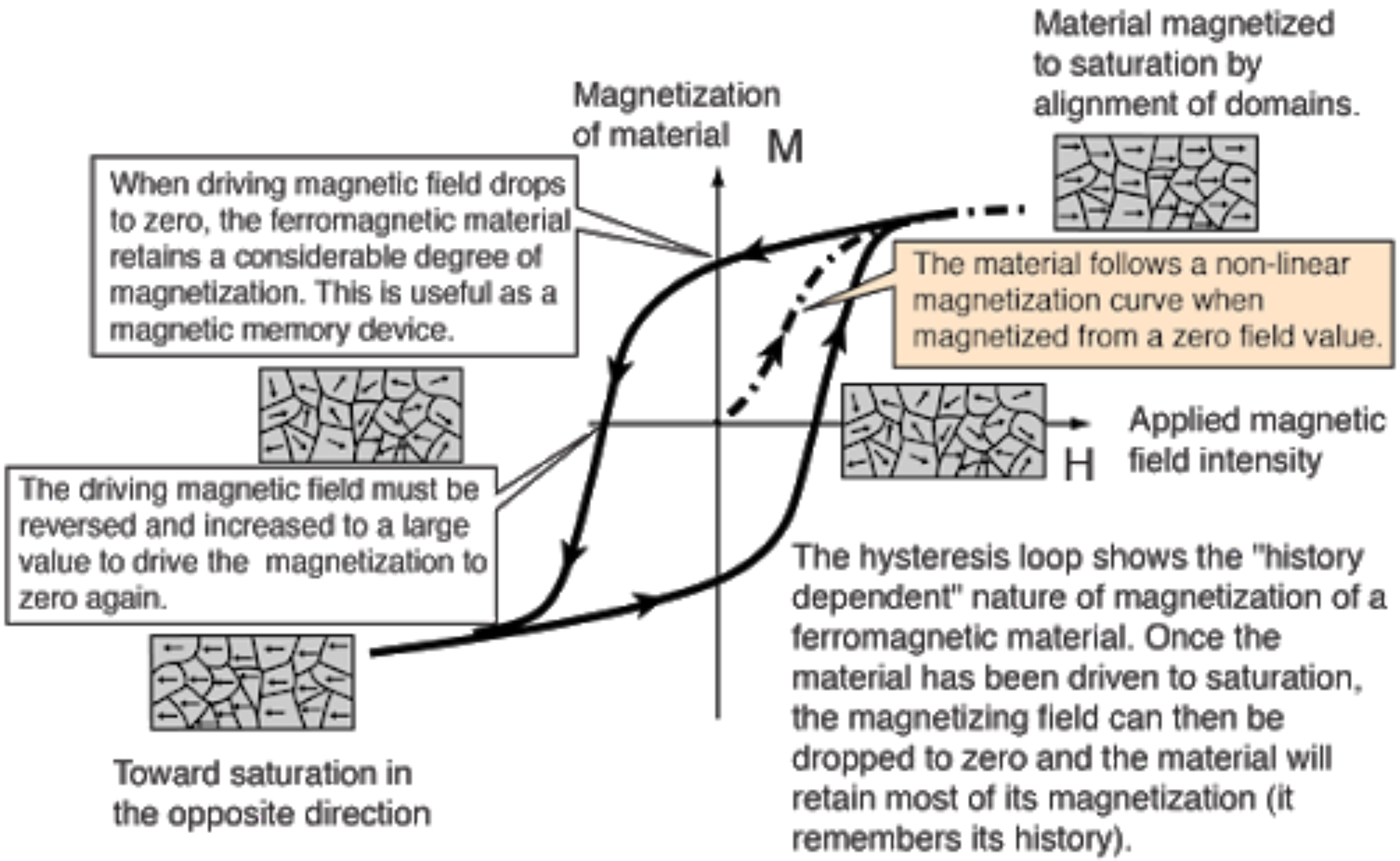
- Magnetostriction





Part A: Magnetic Hysteresis of a Material (Nickel)

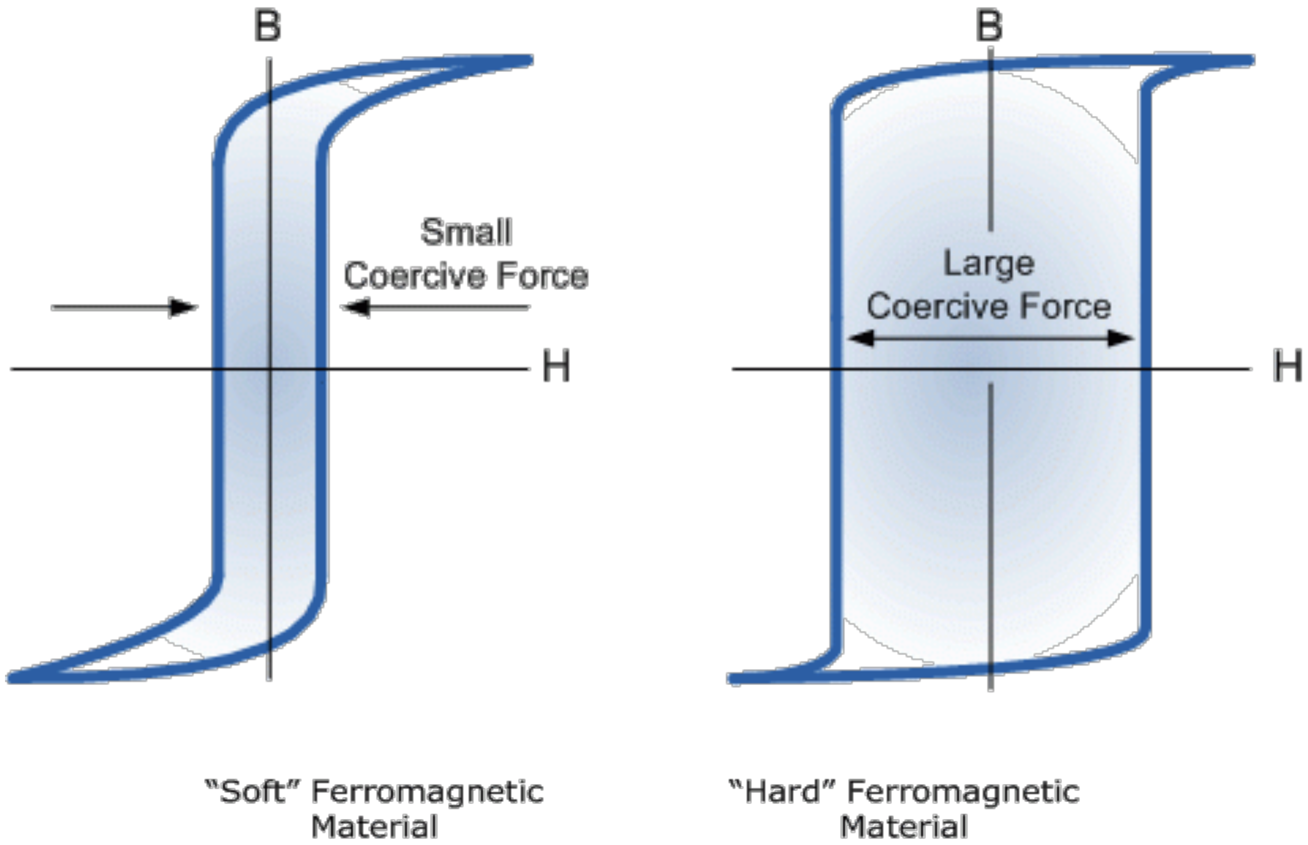
- Energy Loss: Area of the hysteresis loop



Part A: Magnetic Hysteresis of a Material (Nickel)

- Hard Ferromagnetic Material
- Soft Ferromagnetic Material

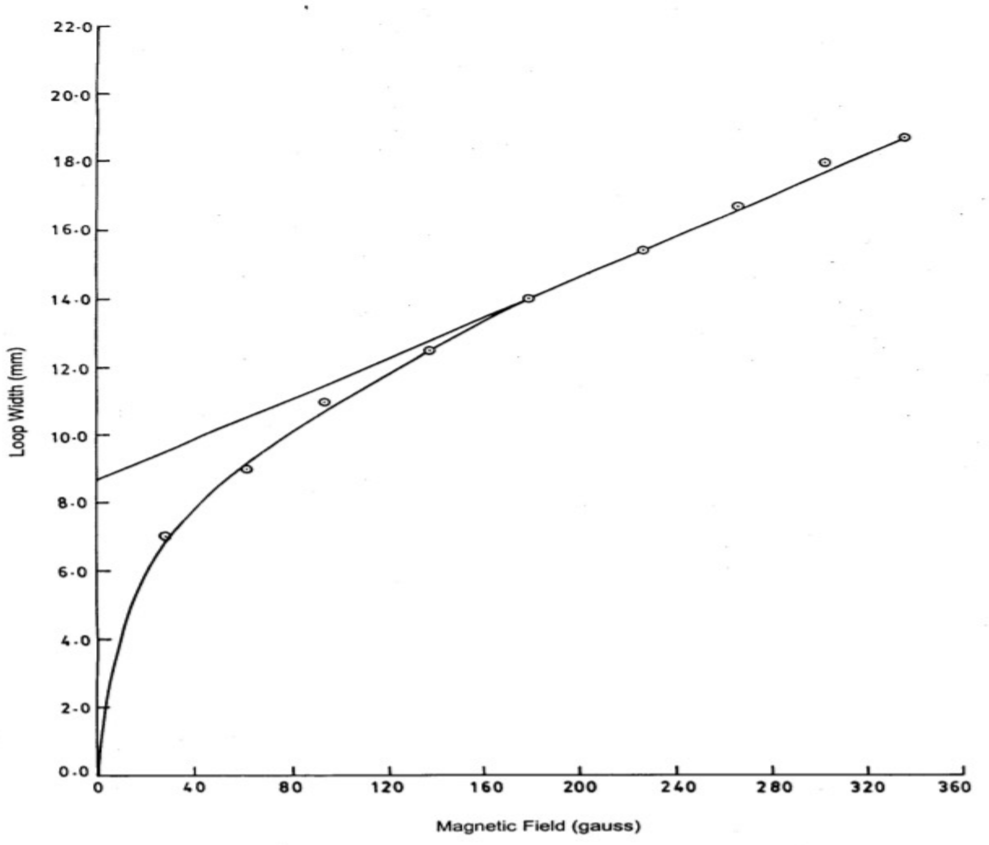
- Q) Which one has higher energy losses?



Part A: Magnetic Hysteresis of a Material (Nickel)

Math

Coercivity

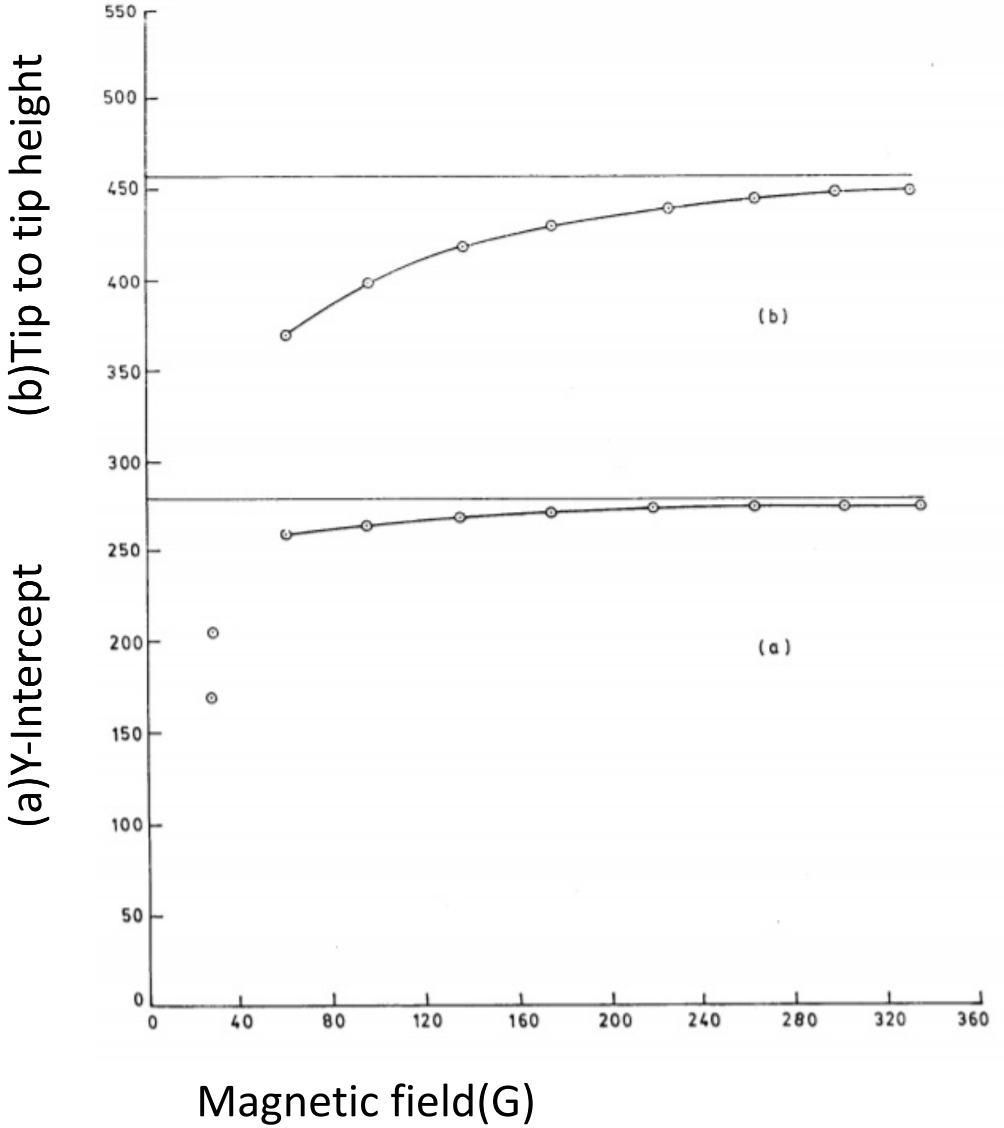


Draw a asymptote to the curve

Take Hc as half the value of intercept(at zero field) to the asymptote

Part A: Magnetic Hysteresis of a Material (Nickel)

Math



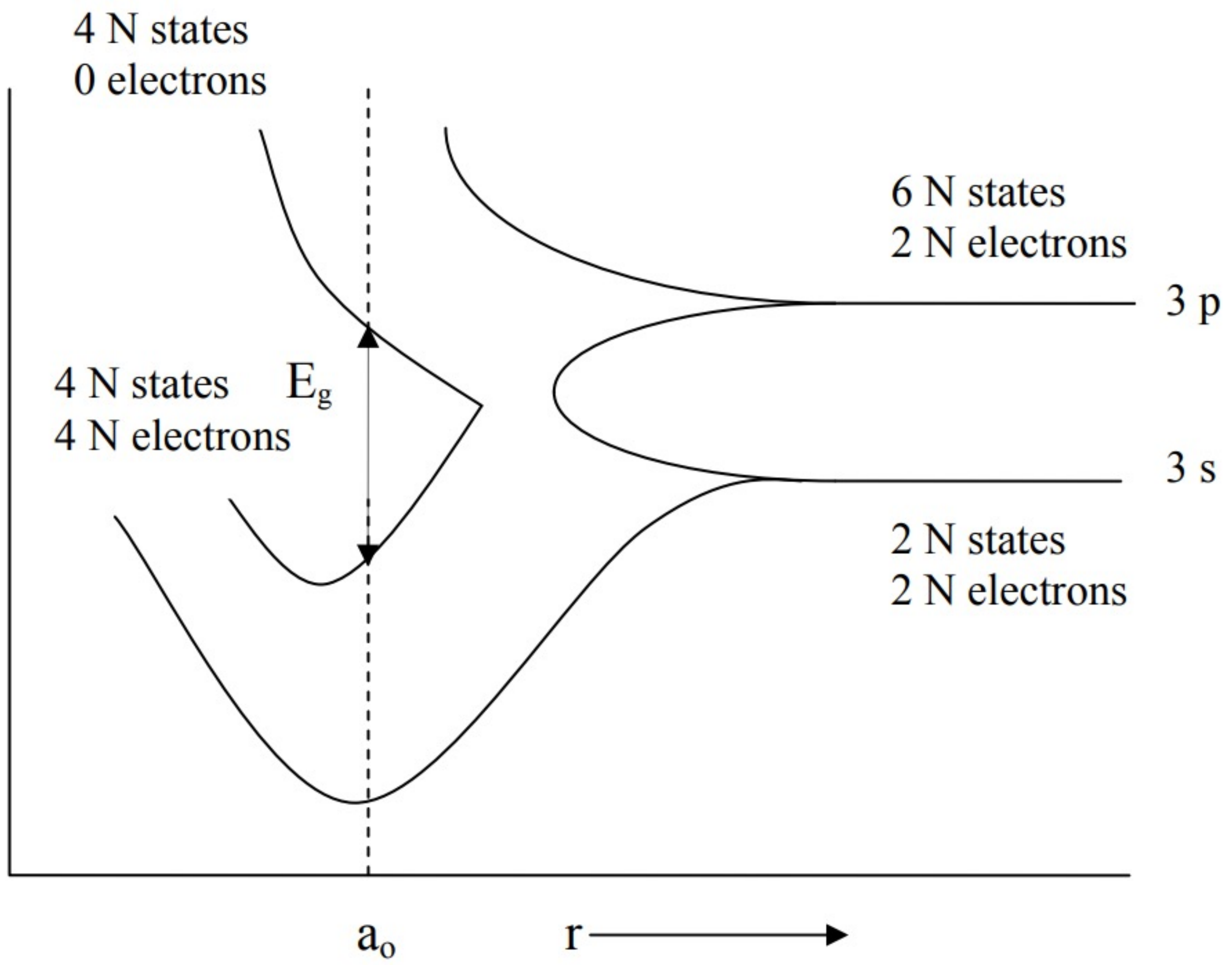
Retentivity: asymptotic value of the y-axis intercept

Saturation: half the asymptotic value of the tip- tip height

Part B: Electrical Characterization of Semiconductors

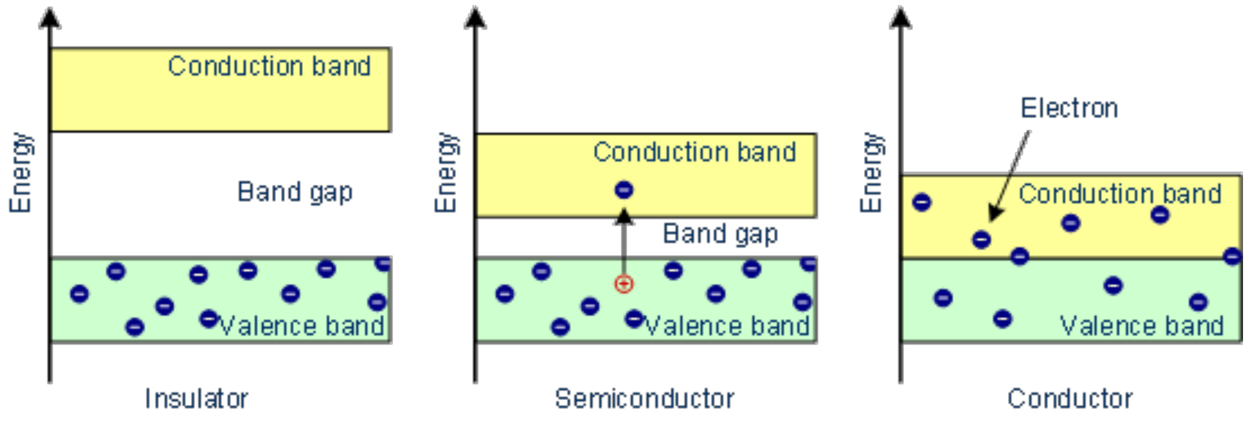
Bands and Energy Levels

- The solid has N atoms, each atomic level must split into N sub-levels
- The energy gap between the allowed energy bands is the forbidden energy gap or band gap E_g.
- The highest completely filled [i.e. occupied with electrons] energy band at 0K is called valence band.
- The next higher band is called the conduction band



Part B: Electrical Characterization of Semiconductors

Band gap of Metals, Semiconductors, Insulators



$E_g \sim 5ev$

$E_g \sim 2ev$

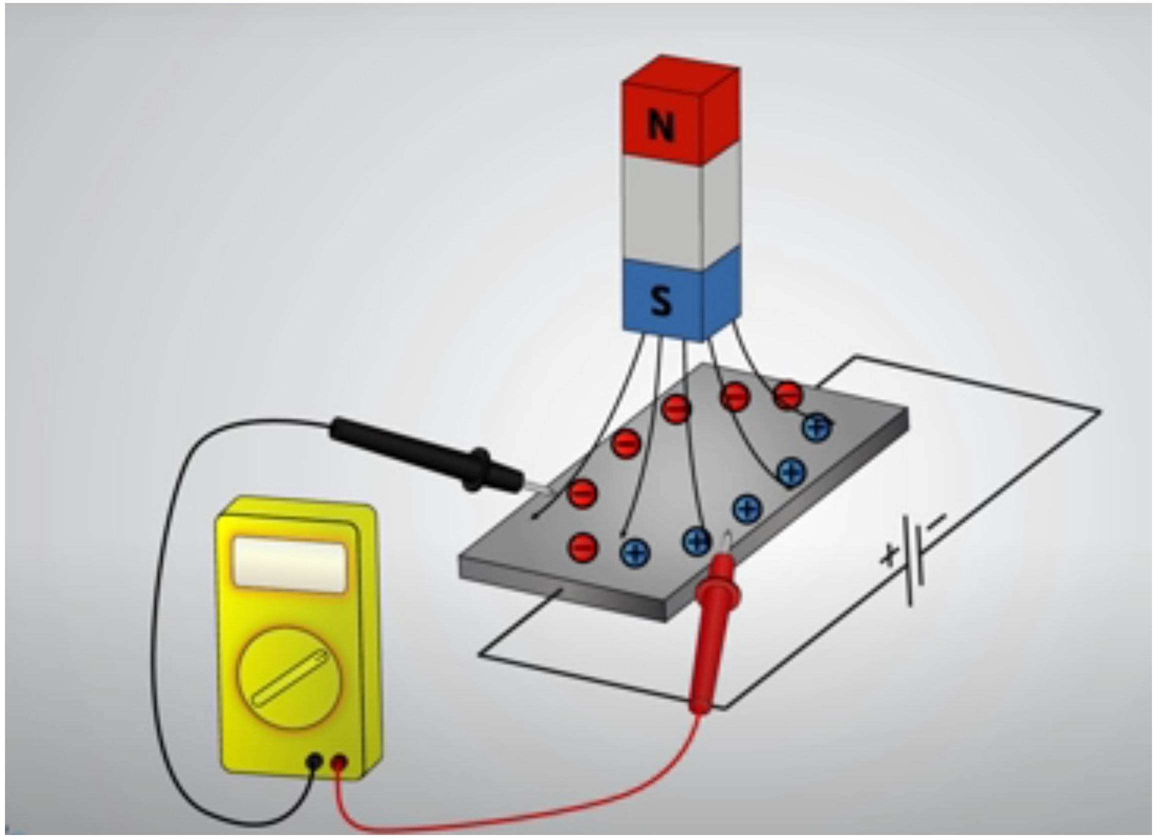
$E_g = 0ev$

Aim: To find the band gap of a semiconductor, resistivity and mobility of electrons.

Part B: Electrical Characterization of Semiconductors

Hall Effect

The Hall effect is the production of a voltage difference across an electrical conductor that is transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current.

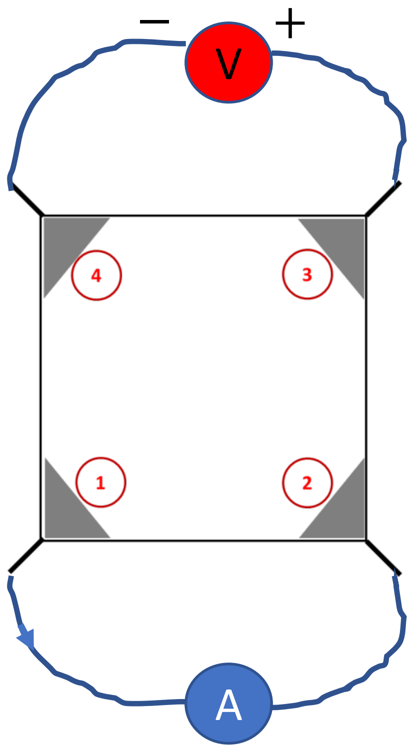


For better Understanding: https://www.youtube.com/watch?v=wpAA3qeOYiI&ab_channel=HowToMechatronics

Part B: Electrical Characterization of Semiconductors

Math

Van der pauw method



$$R_{12,34} = \frac{V_{34}}{I_{12}}$$

$$R_{34,12}, R_{21,43}, R_{43,21}$$

$$R_{Vertical} = \frac{R_{12,34} + R_{34,12} + R_{21,43} + R_{43,21}}{4}$$

$$R_{Horizontal} = \frac{R_{23,41} + R_{41,23} + R_{32,14} + R_{14,32}}{4}$$

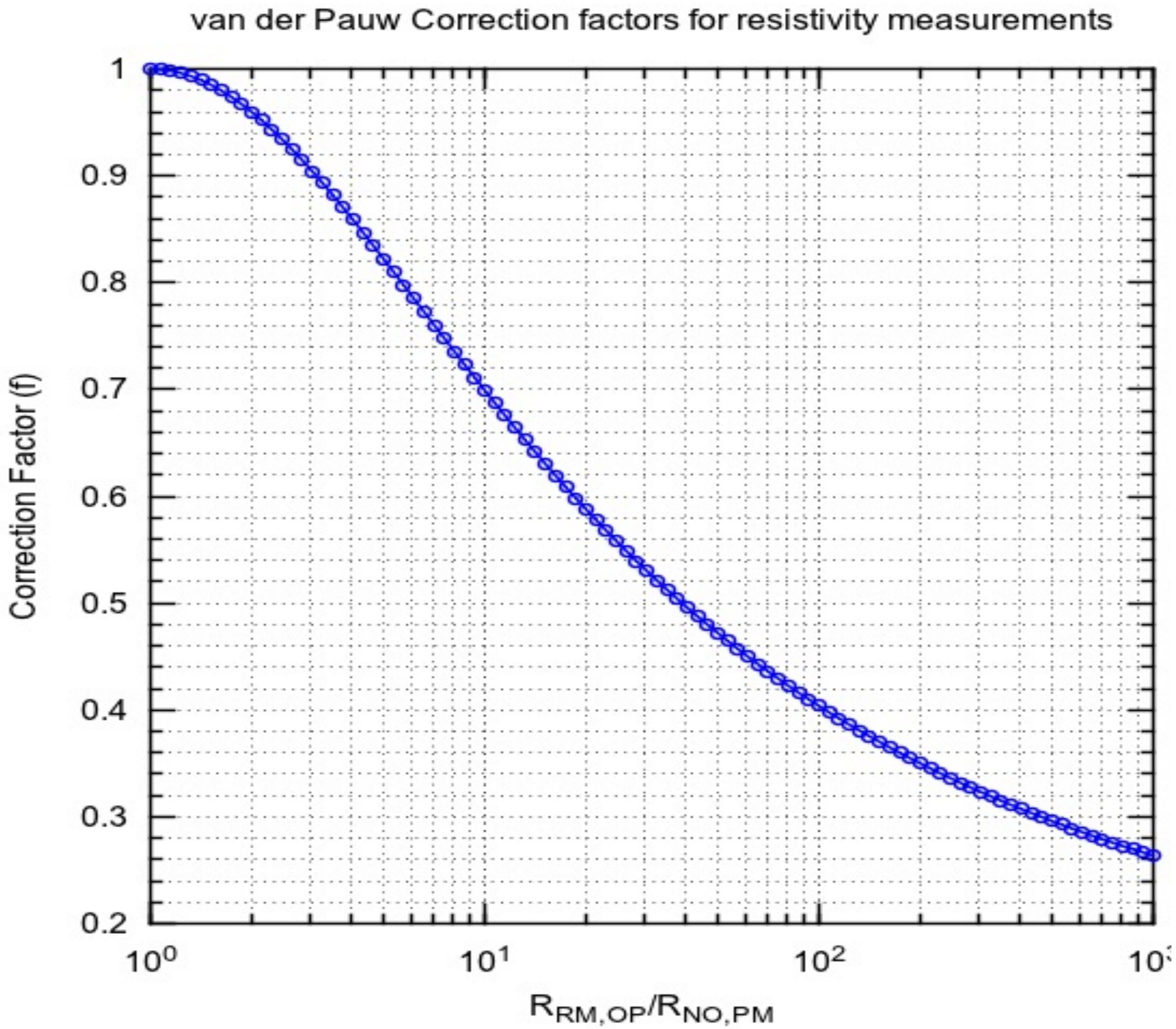
$$t = thickness$$

Part B: Electrical Characterization of Semiconductors

Math

$$\frac{R_{Vertical}}{R_{Horizontal}} \; or \; \frac{R_{Horizontal}}{R_{Vertical}} \geq 1$$

$$\rho = \frac{\pi}{\ln(2)}\, t \left(\frac{R_{Vertical} + R_{Horizontal}}{2}\right) f$$



Part B: Electrical Characterization of Semiconductors

Math

$Parameters\ we\ get\ \ Voltmeter\ reading\ (V), current\ applied\ (I), magnetic\ field (H)\ and\ thickness (t)$

$$\rho = \frac{1}{\sigma} \qquad \rho = resistivity\ , \sigma = conductivity$$

$$R_H = \frac{(V_H . t)}{IH} \qquad R_H = Hall\ co - efficient$$

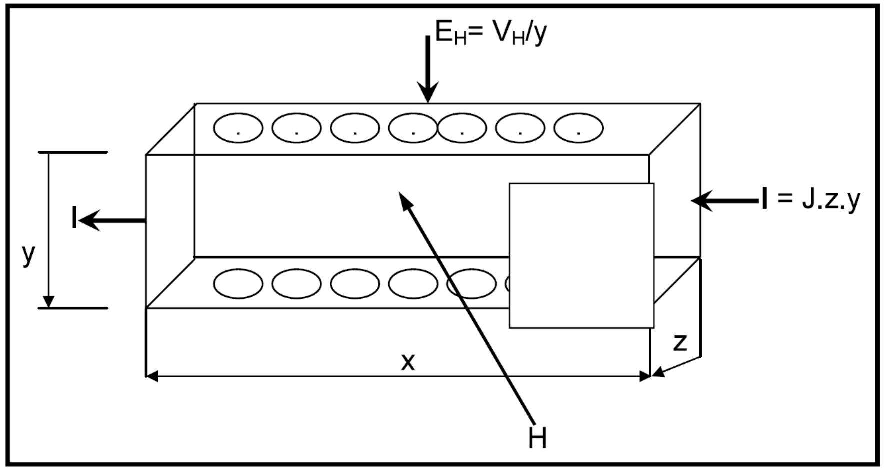
$$\mu = R_H\ . \sigma \qquad \mu = mobility$$

$Supporting\ equations$

$$R_H = \frac{(V_H.Z)}{IH} \qquad I = J.y.Z$$

$$v \times H = E_H \qquad R_H = \frac{E_H}{IH} = \frac{vH}{nqvH} = \frac{1}{nq}$$

$$\sigma = n\ q\ \mu \qquad \mu = R_H \sigma$$



Part B: Electrical Characterization of Semiconductors

Math

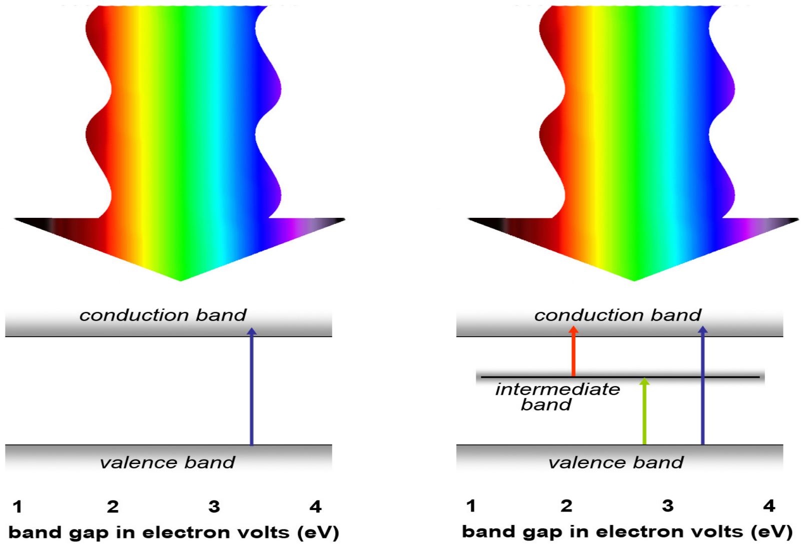
$Parameters\ we\ get\ \ Voltmeter\ reading\ (V), current\ applied\ (I), magnetic\ field (H)\ and\ thickness (t)$

$\rho = 4.532\ t\ \frac{V}{J}$; constant 4.532 depends upon various factors such as sample thickness, sample edges etc.

$$\rho = c\ \exp\left(\frac{E_g}{kT}\right) \Rightarrow \ln\frac{\rho}{c} = \frac{E_g}{kT}$$

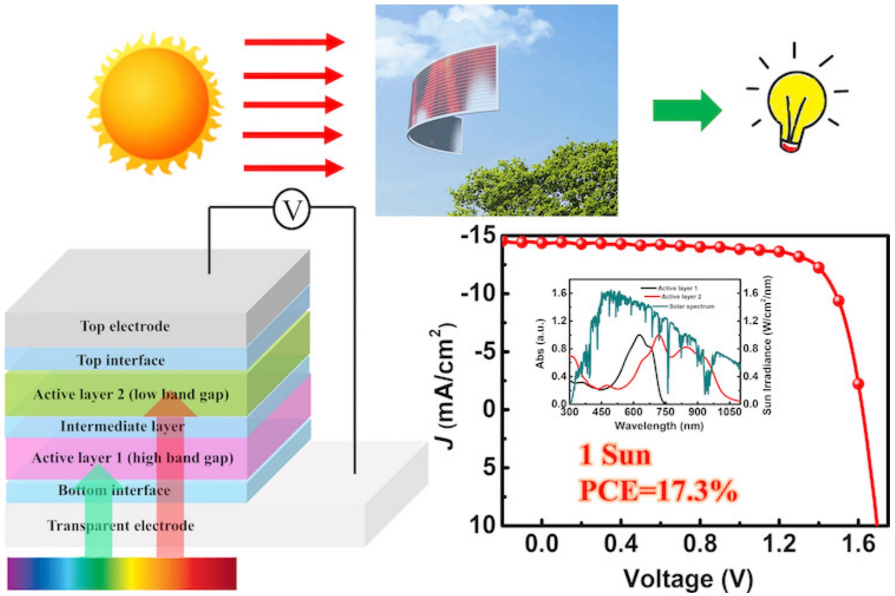
$using\ different\ data\ points\ by\ varying\ the\ temperature\ we\ find\ Eg$

Solar cells



Solar energy of visible region (VIBGYOR) will excite the electrons from valence band to conduction band if incoming solar energy is greater than the band gap.

Tandem Solar cells are used to capture both lower energy and higher energy to get optimized output of current and voltage.



Thank You