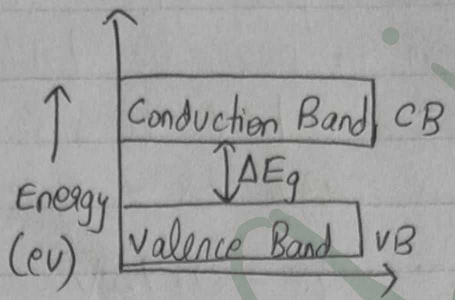
Semiconductors

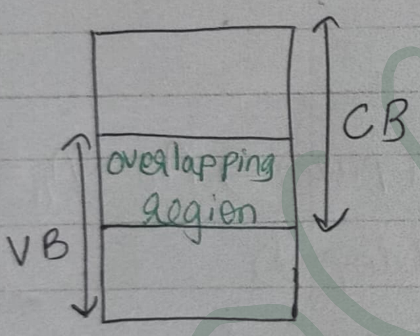
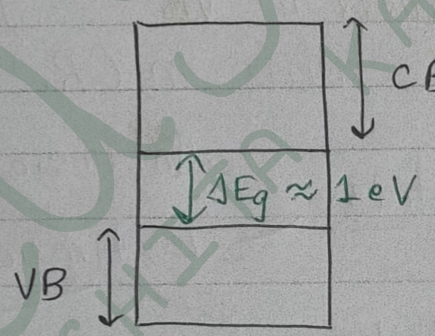
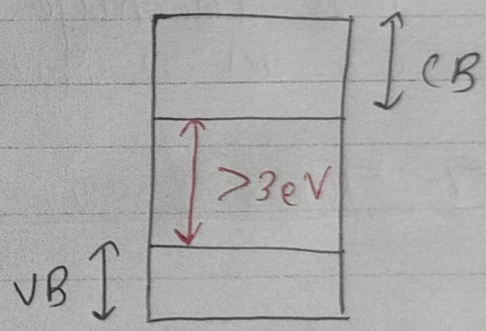
1. All electronic equipments require D.C. supply for operation (not A.C. supply).

2. $\Delta E_g = (CB)_{min} - (VB)_{max}$.
   ↳ Band gap / forbidden energy gap.



- Width of forbidden energy gap depends on the nature of substance.
- If width is more ⇒ the valence e^-s are more strongly attached with nucleus.
- As Temp. ↑es, ΔE_g ↓es (very slightly).

3.

Conductors	Semiconductors	Insulators
		
Cu, Fe, Al, Na, etc.	Si, Ge, GaAs, etc.	Diamond, wood, etc.
• $\Delta E_g = 0$ • ρ is low.	• $E_g < 3eV$ • σ, ρ are medium • e^-s can be thermally excited to CB.	• $E_g > 3eV$ • σ, ρ is high • no electrical conduction possible.

4. Examples of Semiconductors

Elemental : Si, Ge
Inorganic : CdS, GaAs
Organic : anthracene
Organic polymers : poly pyrrole, poly aniline, poly thiophene.

5. Properties of semiconductors

- –ve temp. coefficient (α)
- conduction properties may change by adding small impurities
- position in periodic table ⟶ IV group (generally)
- E_g – 0.1eV to 3eV
- charge carriers – e^-s and holes.

ΔE_g – Ge = 0.7eV Si = 1.1 eV.

6. Holes – it is missing e^- in VB
 – its effective mass is more than e^-
 – its mobility is less than e^-.

→ Hole acts as virtual charge, although there is no physical charge on it.

- Holes are charge carriers in VB
 e^-s act as charge carriers in CB.

7. Types of Semiconductors
 - Intrinsic (pure) $\Rightarrow n_e = n_h = n_i$
 - Extrinsic (doped)

N-type	P-type
• pentavalent impurity (P, As, Sb)	• trivalent impurity (B, Al, In)
• impurity atoms donate free e^-s for conduction ⇒ Donor impurity (N_D).	• impurity atoms accept bonded e^-s from VB ⇒ Acceptor impurity (N_A).
• majority = e^-s, minority = holes.	• majority = holes • minority = e^-s.
$n_e >> n_h$	$n_h >> n_e$.
$\therefore N_D \approx n_e$	$n_A \approx n_h$.

8. Mass Action Law – at thermal equillibrium –

$$\boxed{n_e n_h = n_i^2}$$

9. $J = neV_d$

$= ne\mu E$

$= \sigma E.$

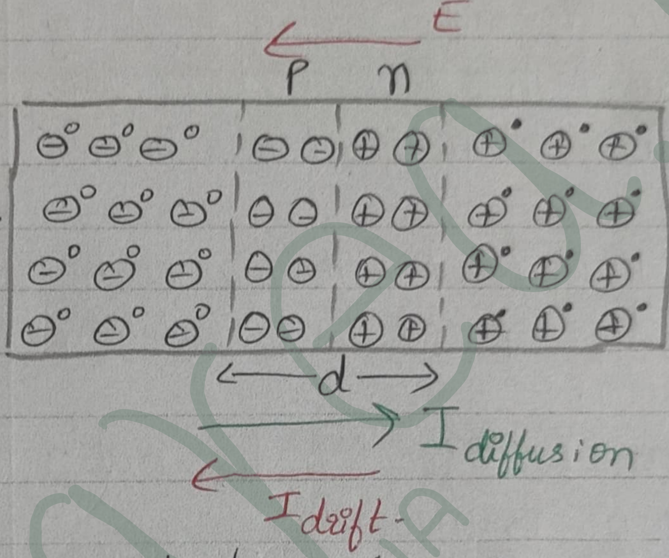
$I = neAV_d$

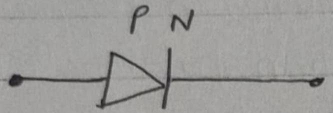
$\sigma = \frac{ne^2\tau}{m} = ne\mu$ $\quad \left(\mu = \frac{V_d}{E} = \frac{eE\tau}{mE} = \frac{e\tau}{m}\right).$

$\rho = \frac{1}{\sigma} = \frac{1}{ne\mu}.$

10. P-N Junction

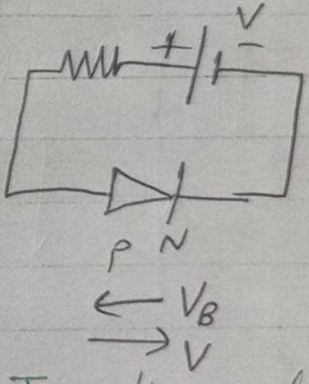
→ Barrier potential $= V_B = Ed.$





- n-side ⇒ high potential
- p-side ⇒ low potential.

11. Forward Bias - p-side = high potential
n-side = low potential.

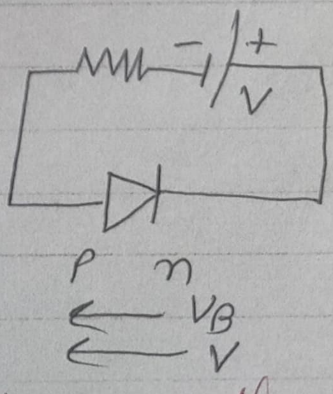


- applied voltage is opposite to the junction barrier voltage.
- effective barrier potential decreases.
- junction width decreases.
- Forward current (mA).

Mainly majority current flows.

In essence, I_{drift} is also in the direction of $I_{diffusion}$.

12. Reverse Bias - p-side = low potential
n-side = high potential.



- applied voltage is in same direction as the junction barrier voltage.
- effective barrier potential increases.
- junction width increases.
- current is very small (μA) Mainly minority current flows.

The current under reverse bias is essentially voltage independent upto a critical reverse bias voltage, known as breakdown voltage (V_{BR}).

when $V = V_{Br}$, the diode reverse current increases sharply. Even a slight increase in the bias voltage causes large change in current. This phenomenon is known as breakdown.

Zener Breakdown	Avalanche Breakdown
① Where covalent bonds of depletion layer, itself break due to high electric field of very high reverse bias voltage.	① Here covalent bonds of depletion layer are broken by collision of minorities which acquire high KE from high electric field of very-very high reverse bias voltage.
② This phenomenon takes place in – • P-N junction having high doping and thin depletion layer.	② This phenomenon happens in – P-N junction having low doping and thick depletion layer.
③ Here P-N junction does not damage permanently. In DC voltage stabilizer, zener phenomenon is used.	③ Here P-N junction damages permanently due to abrupt increment of minorities during repetetive collisions.