# Semiconductor Electronics: Materials, Devices and Simple Circuits

Class 12 · Physics · Quick Revision · **chapternotes.in**

NEET: 3-4 Qs (~12-16 marks) | Boards: 6-8 marks

Scan: practise free

How energy bands sort solids, how doping makes n-type/p-type, and how the p-n junction builds diodes, rectifiers, special diodes, transistors and logic gates.

## 1. Energy Bands: Conductor, Semiconductor, Insulator

*The forbidden gap $E_g$ between valence and conduction bands decides the class.*

**$E_g = E_{CB} - E_{VB}$**
band gap in eV (1 eV = $1.6\times10^{-19}$ J)

**Metal: $E_g \approx 0$ (bands overlap)**
free electrons, high σ

**Semiconductor: $E_g \approx 1$ eV**
Si ≈ 1.1 eV, Ge ≈ 0.7 eV

**Insulator: $E_g > 3$ eV**
diamond ≈ 6 eV

**MUST KNOW** Semiconductor conductivity RISES (resistance falls) with temperature - negative temp. coefficient, opposite to a metal.

**MUST KNOW** At 0 K a pure semiconductor is a perfect insulator (conduction band empty); each electron promoted leaves a hole.

- Band gap $E_g$ (≈1.1 eV for Si) is NOT the diode barrier potential $V_b$ (≈0.7 V for Si).

## 2. Intrinsic vs Extrinsic (Doping)

*Pure semiconductor has equal carriers; doping makes n-type or p-type.*

**Intrinsic: $n_e = n_h = n_i$**
thermal pairs only

**$n_e \cdot n_h = n_i^2$ (mass action)**
constant at fixed T

**n-type: pentavalent donor (As, P, Sb)**
electrons majority

**p-type: trivalent acceptor (B, Al, In)**
holes majority

**MUST KNOW** Mass-action law: raising majority carriers by doping LOWERS the minority - it is a trade, not a free boost of both.

**MUST KNOW** A doped crystal is electrically NEUTRAL overall; each donated electron is balanced by a fixed positive donor ion.

- Donor level sits just below CB (n-type); acceptor level sits just above VB (p-type).

## 3. The p-n Junction & Biasing

*Diffusion leaves fixed ions, building a depletion layer with a barrier potential.*

**$V_b \approx 0.7$ V (Si), ≈ 0.3 V (Ge)**
barrier potential

**Forward bias: p to +, n to −**
barrier & width DECREASE, conducts

**Reverse bias: p to −, n to +**
barrier & width INCREASE, blocks

**$I_{reverse}$ = reverse saturation current**
minority carriers, temp-dependent

**MUST KNOW** Depletion width decreases in forward bias, increases in reverse bias; diode conducts only one way.

**MUST KNOW** The depletion region exists even with NO external battery - it is built-in by diffusion + recombination.

- Reverse current is carried by MINORITY carriers and rises with temperature.

## 4. Diode as Rectifier (Half / Full Wave)

*One-way conduction converts AC to DC; full-wave is more efficient.*

**Half-wave: $f_{out} = f$**
one diode, one pulse/cycle

**Full-wave: $f_{out} = 2f$**
centre-tap (2 diodes) or bridge (4)

**$V_{dc}$ (half-wave) = $V_{peak}/\pi$**
average DC output

**$V_{dc}$ (full-wave) = $2V_{peak}/\pi$**
ripple factor lower

**MUST KNOW** Half-wave output ripple = input frequency f; full-wave output ripple = 2f. A capacitor filter smooths the pulsating DC.

- In a bridge rectifier, 2 diametrically opposite diodes conduct each half-cycle while the other 2 are reverse biased.

## 5. Special Diodes (Zener, LED, Photodiode, Solar)

*Each special diode has one job set by its bias and material.*

**Zener: reverse breakdown**
voltage regulator, heavily doped

**LED: forward biased**
emits light, $V_O$ = output; GaAs/GaAsP not Si/Ge

**Photodiode: reverse biased**
detects light, I rises with light

**Solar cell: NO external bias**
generates emf (photovoltaic)

MUST KNOW Zener works in REVERSE breakdown (regulator); a photodiode is REVERSE biased (large fractional ΔI is easier to measure).

MUST KNOW Si/Ge make poor LEDs - small/indirect gap gives heat or IR, not visible light; LEDs need wide direct-gap materials.

- Photodiode DETECTS light (needs bias); solar cell GENERATES power (no bias) - do not confuse them.

## 6. Transistor & Logic Gates

*A small base current controls a large collector current; gates are the digital building blocks.*

**$I_E = I_B + I_C$**
emitter current is largest

**$\beta = I_C/I_B$**
CE current gain, ~50-300

**$\alpha = I_C/I_E$**
slightly less than 1

**$\beta = \alpha/(1-\alpha)$**
links the two gains

MUST KNOW Active mode: emitter-base FORWARD biased, collector-base REVERSE biased; base is thin & lightly doped, emitter heavily doped.

MUST KNOW CE amplifier inverts the signal - input and output are 180° out of phase. Cutoff = OFF, saturation = ON (switch).

- NAND and NOR are UNIVERSAL gates (any circuit from them alone); OR: Y=A+B, AND: Y=A·B, NOT: Y=Ā.

### n-type vs p-type

| | n-type | p-type |
|---|---|---|
| Dopant | Pentavalent (As, P, Sb) | Trivalent (B, Al, In) |
| Impurity role | Donor | Acceptor |
| Majority carrier | Electrons | Holes |
| Minority carrier | Holes | Electrons |
| Impurity level | Just below CB | Just above VB |

### Band Gap of Solids

| Solid | Band gap $E_g$ | Bands |
|---|---|---|
| Conductor (metal) | ≈ 0 eV | VB & CB overlap |
| Semiconductor | ≈ 1 eV (Si 1.1, Ge 0.7) | Small gap |
| Insulator | > 3 eV (diamond ≈ 6) | Large gap |

**Mnemonic - Dopant valency to carrier type: pentavalent gives n-type, trivalent gives p-type**
PeNta → N-type (electrons); Tri → P-type (holes)

**Common traps**

- Band gap $E_g$ (1.1 eV for Si) is NOT the barrier potential $V_b$ (0.7 V for Si) - keep the two separate.
- An n-type crystal is electrically NEUTRAL, not negatively charged; only its mobile carriers are mostly electrons.
- Ripple frequency: half-wave → f, full-wave → 2f. Swapping these is the classic rectifier blunder.
- Zener regulates in REVERSE breakdown and a photodiode is REVERSE biased - only the LED is forward biased.
- Emitter current is largest: $I_E = I_B + I_C$, NOT $I_C = I_E + I_B$.

**Most asked in NEET »** n-type vs p-type / dopant valency | Mass-action law $n_e n_h = n_i^2$ | Forward vs reverse bias & depletion width | Half-wave vs full-wave ripple (f, 2f) | LED/photodiode band gap → wavelength ($E_g = hc/\lambda$) | Transistor gains $\beta = \alpha/(1-\alpha)$