Physics: Waves and Optics & Quantum Mechanics
Subject code: BSC-PHY-102G

EEE

IIst Semester

Unit 4: Introduction to solids and semiconductors

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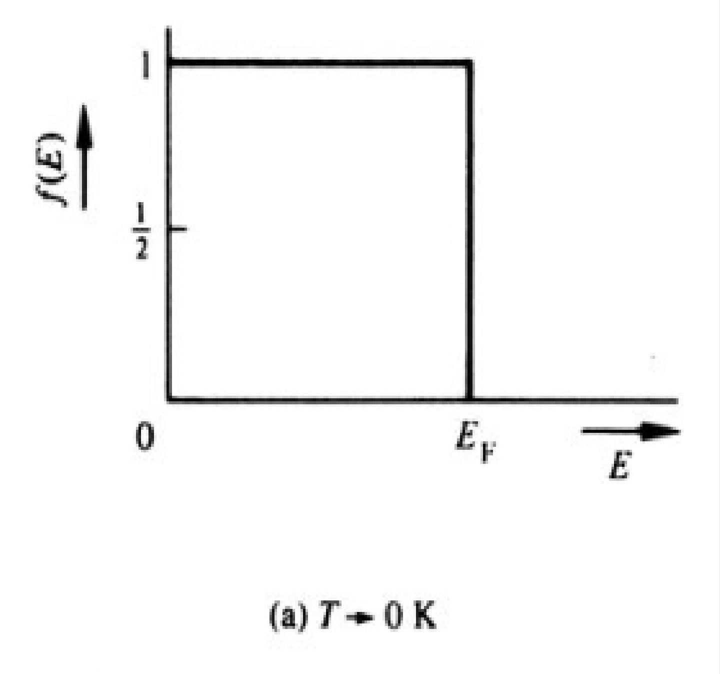
Classical free electron theory: Drude-Lorentz theory

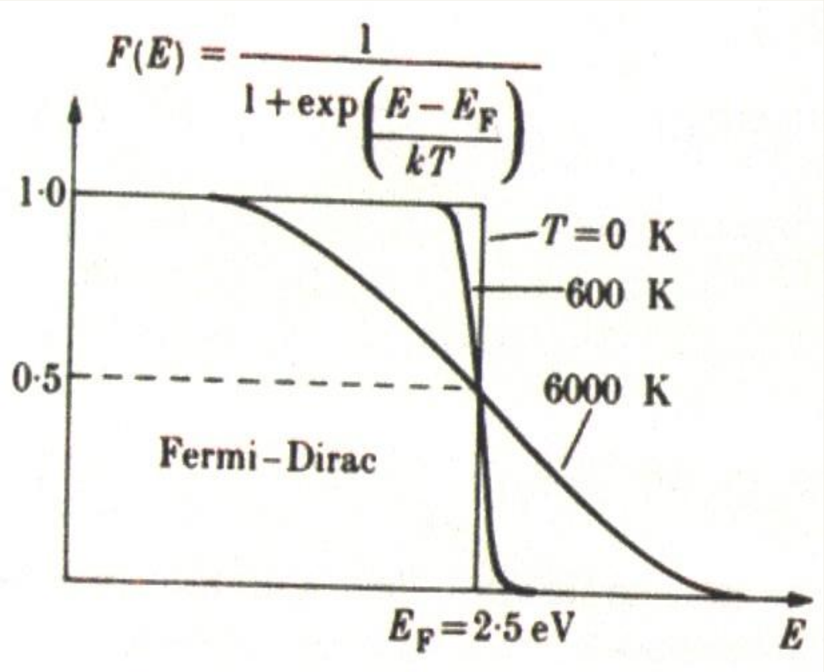
- Metals consist of large number of free electrons that behaves like a molecules of perfect gas.
- Assembly of free electrons in a metal: free electron gas
- Random motion of free electron gas: speed is function of temperature, no practical contribution to conductivity
- On application of external field, random motion is modified, e- have some drift velocity
- All valence electrons can absorb energy. Average K.E.= 3/2 KT
- Follows Maxwell-Boltzman statistics
- Potential is uniform everywhere inside the crystal
- P.E. of electron inside the metal is neglected. Therefore, Total Energy= K.E.

Failure of Classical free electron theory

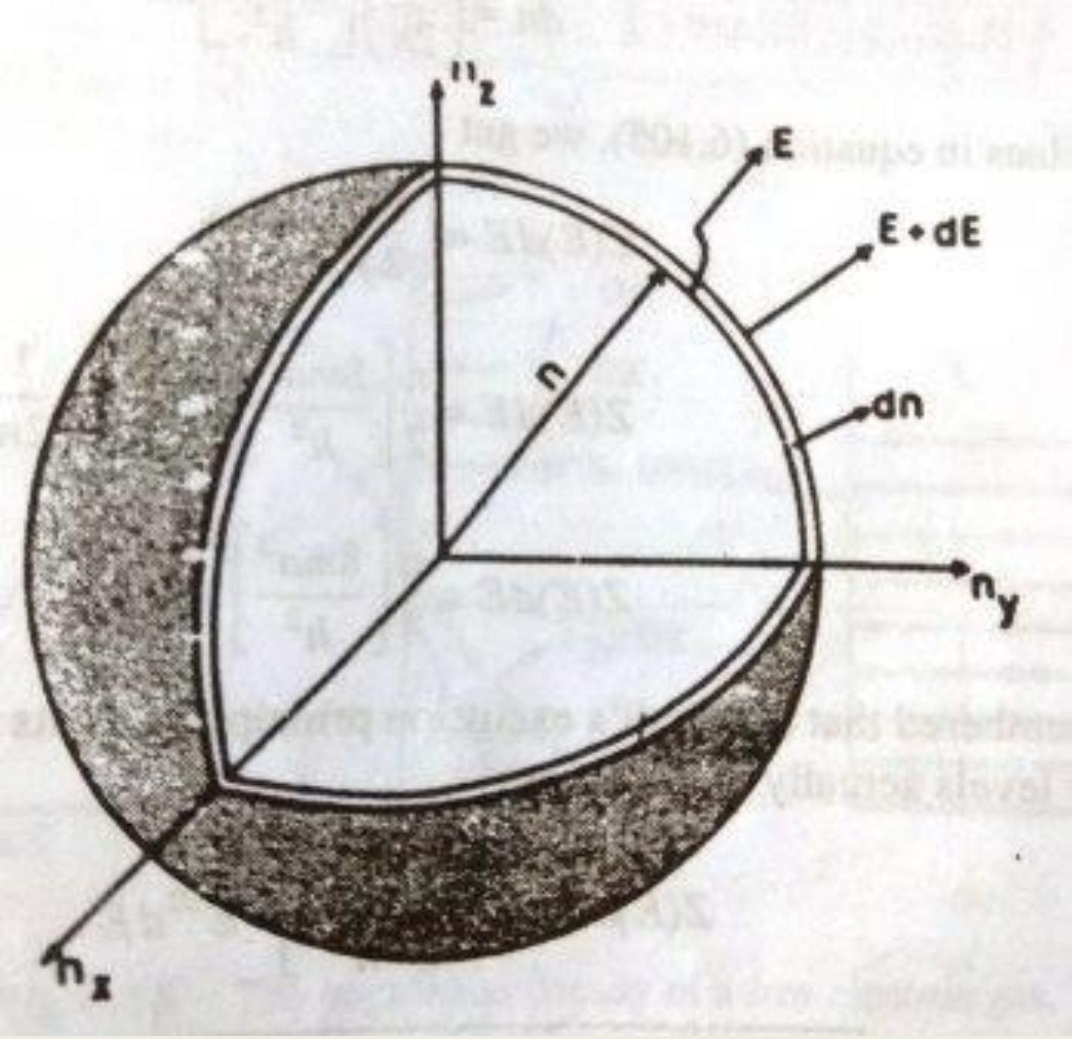
- Could not explain heat capacity of free electron gas
- Could not explain paramagnetic susceptibility of free elelctrons
- Could not explain variation in electrical conductivity with temperature
- Could not explain Wiedemann-Frenz law
- Could not explain long mean free path at low temperatures

Fermi-Dirac Statistics: Occupation Probability





Density of states



Failures of Quantum free electron theory

- This theory did not include mean free path.
- Could not explain conductivity of divalent and trivalent atoms
- Relaxation time is assumed to be same for thermal and electrical conductivity but they are not same. Phonons also carry thermal energy.
- Fermi surface considered spherical but it is not spherical
- Could not explain metallic properties of crystals

Material	Valency	ρ (Ω•m) at 20 °C Resistivity	σ (S/m) at 20 °C Conductivity
Silver	1	1.59×10^{-8}	6.30×10^{7}
Copper	1,2	1.68×10^{-8}	5.96×10^{7}
Gold	1,3	2.44×10^{-8}	4.10×10^{7}
Aluminum	3	2.82×10^{-8}	3.5×10^{7}
Zinc	2	5.90×10^{-8}	1.69×10^{7}

Band theory of solids

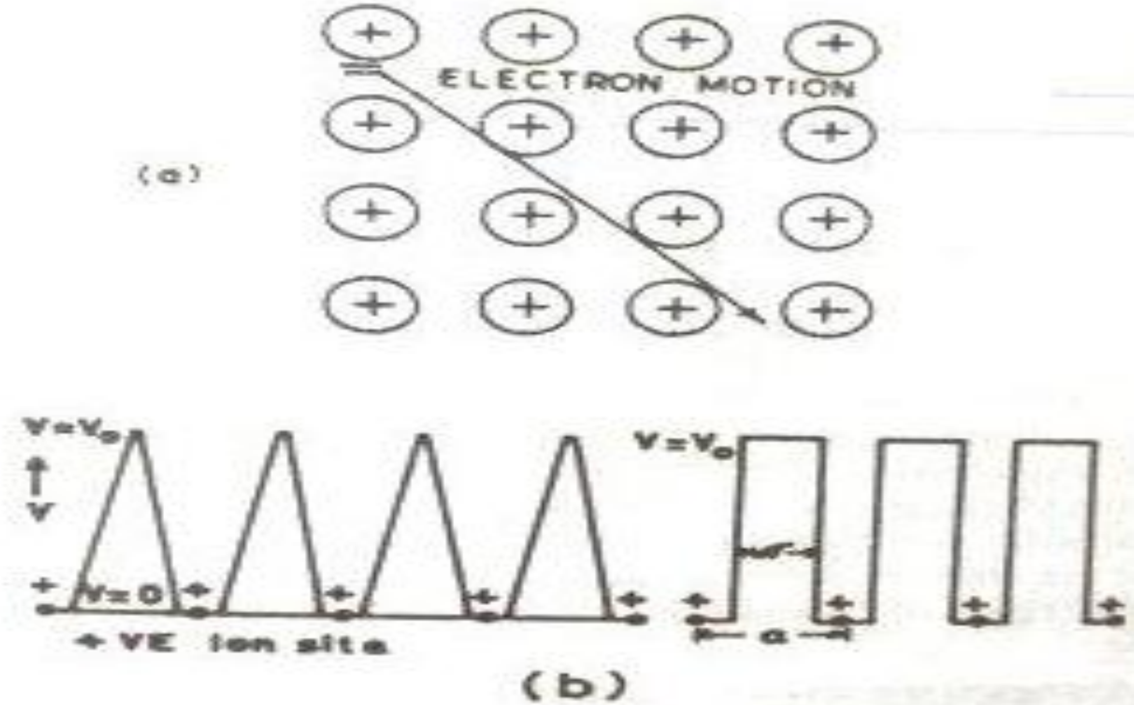
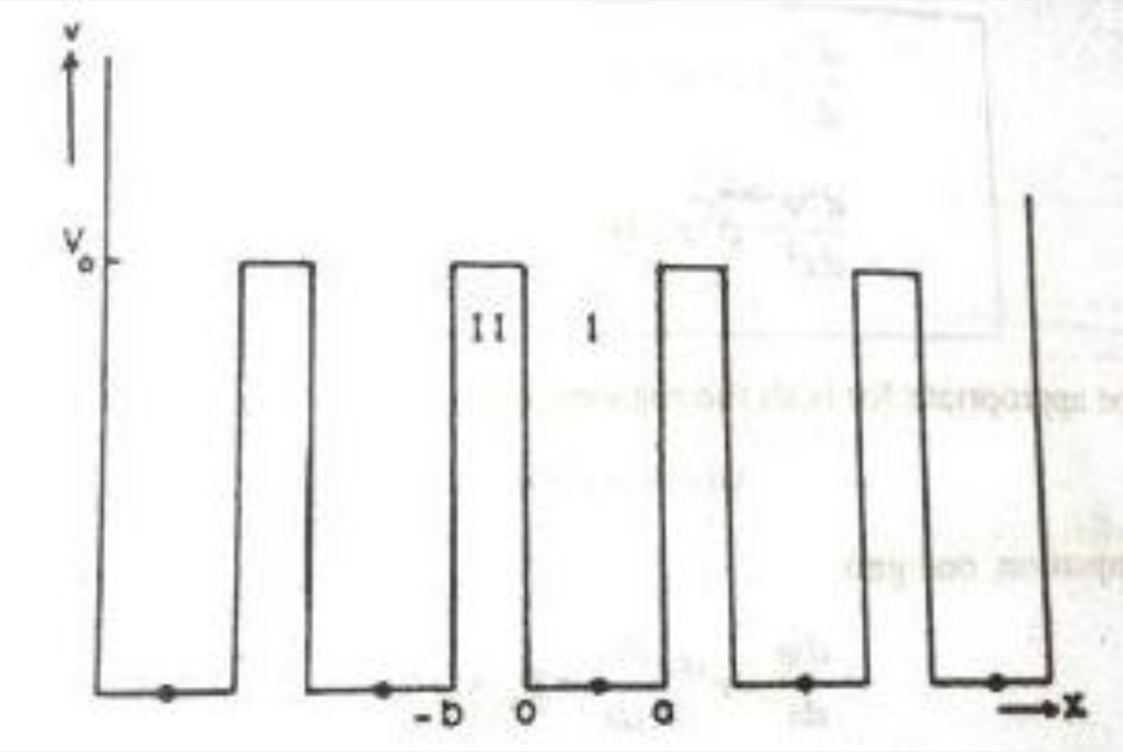
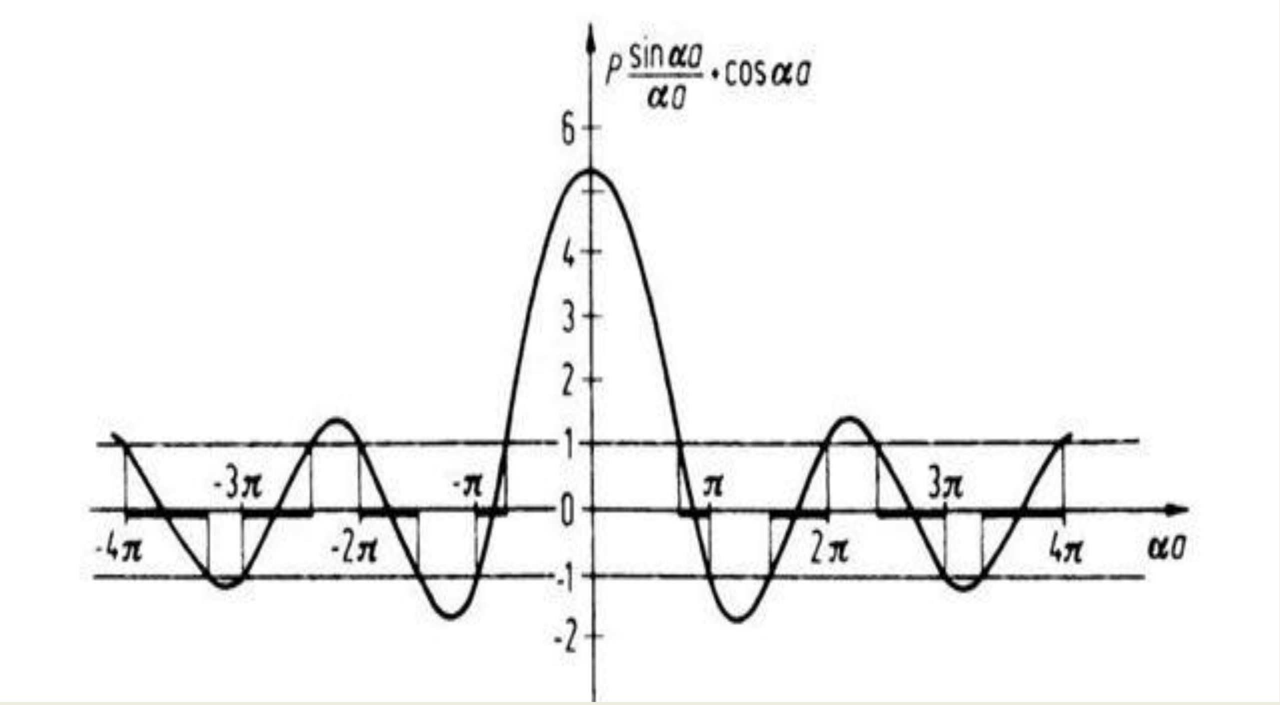


Fig. 6.42 One dimensional periodic potential distribution for a crystal.

Kronig- Penney Model





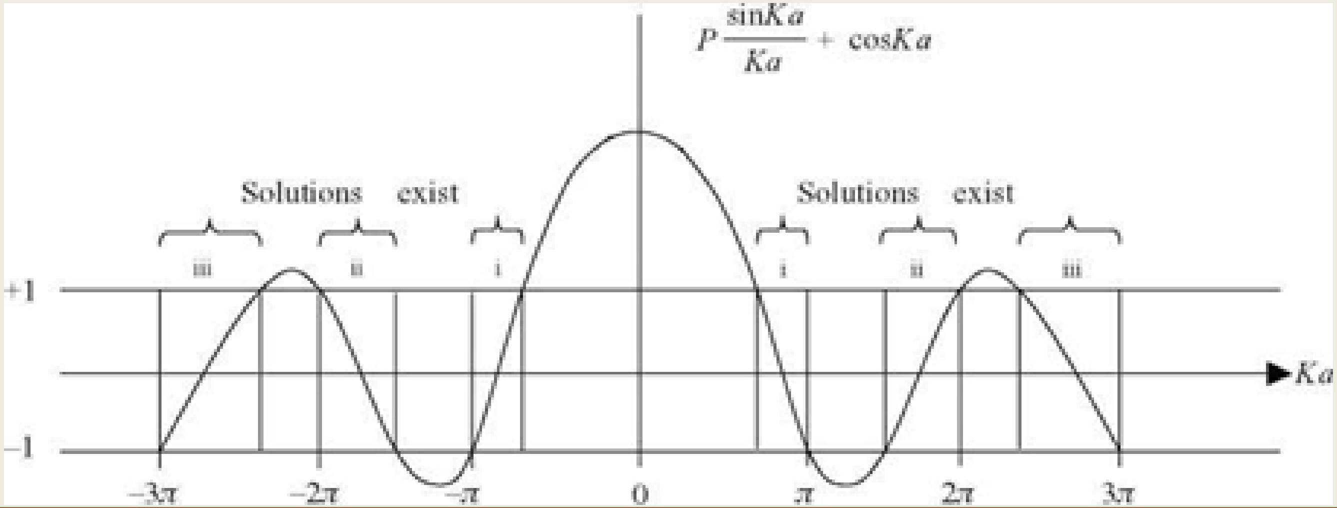


Figure 1.2 Graph of right hand side of Equation 1.8 as a function of P for P = 2

Drift and diffusion current

- Drift current is the electric current, or movement of charge carriers, which is due to the applied electric field, often stated as the electromotive force over a given distance. When an electric field is applied across a semiconductor material, a current is produced due to the flow of charge carriers.
- Diffusion Current is a current in a semiconductor caused by the diffusion of charge carriers (holes and/or electrons). This is the current which is due to the transport of charges occurring because of non-uniform concentration of charged particles in a semiconductor.

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P-N Junction

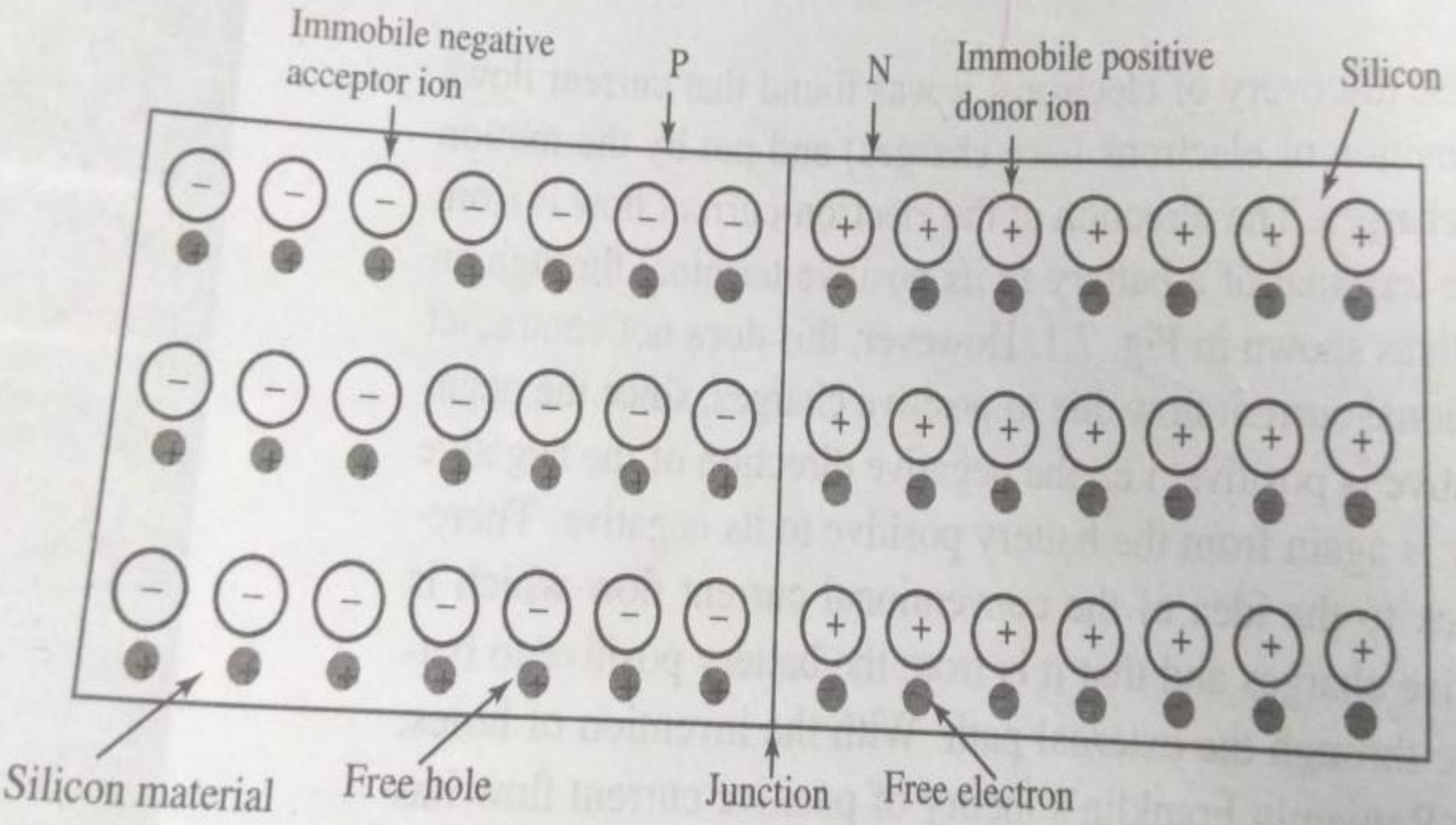

Fig. 7.2 *P-N junction immediately after its formation*

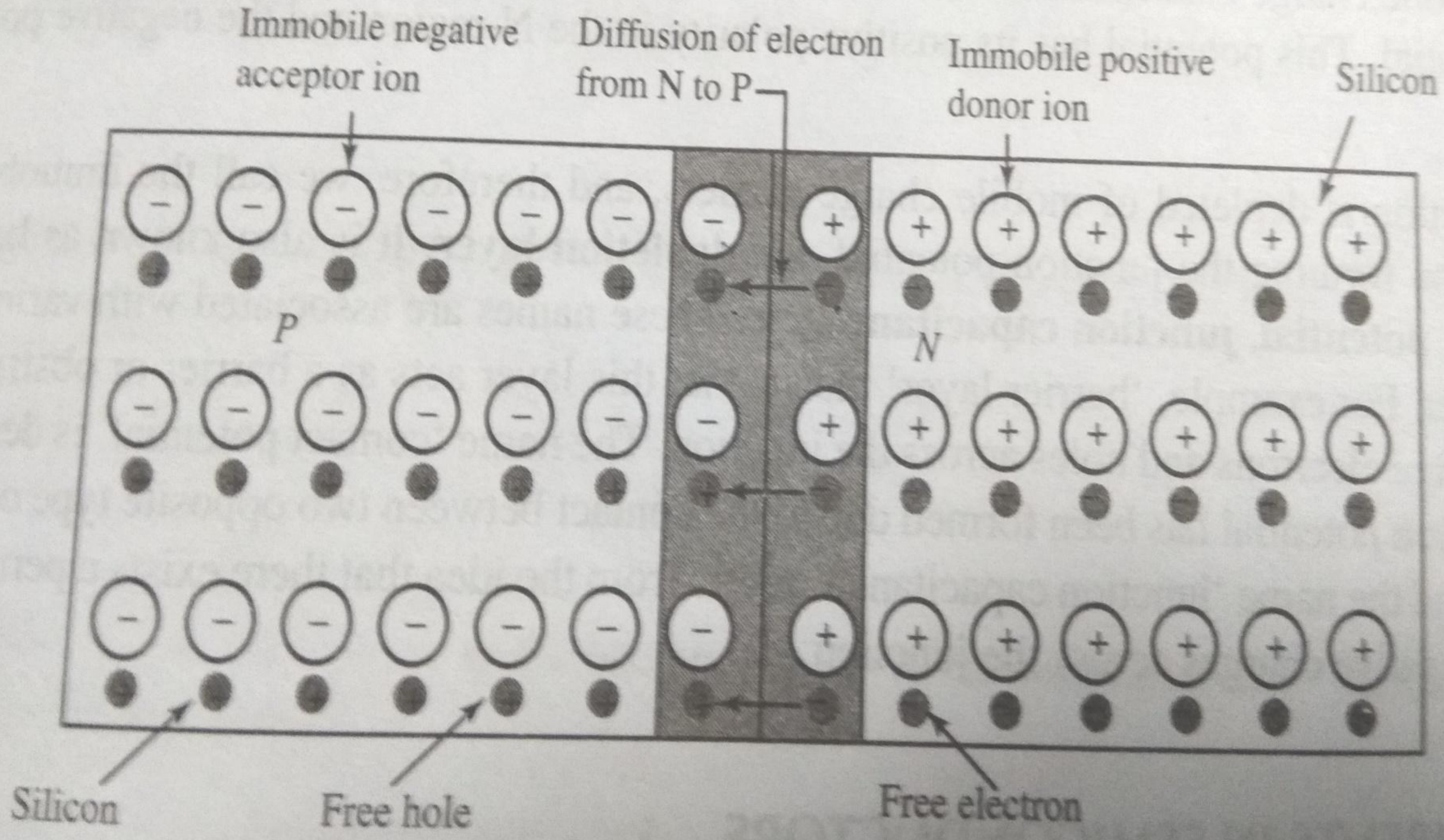

Fig. 7.3 *Electron-hole diffusion across the junction*

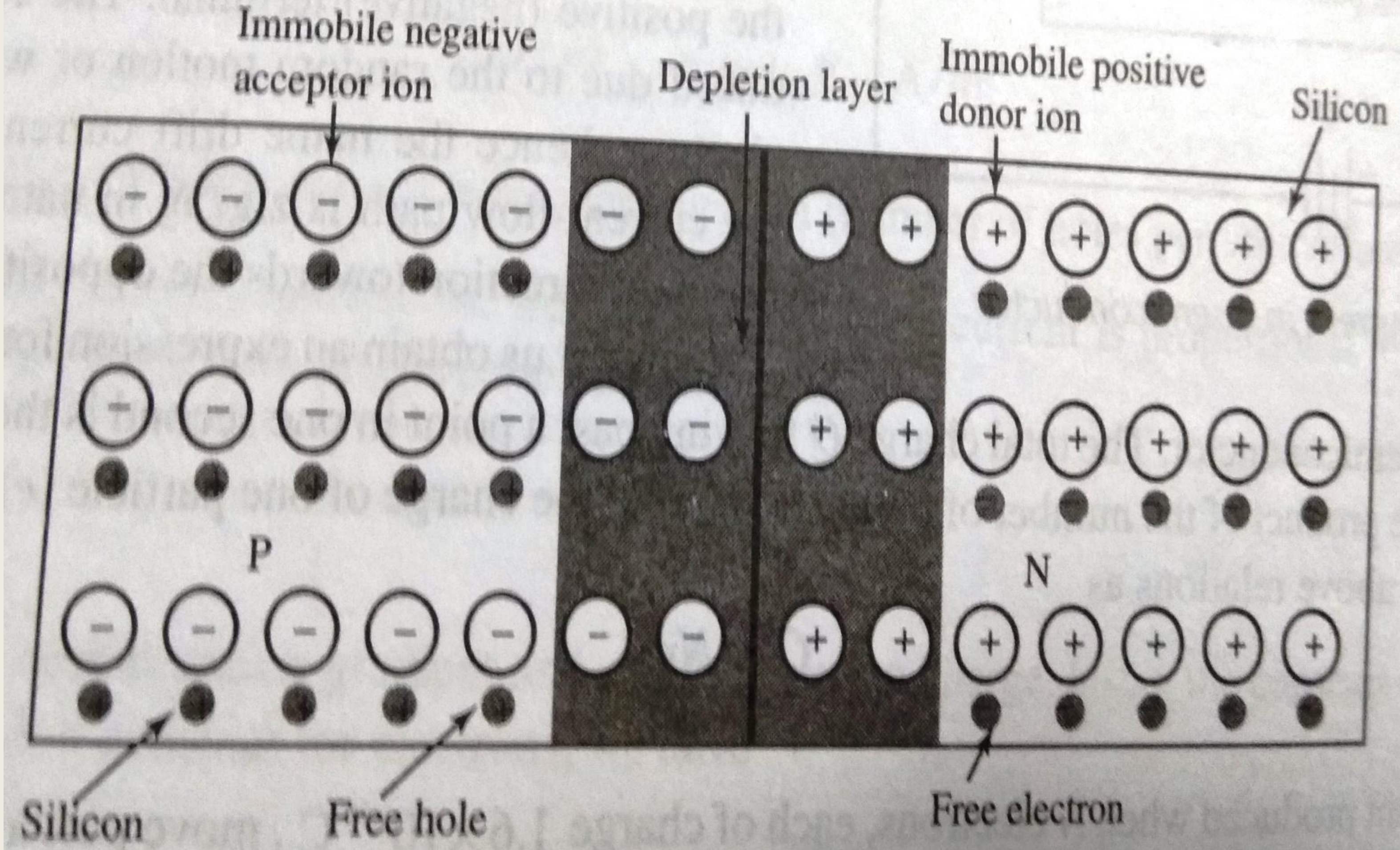

Fig. 7.4 *P-N junction after equilibrium state is reached*

Future Scope and relevance to industry

Devices based on

- p-n Junctions
- Light-Emitting Diodes/Photodetectors
- Bipolar Junction Transistors
- Field Effect Transistors

Research:

https://www.tandfonline.com/doi/abs/10.1080/02564602.2003.11417075

NPTEL/other online link

- https://nptel.ac.in/courses/117102061/
- https://nptel.ac.in/courses/108108112/
- https://nptel.ac.in/courses/117103063/2
- https://nptel.ac.in/courses/117107095/