A Handbook on

Electronics Engineering

Revised & Updated

Contains well illustrated formulae & key theory concepts

For

ESE, GATE, PSUs

& OTHER COMPETITIVE EXAMS

MADE EASY
Publications

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Director's Message

B. Singh (Ex. IES)

During the current age of international competition in Science and Technology, the Indian participation through skilled technical professionals have been challenging to the world. Constant efforts and desire to achieve top positions are still required.

I feel every candidate has ability to succeed but competitive environment and quality guidance is required to achieve high level goals. At MADE EASY, we help you to discover your hidden talent and success quotient to achieve your ultimate goals. In my opinion CSE, ESE, GATE & PSUs exams are tool to enter in to main stream of Nation serving. The real application of knowledge and talent starts, after you enter in to the working system. Here in MADE EASY you are also trained to become winner in your life and achieve job satisfaction.

MADE EASY alumni have shared their winning stories of success and expressed their gratitude towards quality guidance of MADE EASY. Our students have not only secured All India First Ranks in ESE, GATE and PSUs entrance examinations but also secured top positions in their career profiles. Now, I invite you to become alumni of MADE EASY to explore and achieve ultimate goal of your life. I promise to provide you quality guidance with competitive environment which is far advanced and ahead than the reach of other institutions. You will get the guidance, support and inspiration that you need to reach the peak of your career.

I have true desire to serve Society and Nation by way of making easy path of the education for the people of India.

After a long experience of teaching in Electronics Engineering over the period of time MADE EASY team realised that there is a need of good *Handbook* which can provide the crux of Electronics Engineering in a concise form to the student to brush up the formulae and important concepts required for ESE, GATE, PSUs and other competitive examinations. This *handbook* contains all the formulae and important theoretical aspects of Electronics Engineering. It provides much needed revision aid and study guidance before examinations.

B. Singh (Ex. IES)
CMD, MADE EASY Group

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CONTENTS

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Electronics Engineering

1

Electronic Devices and Circuits

CONTENTS

1 Energy Band and Charge Carriers in Semiconductors

Energy Bandgap

- Difference between the lower energy level of conduction band E_c and upper energy level of valence band E_v is called ***energy band gap***.

$$E_g = E_c - E_v$$

- In ***metals*** the conduction band is either partially filled or overlaps the valence band.
- In ***insulator*** energy band gap is very high.
- In ***semiconductor*** band gap is relatively small.
- An empty state in valence band is referred as hole.
- A perfect semiconductor crystal with no impurities or lattice defects is called ***intrinsic*** semiconductor.
- When a semiconductor is doped such that equilibrium concentration n_0 and p_0 are different from intrinsic carrier concentration n_i, the material is said to be ***extrinsic***.

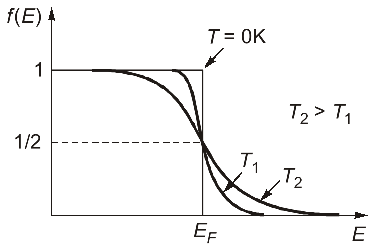
Fermi Level

- Fermi level is energy state having probability '1/2' of being occupied by an electron if there is no forbidden band.
- Energy of fastest moving electron at 0K is called Fermi energy.
- ***Fermi Dirac distribution function*** $f(E)$ gives the probability that an available energy state E will be occupied by an electron at absolute temperature T, under conditions of thermal equilibrium

$$f(E) = \frac{1}{1 + \exp[(E - E_F)/kT]}$$

where, $E_F \rightarrow$ Fermi energy level ; $K \rightarrow$ Boltzmann's constant
$T \rightarrow$ Absolute temperature in Kelvin

- The Fermi Dirac distribution function is given as



Note:

[1 – $f(E)$] gives the probability that energy state E will be occupied by a hole.

Density of States

The density of allowed energy states per energy range per unit volume.

Density of states in conduction band

$$\rho_c(E) = 4\pi\left(\frac{2m_n^*}{h^2}\right)^{3/2}(E - E_c)^{1/2}$$

where, m_n^* → Effective mass of electrons

E_c → Energy level of lowest conduction level

h → Plank's constant

Density of states in valence band

$$\rho_v(E) = 4\pi\left(\frac{2m_p^*}{h^2}\right)^{3/2}(E_v - E)^{1/2}$$

where, m_p^* → Effective mass of holes

E_v → Highest energy level of valence band

Concentration of Carriers

- Concentration of electrons in conduction band

$$n_0 = \int_{E_c}^{\infty} \rho_c(E)\, f(E)\, dE$$

- Concentration of electrons in conduction band is given by

$$n_0 = N_c\, e^{-(E_C - E_F)/kT}$$

where, n_0 → Concentration e^-_s in conduction band

E_F → Fermi energy level

k → Boltzmann's constant

T → Absolute temperature

N_C → Effective density of states in conduction band

- Effective density of states N_C is given by

$$N_C = 2\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/2}$$

- Concentration of holes in valence band

$$p_0 = \int_{-\infty}^{E_V} \rho_V(E)\,[1 - f(E)]\,dE$$

- Concentration of holes in valence band is given by

$$p_0 = N_v\, e^{-(E_F - E_V)/kT}$$

where, $p_0 \rightarrow$ Concentration of holes
$N_v \rightarrow$ Effective density of states in valence band
$E_F \rightarrow$ Fermi energy level

- Effective density of sates in valence band is given by

$$N_v = 2\left[\frac{2\pi m_p^* kT}{h^2}\right]^{3/2}$$

Mass Action Law

- It states that at thermal equilibrium product of concentration of free electrons and holes is equal to the square of intrinsic concentration at that temperature i.e.

$$n_0 p_0 = n_i^2$$

where, $n_0 \rightarrow$ Concentration of electron in conduction band
$p_0 \rightarrow$ Concentration of holes in valence band
$n_i \rightarrow$ Intrinsic concentration at given temperature

- Intrinsic concentration is given by

$$n_i = \sqrt{N_c N_v}\, e^{-E_g/2kT}$$ where, $E_g \rightarrow$ band gap

- n_i can also be given as

$$n_i^2 = A_0 T^3 e^{-E_g/kT}$$ where, $A_0 \rightarrow$ is a constant

- Concentration of electrons in conduction band can also be given as

$$n_0 = n_i\, e^{(E_F - E_i)/kT}$$

where, $E_i \rightarrow$ intrinsic level lies near the middle of bandgap

- Concentration of holes in valence band can also be given as

$$p_0 = n_i\, e^{(E_i - E_F)/kT}$$