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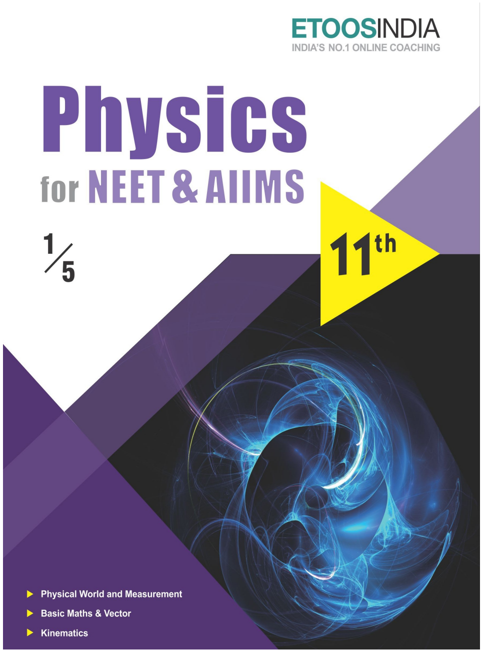

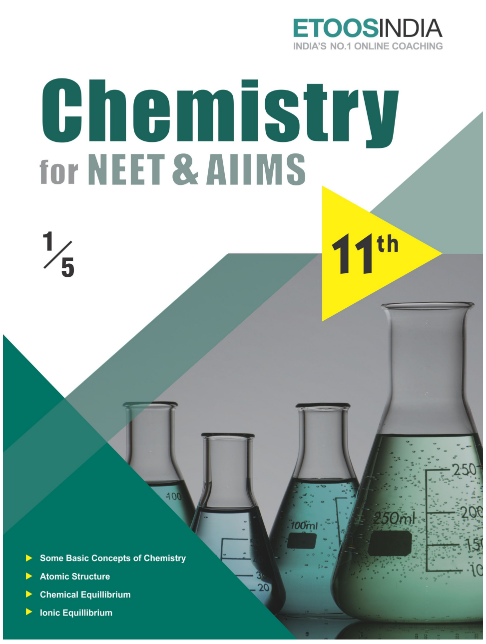

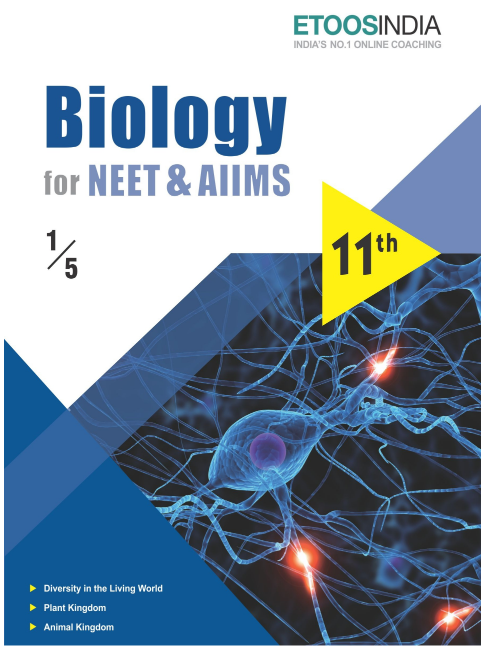

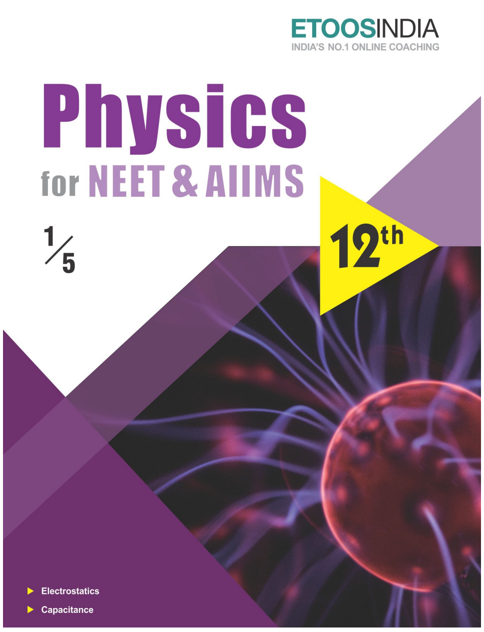

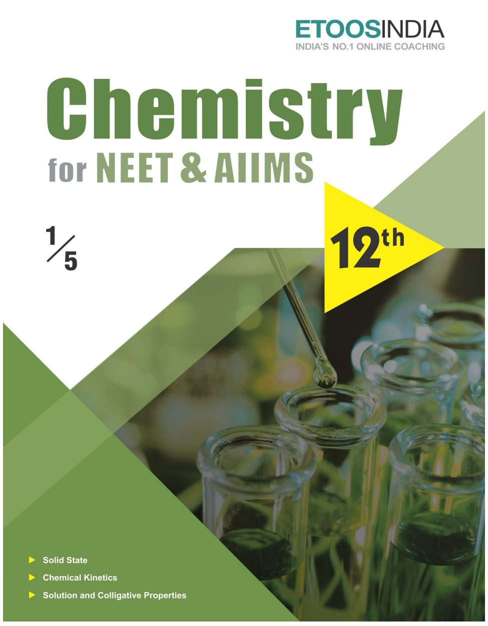

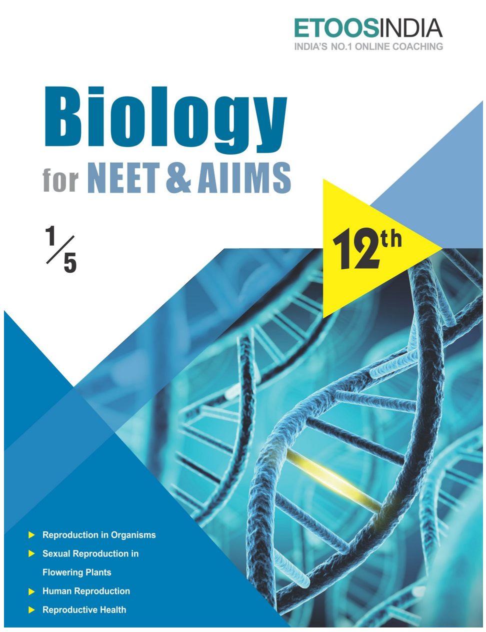

ETOOS Comprehensive Study Material
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CHAPTER 10

SOLID AND SEMICONDUCTORS

I have always consistently opposed high-tension and alternating systems of electric lighting, not only on account of danger, but because of their general unreliability and unsuitability for any general system of distribution.

"THOMAS EDISON"

INTRODUCTION

Electronic instruments are being utilized in various fields like telecommunication, entertainment, computers, nuclear physics and many more. Although the history started with the advent of vacuum tubes, however the rapid advancement in electronics which we see today is due to the valuable contributions of semiconductor devices.

Semiconductor devices are not only small in size, consumes less power, have long life times and are more efficient than vacuum tubes but also are of low cost. That is why these have replaced vacuum tubes nearly in all applications. As an Ex. we can consider the case of a computer. In early days, the vacuum tube based computers were as big as the size of a room and were capable of performing simple calculations only. At present the personal computer (PC) that you see in laboratory or at your home is much smaller in size and capable of performing many operations. Needless to say this is possible because of the advances in semiconductor technology.

We will learn the basic concept of semiconductors. This will enable us to understand the operation of many semiconductor devices and then we will be discussing few semiconductor devices like diode, transistor along with their applications.

static, there will be no further feedback from T_2 to T_1. Without continued feedback, the emitter current begins to fall. Consequently, collector current decreases causes the magnetic field to decay around the coil T_2. Thus, T_1 is now seeing a decaying field in T_2 (opposite from what it saw when the field was growing at the initial start operation). This causes a further decrease in means that both I_E and I_C cease to flow. Therefore, the transistor has reverted back to its original state (when the power was first switched on). The whole process now repeat itself. The transistor is driven to saturation, then to cut-off, and then back to saturation. The time for change from saturation to cut-off and back is determined by the constant of the tank circuit or tuned circuit (inductance L of Coil T_2 and C connected in parallel to it). The resonance frequency **(v)** of this tuned circuit determines the frequency at which the oscillator will oscillate.

$$\nu = \frac{1}{2\pi\sqrt{LC}}$$

9. Analogue Circuits and Digital Circuits and signal :

There are two types of electronic circuits : analogue circuits and digital circuits :

In analogue circuits, the voltage (or current) varies continuously with time (figure a). Such a voltage (or current) signal is called an 'analogue signal'.Figure shows a typical voltage analogue signal varying sinusoidally between 0 and 5V.

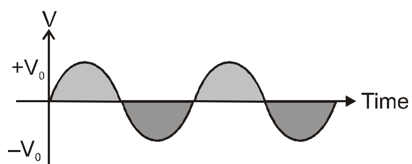


Figure (A)

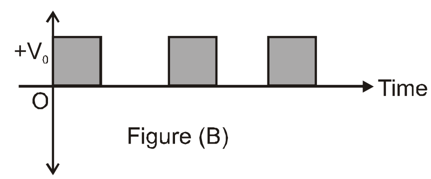


Figure (B)

On the other hand, in digital circuits, the voltage (or current) has only two levels, either zero or some constant value of voltage (figure b). A signal having only two levels of voltage (or current) is called a 'digital signal'. Figure shows a typical digital signal in which the voltage at any time is either 0 or 5V.

In digital circuits, the binary number system is used, according to which the two levels of the (digital) signal are repressented by the digits 0 and 1 only.

The digital circuits are the basis of calculators, computers, etc.

10. Logic Gates :

A logic gate is a digital circuit which works according to some logical relationship between input and output voltages. It either allows a signal to pass through or stops it.

A gate is a digital circuit that follows curtain logical relationship between the input and output voltages. Therefore, they are generally known as logic gates — gates because they control the flow of information. The five common logic gates used are NOT, AND, OR, NAND, NOR. Each logic gate is indicated by a symbol and its function is defined by a truth table that shows all the possible input logic level combinations with their respective output logic levels. Truth tables help understand the behaviour of logic gates. These logic gates can be realised using semiconductor devices.

(a) The NOT Gate :

The NOT gate has only one input and one output. It combines the input A with the output Y, according to the Boolean expression $\overline{A} = Y$,

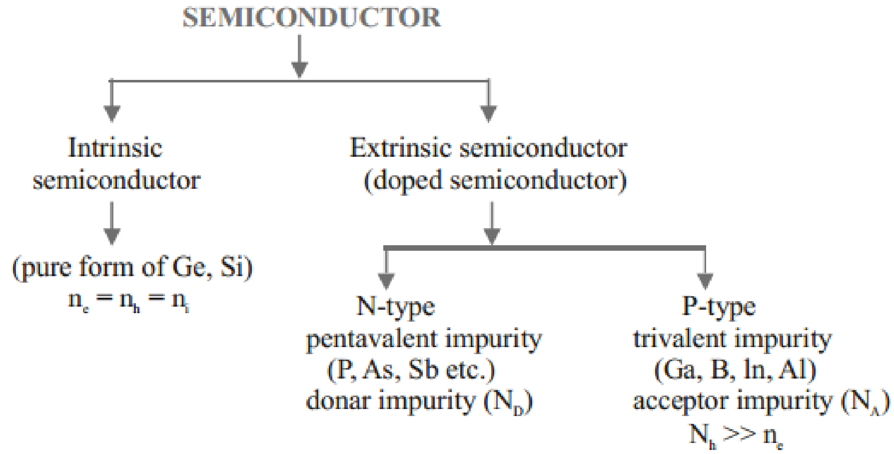
read as 'NOT A equals Y'. It means that Y is negation (or inversion) of A. Since there are only two digits 0 and 1 in the binary system, we have, Y = 0, if A = 1 and Y = 1 if A = 0 . The logic symbol of the NOT gate is shown in figure.

Etoos Tips & Formulas

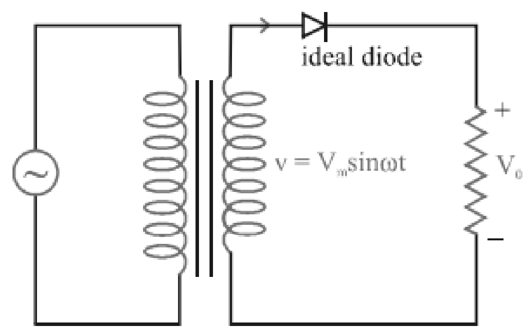
1. **Number of electrons reaching from valence band to conduction band**

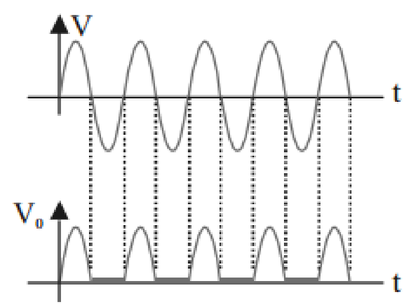
$$n = AT^{3/2}e^{-\frac{\Delta Eg}{2kT}}$$

2. **Classification of Semiconductors :**

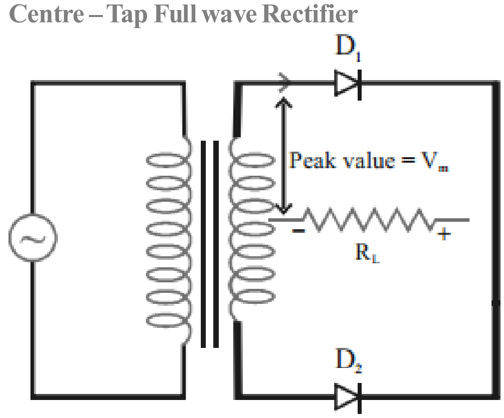


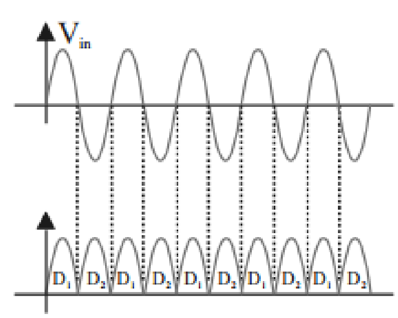
3. **Mass-action law** $n_i^2 = n_e \times n_h$
   (a) For N-type semiconductor $n_e = N_D$
   (b) For P-type semiconductor $n_h = N_A$
4. **Conductivity** $n_i e(\mu_e + \mu_h)$
5. **Half wave rectifier**





6. **Centre – Tap Full wave Rectifier**





SOLVED EXAMPLE

Ex.1 A doped semiconductor has impurity levesl 30 meV below the conduction band. **(a)** Is the material n-type or p-type ? **(b)** In a thermal collision, an amount kT of energy is given to the extra electron loosely bound to the impurity ion and this electron is just able to jump into the conduction band. Calculate the temperature T.

Sol. **(a)** The impurity provides impurity leves close to the conduction band and a number of electrons from the impurity level will populate the conduction band. Thus, the majority carriers are electrons and the material is n-type.

(b) According to the question, kT = 30 meV

or, $$T = \frac{30\,\text{meV}}{k}$$

$$= \frac{0.03\,\text{eV}}{8.62 \times 10^{-5}\,\text{eVK}^{-1}} = 348\,\text{K}$$

Ex.2 The energy of a photon of sodium light (λ = 589 nm) equals the band gap of a semiconducting material. (a) Find the minimum energy E required to creat a hole-electron pair. (b) Find the value of E/kT at a temperature of 300 K.

Sol. **(a)** The energy of the photon is $E = \frac{hc}{\lambda}$

$$= \frac{1242\text{eVnm}}{589\,\text{nm}} = 2.1\text{eV}$$

Thus the band gap is 2.1 eV. This is also the minimum energy E required to push an electron from the valence band into the conduction band. Hence, the minimum energy required to creat a hole-electron pair is 2.1 eV.

(b) At $T = 300\,\text{K}$

$$kT = (8.62 \times 10^{-5}\,\text{eVK}^{-1})(300\,\text{K})$$

$$= 25.86 \times 10^{-3}\,\text{eV}.$$

Thus, $$\frac{E}{kT} = \frac{2.1\text{eV}}{25.86 \times 10^{-3}\text{eV}} = 81$$

So it is difficult for the thermal energy to create the hole-electron pair but a photon of light can do it easily.

Ex.3 A p-type semiconductor has acceptor levels 57 meV above the valence band. Find the maximum wavelength of light which can create a hole.

Sol. To create a hole, an electron from the valenec band should be given sufficient energy to go into one of the acceptor levels. Since the acceptor levels are 57 meV above the valence band, at least 57 meV is needed to create a hole.

If λ be the wavelength of light, its photon will have an energy hc/λ. To create a hole,

$$\frac{hc}{\lambda} \geq 57\,\text{meV}$$

or, $$\lambda \leq \frac{hc}{57\,\text{meV}}$$

$$= \frac{1242\,\text{eV nm}}{57 \times 10^{-3}\,\text{eV}} = 2.18 \times 10^{-5}\,\text{m}$$

Ex.4 The band gap in germanium is ΔE = 0.68 eV. Assuming that the number of hole-electron pairs is proportional to $e^{-\Delta E/2kT}$, find the percentage increase in the number of charge carriers inpure germanium as the temperature is increased from 300 K to 320 K.

Sol. The number of charge carriers in an intrinsic semiconductor is double the number of hole-electron pairs. If N_1 be the number of charge carriers at temperature T_1 and N_2 at T_2, we have

$$N_1 = N_0 e^{-\Delta E/2kT_1}$$

and $$N_2 = N_0 e^{-\Delta E/2kT_2}$$

The percentage increase as the temperature is raised from T_1 to T_2 is

$$f = \frac{N_2 - N_1}{N_1} \times 100 = \left(\frac{N_2}{N_1} - 1\right) \times 100$$

$$= 100\left[e^{\frac{\Delta E}{2k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} - 1\right]$$

Now $$\frac{\Delta E}{2k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$= \frac{0.68\,\text{eV}}{2 \times 8.62 \times 10^{-5}\,\text{eV K}^{-1}}\left(\frac{1}{300\,\text{K}} - \frac{1}{320\,\text{K}}\right)$$

$= 0.82.$

Exercise # 1

SINGLE OBJECTIVE — NEET LEVEL

1. The nature of binding for a crystal with alternate and evenly spaced positive and negative ions is
(A) Covalent (B) Metallic
(C) Dipolar (D) Ionic

2. For a crystal system, $a = b = c$, $\alpha = \beta = \gamma \neq 90^o$, the system is
(A) Tetragonal system
(B) Cubic system
(C) Orthorhombic system
(D) Rhombohedral system

3. Biaxial crystal among the following is
(A) Calcite (B) Quartz
(C) Selenite (D) Tourmaline

4. The temperature coefficient of resistance of a conductor is
(A) Positive always (B) Negative always
(C) Zero (D) Infinite

5. Potassium has a *bcc* structure with nearest neighbour distance 4.525 $\mathring{A}$. Its molecular weight is 39. Its density in kg/m^3 is
(A) 900 (B) 494
(C) 602 (D) 802

6. The expected energy of the electrons at absolute zero is called
(A) Fermi energy (B) Emission energy
(C) Work function (D) Potential energy

7. In a triclinic crystal system
(A) $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma$
(B) $a = b = c$, $\alpha \neq \beta \neq \gamma$
(C) $a \neq b \neq c$, $\alpha \neq \beta = \gamma$
(D) $a = b \neq c$, $\alpha = \beta = \gamma$

8. Metallic solids are always opaque because
(A) Solids effect the incident light
(B) Incident light is readily absorbed by the free electron in a metal
(C) Incident light is scattered by solid molecules
(D) Energy band traps the incident light

9. In which of the following ionic bond is present
(A) *NaCl* (B) *Ar*
(C) *Si* (D) *Ge*

10. Which of the following materials is non crystalline
(A) Copper (B) Sodium chloride
(C) Wood (D) Diamond

11. The majority charge carriers in *P*-type semiconductor are
(A) Electrons (B) Protons
(C) Holes (D) Neutrons

12. A *P*-type semiconductor can be obtained by adding
(A) Arsenic to pure silicon
(B) Gallium to pure silicon
(C) Antimony to pure germanium
(D) Phosphorous to pure germanium

13. The valence of an impurity added to germanium crystal in order to convert it into a *P*-type semi conductor is
(A) 6 (B) 5
(C) 4 (D) 3

14. In a semiconductor, the concentration of electrons is $8 \times 10^{14} / cm^3$ and that of the holes is $5 \times 10^{12} cm^3$. The semiconductor is
(A) *P*-type (B) *N*-type
(C) Intrinsic (D) *PNP*-type

15. In *P*-type semiconductor, there is
(A) An excess of one electron
(B) Absence of one electron
(C) A missing atom
(D) A donar level

16. The valence of the impurity atom that is to be added to germanium crystal so as to make it a *N*-type semiconductor, is
(A) 6 (B) 5
(C) 4 (D) 3

17. Silicon is a semiconductor. If a small amount of *As* is added to it, then its electrical conductivity
(A) Decreases (B) Increases
(C) Remains unchanged (D) Becomes zero

Exercise # 2

SINGLE OBJECTIVE | AIIMS LEVEL

1. Fermi energy is the-
(A) Minimum energy of electrons in metal at 0 K
(B) Minimum energy of electrons in metal at 0°C
(C) Maximum energy of electrons in metal at 0 K
(D) Maximum energy of electrons in metal at 0°C

2. The forbidden energy band gap in conductors, semiconductors and insulators are EG_1, EG_2 and EG_3 respectively, The relation among them is
(A) $EG_1 = EG_2 = EG_3$ (B) $EG_1 < EG_2 < EG_3$
(C) $EG_1 > EG_2 > EG_3$ (D) $EG_1 < EG_2 > EG_3$

3. Which of the following statements is true-
(A) In insulators the conduction band is completely empty.
(B) In conductor the conduction band is completely empty.
(C) In semiconductor the conduction band is partially empty at low temperature.
(D) In insulators the conduction band is completely filled with electrons.

4. The valence band at 0 K is-
(A) completely filled (B) completely empty
(C) partially filled (D) nothing can be said

5. Which of the following statement is true-
(A) At absolute zero temperature, the semiconductor behave as a conductor
(B) The energy gap in semiconductor is more than that for insulator
(C) The resistance of semiconductor increases with increase in temperature
(D) The resistance of semiconductor decreases with increase in temperature

6. An electric field is applied to a semiconductor. Let the number of charge carries be n and the average drift speed be v. If the temperature is increased,
(A) both n and v will increase
(B) n will increase but v will decrease
(C) v will increases but n will decrease
(D) both n and v will decrease

7. Electric conduction in a semiconductor takes place due to
(A) electrons only
(B) holes only
(C) both electrons and holes
(D) neither electron nor holes

8. The free electron concentration (n) in the conduction band of a semiconductor at a temperature T Kelvin is described in terms of E_g and T as-
(A) $n = ATe^{-Eg/kT}$
(B) $n = AT^2e^{-Eg/kT}$
(C) $n = AT^2e^{-Eg/2kT}$
(D) $n = AT^{3/2}e^{-Eg/2kT}$

9. The mobility of free electron is greater than that of free holes because
(A) They carry negative charge
(B) They are light
(C) They mutually collide less
(D) They require low energy to continue their motion

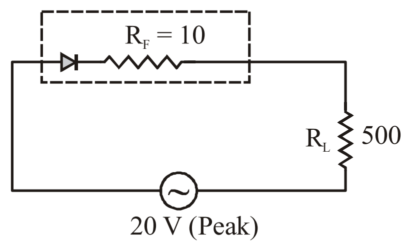
10. Let n_p and n_e be the numbers of holes and conduction electrons in an extrinsic semiconductor
(A) $n_p > n_e$ (B) $n_p = n_e$
(C) $n_p < n_e$ (D) $n_p \neq n_e$

11. The electrical conductivity of pure germanium can be increased by
(A) increassing the temperature
(B) doping acceptor impurities
(C) doping donor impurities
(D) irradiating ultraviolet light on it.

12. A N-type semiconductor is
(A) Negatively charged
(B) Positively charged
(C) Neutral
(D) None of these

Exercise # 3 PART - 1 MATRIX MATCH COLUMN

1. In the circuit shown the barrier voltasge of diode is 0.7 V. Match the physical quantities given in column-I to the results given in column-II



	Column I		Column II
(A)	Peak current (in mA) in diode	(p)	37.8
(B)	Peak voltage (in volts) at the ends of load	(q)	40.0
(C)	Peak current (in mA) if diode is ideal	(r)	20.0
(D)	Peak voltage (in volts) at the ends of load if diode is ideal	(t)	Zero

Exercise # 4 | PART - 1 | PREVIOUS YEAR (NEET/AIPMT)

1. If α and β are current gains in common - base and common - emitter configurations of a transistor, then β equal to **[CBSE AIPMT-2000]**

(A) $\frac{1}{\alpha}$ (B) $\frac{\alpha}{1+\alpha}$

(C) $\frac{\alpha}{1-\alpha}$ (D) $\alpha - \frac{1}{\alpha}$

2. The truth table given below **[CBSE AIPMT-2000]**

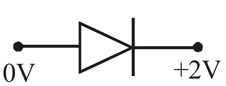
Input		Output
A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

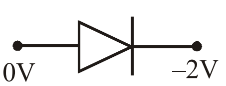
represents

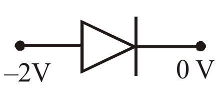
(A) AND gate (B) NOR gate

(C) OR gate (D) NAND gate

3. In which of the following figures, junction diode is forwared biased ? **[CBSE AIPMT-2000]**

(A) 

(B) 

(C) 

(D) 5 V

4. Si and Cu are cooled to a temperature of 300 K, then resistivity **[CBSE AIPMT-2001]**

(A) for Si increases and for Cu decreases

(B) for Cu increases and for Si decreases

(C) decreases for both Si and Cu

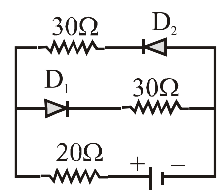
(D) increases for both Si and CU

5. In a common - base configuration of a transisitor $\frac{\Delta i_c}{\Delta i_e} = 0.98$, then current gain in common emitter configuration of transisitor will be **[CBSE AIPMT-2001]**

(A) 49 (B) 98

(C) 4.9 (D) 24.5

6. If internal resistance of cell is negligible, then current flowing through the circuit is **[CBSE AIPMT-2001]**



(A) $\frac{3}{50}$A (B) $\frac{5}{50}$A

(C) $\frac{4}{50}$A (D) $\frac{2}{50}$A

7. In bcc structure of lattice constant a, the minimum distance between atoms is **[CBSE AIPMT-2001]**

(A) $\frac{\sqrt{3}}{2}a$ (B) $\sqrt{2}a$

(C) $\frac{a}{\sqrt{2}}$ (D) $\frac{a}{2}$

8. The number of atoms per unit cell in bcc lattice is **[CBSE AIPMT-2002]**

(A) 1 (B) 2

(C) 4 (D) 9

9. For a transistor $\frac{i_c}{i_e} = 0.96$, the current gain in common-emitter configuration is **[CBSE AIPMT-2002]**

(A) 6 (B) 12

(C) 24 (D) 48

MOCK TEST

STRAIGHT OBJECTIVE TYPE

1. A silicon speciman is made into a *P*-type semi-conductor by dopping, on an average, one Indium atom per 5×10^7 silicon atoms. If the number density of atoms in the silicon specimen is 5×10^{28} atoms $/ m^3$ then the number of acceptor atoms in silicon per cubic centimetre will be

(A) 2.5×10^{30} *atoms* $/ cm^3$ (B) 1.0×10^{13} *atoms* $/ cm^3$ (C) 1.0×10^{15} *atoms* $/ cm^3$ (D) 2.5×10^{36} *atoms* $/ cm^3$

2. The probability of electrons to be found in the conduction band of an intrinsic semiconductor at a finite temperature

(A) Decreases exponentially with increasing band gap
(B) Increases exponentially with increasing band gap
(C) decreases with increasing temperature
(D) Is independent of the temperature and the band gap

3. The typical ionisation energy of a donor in silicon is

(A) 10.0 eV (B) 1.0 eV (C) 0.1 eV (D) 0.001 eV

4. In *PN*-junction diode the reverse saturation current is 10^{-5} *amp* at $27°C$. The forward current for a voltage of $0.2 volt$ is

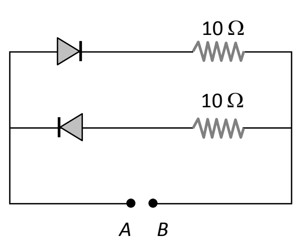
(A) 2037.6×10^{-3} *amp* (B) 203.76×10^{-3} *amp* (C) 20.376×10^{-3} *amp* (D) 2.0376×10^{3} *amp*

$[\exp(7.62) = 2038.6, K = 1.4 \times 10^{-23} J / K]$

5. When a potential difference is applied across, the current passing through

(A) An insulator at $0 K$ is zero
(B) A semiconductor at 0 K is zero
(C) A *P-N* diode at 300 K is finite, if it is reverse biased
(D) All options are correct

6. A 2*V* battery is connected across the points *A* and *B* as shown in the figure given below. Assuming that the resistance of each diode is zero in forward bias and infinity in reverse bias, the current supplied by the battery when its positive terminal is connected to *A* is



(A) 0.2 *A* (B) 0.4 *A* (C) Zero (D) 0.1 *A*

11th Class Modules Chapter Details

Physics
5
Modules

Chemistry
5
Modules

Mathematics
5
Modules

PHYSICS	CHEMISTRY	BIOLOGY
Module-1 1. Physical World & Measurements 2. Basic Maths & Vector 3. Kinematics **Module-2** 1. Law of Motion & Friction 2. Work, Energy & Power **Module-3** 1. Motion of system of particles & Rigid Body 2. Gravitation **Module-4** 1. Mechanical Properties of Matter 2. Thermal Properties of Matter **Module-5** 1. Oscillations 2. Waves	**Module-1(PC)** 1. Some Basic Conceps of Chemistry 2. Atomic Structure 3. Chemical Equilibrium 4. Ionic Equilibrium **Module-2(PC)** 1. Thermodynamics & Thermochemistry 2. Redox Reaction 3. States Of Matter (Gaseous & Liquid) **Module-3(IC)** 1. Periodic Table 2. Chemical Bonding 3. Hydrogen & Its Compounds 4. S-Block **Module-4(OC)** 1. Nomenclature of Organic Compounds 2. Isomerism 3. General Organic Chemistry **Module-5(OC)** 1. Reaction Mechanism 2. Hydrocarbon 3. Aromatic Hydrocarbon 4. Environmental Chemistry & Analysis Of Organic Compounds	**Module-1** 1. Diversity in the Living World 2. Plant Kingdom 3. Animal Kingdom **Module-2** 1. Morphology in Flowering Plants 2. Anatomy of Flowering Plants 3. Structural Organization in Animals **Module-3** 1. Cell: The Unit of Life 2. Biomolecules 3. Cell Cycle & Cell Division 4. Transport in Plants 5. Mineral Nutrition **Module-4** 1. Photosynthesis in Higher Plants 2. Respiration in Plants 3. Plant Growth and Development 4. Digestion & Absorption 5. Breathing & Exchange of Gases **Module-5** 1. Body Fluids & Its Circulation 2. Excretory Products & Their Elimination 3. Locomotion & Its Movement 4. Neural Control & Coordination 5. Chemical Coordination and Integration

12th Class Modules Chapter Details

Physics
5
Modules

Chemistry
5
Modules

Mathematics
5
Modules

PHYSICS

Module-1

1. Electrostatics
2. Capacitance

Module-2

1. Current Electricity
2. Magnetic Effect of Current and Magnetism

Module-3

1. Electromagnetic Induction
2. Alternating Current

Module-4

1. Geometrical Optics
2. Wave Optics

Module-5

1. Modern Physics
2. Nuclear Physics
3. Solids & Semiconductor Devices
4. Electromagnetic Waves

CHEMISTRY

Module-1(PC)

1. Solid State
2. Chemical Kinetics
3. Solutions and Colligative Properties

Module-2(PC)

1. Electrochemistry
2. Surface Chemistry

Module-3(IC)

1. P-Block Elements
2. Transition Elements (d & f block)
3. Co-ordination Compound
4. Metallurgy

Module-4(OC)

1. HaloAlkanes & HaloArenes
2. Alcohol, Phenol & Ether
3. Aldehyde, Ketone & Carboxylic Acid

Module-5(OC)

1. Nitrogen & Its Derivatives
2. Biomolecules & Polymers
3. Chemistry in Everyday Life

BIOLOGY

Module-1

1. Reproduction in Organisms
2. Sexual Reproduction in Flowering Plants
3. Human Reproduction
4. Reproductive Health

Module-2

1. Principles of Inheritance and Variation
2. Molecular Basis of Inheritance
3. Evolution

Module-3

1. Human Health and Disease
2. Strategies for Enhancement in Food Production
3. Microbes in Human Welfare

Module-4

1. Biotechnology: Principles and Processes
2. Biotechnology and Its Applications
3. Organisms and Populations

Module-5

1. Ecosystem
2. Biodiversity and Conservation
3. Environmental Issues