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ECE Dept.

Exam.

Internal Assessment

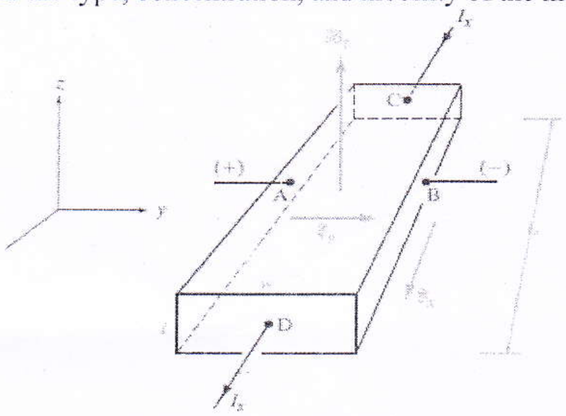
Odd Sem(2019-20)

FIRST INTERNAL ASSESSMENT

Sem: III EC | **Sub: Electronic Devices** | **Sub. Code: 18EC33**

Date: 16/09/2019 | **Time: 11-12 noon** | **Max. Marks:30**

Note: Answer two full questions, draw sketches wherever necessary.

Q. No		Description of Question	Marks	CO	RBT LEVEL
1	a	Explain metal, semiconductor and insulator with their energy band diagram.	8	C203.1	L2
	b	consider a semiconductor bar with $w = 0.1$ mm, $t = 10$ μm, and $L = 5$ mm. For b = 10 kG in the direction shown in figure 1(b) (1 kG = 10^{-5} Wb/cm^2) and a current of 1 mA, we have $V_{AB} = -2$ mV and $V_{CD} = 100$ mV. Find the type, concentration, and mobility of the majority carrier.  Fig1(b)	7	C203.1	L3
		OR			
2	a	Explain the formation of P and N type semiconductors with their energy band diagram.	8	C203.1	L2
	b	Explain different chemical bonding in solids.	7	C203.1	L2
3	a	Differentiate direct and indirect semiconductor	8	C203.1	L2
	b	A Si bar 1 μm long and 100 μm^2 in cross-sectional area is doped with 10^{17} cm^{-3} phosphorus. Find (a)the current at 300 K with 10 V applied. (b) How long does it take an average electron to drift 1 μm in pure Si at an electric field of 100 V/cm?	7	C203.1	L3
		OR			
4	a	Explain qualitative description of current flow at a PN Junction.	8	C203.2	L3
	b	Differentiate Zener and avalanche breakdown.	7	C203.2	L2

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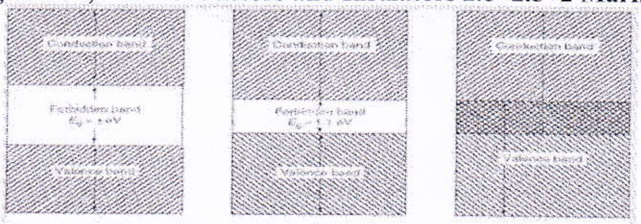
IA - 1 SCHEME OF EVALUATION

Sem :III	Subject : Electronic Devices	Sub Code :18EC33	Date :16/09/2019

Q. No.	Bit	Description	Marks	CO's	RBT Level
1	a)	**Explaining Metals, Semiconductors and Insulators 2.5+2.5+2 Marks**	8	C203.1	L2



Insulator :An insulator is a material that offers a very low level (or negligible) of conductivity when voltage is applied. Eg: Paper, Mica, glass, quartz. Typical resistivity level of an insulator is of the order of 10^{10} to 10^{12} Ω-cm. The energy band structure of an insulator is shown in the fig.1.1For an insulator, as shown in the fig.1.1 (a) there is a large forbidden band gap of greater than 5Ev. Because of this large gap there a very few electrons in the CB and hence the conductivity of insulator is poor. Even an increase in temperature or applied electric field is insufficient to transfer electrons from VB to CB.

Semiconductor: A semiconductor is a material that has its conductivity somewhere between the insulator and conductor. The resistivity level is in the range of 10 and 10^4 Ω-cm. Two of the most commonly used are Silicon (Si=14 atomic no.) and germanium (Ge=32 atomic no.). The forbidden band gap is in the order of 1.1eV. For eg., the band gap energy for Si, Ge and GaAs is 1.21, 0.785 and 1.42 eV, respectively at absolute zero temperature (0K). At 0K and at low temperatures, the valance band electrons do not have sufficient energy to move from V to CB. Thus semiconductors act a insulators at 0K. as the temperature increases, a large number of valance electrons acquire sufficient energy to leave the VB, cross the forbidden bandgap and reach CB.

Metals: Metals conduct electricity easily. They have large number of free electronics. In metals the bands either overlap or are only partially filled. Thus electrons and empty energy states are intermixed within the bands so that electrons can move freely under the influence of an electric field. As expected from the metallic band structures of Fig.1.1 (c), metals have a high electrical conductivity.

Q. No.	Bit	Description	Marks	CO's	RBT Level
	b)	Type of Carrier 1M+ Mobility 3M + Concentratation 3M	7	C203.1	L3

$$\mathcal{B}_z = 10^{-4}\ \text{Wb/cm}^2$$

From the sign of V_{AB}, we can see that the majority carriers are electrons:

$$n_0 = \frac{I_x \mathcal{B}_z}{qt(-V_{AB})} = \frac{(10^{-3})(10^{-4})}{1.6 \times 10^{-19}(10^{-3})(2 \times 10^{-3})} = 3.125 \times 10^{17}\ \text{cm}^{-3}$$

$$\rho = \frac{R}{L/wt} = \frac{V_{CD}/I_x}{L/wt} = \frac{0.1/10^{-3}}{0.5/0.01 \times 10^{-3}} = 0.002\ \Omega \cdot \text{cm}$$

$$\mu_n = \frac{1}{\rho q n_0} = \frac{1}{(0.002)(1.6 \times 10^{-19})(3.125 \times 10^{17})} = 10{,}000\ \text{cm}^2(\text{V} \cdot \text{s})^{-1}$$

OR

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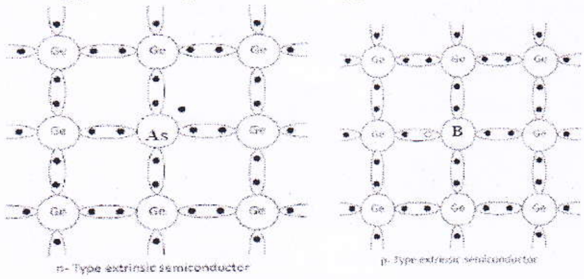
Q. No.	Bit	Description	Marks	CO's	RBT Level
2	a)	**Explaination of N type with figure 4M + P type 4M**	8	C203.1	L2



n- Type extrinsic semiconductor p- Type extrinsic semiconductor

Doping, *is the most common technique for varying* the conductivity of semiconductors. By doping, a crystal can be altered so that it has a predominance of either electrons or holes. Thus there are two types of doped semiconductors, n-type (mostly electrons) and p-type (mostly holes). Semiconductors doped with a significant number of donor atoms will have n0 > *(ni, p0) at room temperature.* this is n-type material. An As atom (column V) in the Si lattice has the four necessary valence electrons to complete the covalent bonds with the neighboring Si atoms, plus one extra electron. This fifth electron does not fit into the bonding structure of the lattice and is therefore loosely bound to the As atom.

Doping with acceptor impurities can create a semiconductor with a hole concentration *p0 much greater than the conduction band electron concentration n0* this type is p-type material. In the covalent bonding model, donor and acceptor atoms can be visualized as shown in Fig. 3–12c. and also shown below figure Boran –Germanium covalent bond diagram.

Q. No.	Bit	Description	Marks	CO's	RBT Level
	b)	**Explaining Covalent, Matallic and Ionic bonding 3+2+2 M each**	7	C203.1	L2

Metallic Bonding: In the metal the outer electron of each alkali atom is contributed to the crystal as a whole, so that the solid is made up of ions with closed shells immersed in a sea of free electrons. The forces holding the lattice together arise from an interaction between the positive ion cores and the surrounding free electrons. This is one type of *metallic bonding. Metallic bonds are formed by the attraction between metal ions and delocalized, or "free" electrons.*

Covalent Bond: A third type of bonding is exhibited by the diamond lattice semiconductors. The Ge, Si, or C diamond lattice is surrounded by four nearest neighbors, each with four electrons in the outer orbit. In these crystals each atom shares its valence electrons with its four neighbors.

Ionic bonding The interaction of electrons in neighboring atoms of a solid serves the very important function of holding the crystal together such as NaCl are called as ***ionic bonding.*** The Na+ ion has a net positive charge, having lost an electron, and the Cl- ion has a net negative charge, having gained an electron. Each Na+ ion exerts an electrostatic attractive force upon its six Cl neighbors, and vice versa

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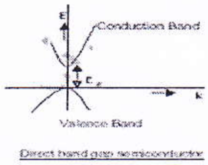
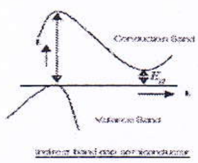
Sem :III	Subject : Electronic Devices	Sub Code :18EC33	Date :16/09/2019

Q. No.	Bit	Description	Marks	CO's	RBT Level
3	a	Differentiating direct and indirect semiconductors each carry 1x8=8	8	C203.1	L2

Differences between direct and indirect band gap semiconductor

Direct band gap semiconductors	Indirect gap semiconductors
1. In direct gap semiconductors the band diagram between energy and wave vector is shown in figure 	1. In in-direct gap semiconductors the band diagram between energy and wave vector is shown in figure 
2. In direct band gap semiconductors the maximum of the valance band and minimum of the conduction band present at the same of k	2. In in-direct band gap semiconductors the maximum of the valance band and minimum of the conduction band present at the different values of k
3. In direct band gap semiconductors, when an electron recombines with the hole, it emits their energy in terms of light.	3. In direct band gap semiconductors, when an electron recombines with the hole, it emits their energy in terms of heat.
4. Life time(recombination time) of charge carriers is very less.	4. Life time (recombination time) of charge carriers is more.
5. These are mostly form the compound semiconductors.	5. These are mostly form the elemental semiconductors.
6. Examples: InP, GaAs.	6. Examples: Germanium and silicon.
7. Band gap of InP=1.35eV and , GaAs=1.42eV	7. Band gap of Ge=0.7eV and Si=1.12eV
8. Direct band gap semiconductors are used to fabricate LEDs and laser diodes	8. Indirect band gap semiconductors are used to fabricate diodes and transistors

Q. No.	Bit	Description	Marks	CO's	RBT Level
	b)	Finding current and time each carry 2x3.5=7	7	C203.1	L3

With $\mathcal{E} = \frac{10\ V}{10^{-4}\ \text{cm}} = 10^5 \frac{V}{\text{cm}}$ the sample is in the velocity saturation regime.

From Fig. 3–24, $v_s = 10^7 \frac{\text{cm}}{\text{s}}$.

$$I = q \cdot A \cdot n \cdot v_s = 1.6 \cdot 10^{-19}\ \text{C} \cdot 10^{-6}\ \text{cm}^2 \cdot 10^{17} \frac{1}{\text{cm}^3} \cdot 10^7 \frac{\text{cm}}{\text{s}} = 0.16\ \text{A}$$

From Appendix III, $\mu_n = 1350\ \frac{cm^2}{V\text{-}s}$

low field: $v_d = \mu_n \cdot \mathcal{E} = 1350\ \frac{\text{cm}^2}{V\text{-}s} \cdot 100 \frac{V}{\text{cm}} = 1.35 \cdot 10^5 \frac{\text{cm}}{\text{s}}$

$$t = \frac{L}{v_d} = \frac{10^{-4}\ \text{cm}}{1.35 \cdot 10^5 \frac{\text{cm}}{\text{s}}} = 7.4 \cdot 10^{-10}\ \text{s} = 0.74\ \text{ns}$$

OR

IA - 1 SCHEME OF EVALUATION

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Q. No.	Bit	Description		Marks	CO's	RBT Level
4	a)	Explaining any four Important features of the junction.2x4=8		8	C203.2	L2

Explaining any four Important features of the junction.2x4=8

1)Electrostatic potential barrier: The electrostatic potential barrier at the junction is lowered by a forward bias Vf from the equilibrium contact potential V0 to the smaller value V0 - Vf . This lowering *of* the potential barrier occurs because a forward bias (p positive with respect to n) raises the electrostatic potential on the p side relative to the n side.

2)**The *electric field*** :The electric field within the transition region can be deduced or analysed from the potential barrier. We notice that the field decreases with forward bias, since the applied electric field opposes the built-in field.

$$W = \left[\frac{2\epsilon V_0}{q}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{1/2}$$

3)**Energy bands** :The height of the electron energy barrier is simply the electronic charge q times the height of the electrostatic potential barrier. Thus the bands are separated less [q(V0 - Vf)] under forward bias than at equilibrium, and more [q(V0 + Vr)] under reverse bias. Therefore, the shifting of the energy bands under bias implies a separation of the Fermi levels on either side of the

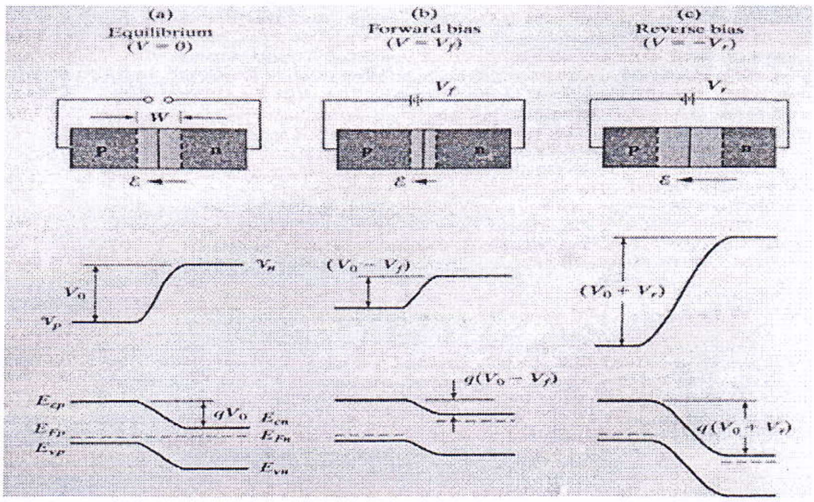

Fig 4(a)

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Q. No.	Bit	Description		Marks	CO's	RBT Level
		4) Diffusion current :The *diffusion current is composed of majority carrier electrons on the* n side surmounting the potential energy barrier to diffuse to the p side, and holes surmounting their barrier from p to n. There is a distribution of energies for electrons in the n-side conduction band and some electrons in the high-energy "tail" of the distribution have enough energy to diffuse from n to p at equilibrium in spite of the barrier. **5)*Drift current*** :The *drift current is relatively insensitive to the height of the potential* barrier and therefore we expect drift current to be simply proportional to the applied field. ***6)Total current :***The *total current crossing the junction is composed of the sum of the* diffusion and drift components. As Fig. 4(a) indicates, the electron and hole diffusion currents are both directed from p to n and the drift currents are from n to p.				
	b)	Mentioning any five difference 1.5+1.5 +1.5+1.5+1 =7		7	C203.2	L2

Zener Breakdown	Avalanche breakdown
1.This occurs at junctions which being heavily doped have narrow depletion layers	1. This occurs at junctions which being lightly doped have wide depletion layers.
2. This breakdown voltage sets a very strong electric field across this narrow layer.	2. Here electric field is not strong enough to produce Zener breakdown.
3. Here electric field is very strong to rupture the covalent bonds thereby generating electron-hole pairs. So even a small increase in reverse voltage is capable of producing Large number of current carriers.	3. Her minority carriers collide with semi conductor atoms in the depletion region, which breaks the covalent bonds and electron-hole pairs are generated. Newly generated charge carriers are accelerated by the electric field which results in more collision and generates avalanche of charge carriers. This results in avalanche breakdown.
4. Zener diode exhibits negative temp: coefficient. Ie. breakdown voltage decreases as temperature increases.	4. Avalanche diodes exhibits positive temp: coefficient. i.e breakdown voltage increases with increase in temperature.
5The Zener breakdown is because of low reverse potential.	The avalanche breakdown voltage causes because of high reverse potential because it is lightly doped

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