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| **Name:**<br>**Enrolment No:** | |

**UPES**

**End Semester Examination, May 2023**

**Course: Physics of Semiconductor Devices** **Semester: II**

**Program: B. Tech Electronics and Communication Engineering, Electronics and Computer Engineering**

**Time: 03 hrs.**

**Course Code: Phys 2202** **Max. Marks: 100**

**Instructions: The variables used in the text and equations having their usual meaning as introduced in the lectures. Boltzmann's constant, k=1.38 x $10^{-23}$ Joule/K, Charge on electron, q=1.6 x $10^{-19}$ C.**

## SECTION A

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| Q 1 | (i) Which one of the following is trivalent material?<br>(a) Antimony (b) Phosphorus (c) Arsenic (d) Boron<br>(ii) In a material, the Fermi-level is located between the center of the forbidden band and the conduction band. Then what is that material?<br>(a) A p-type semiconductor (b) An n-type semiconductor<br>(c) An intrinsic semiconductor (d) An insulator<br>(iii) As per Hall effect, if any specimen carrying a current, I is placed in a transverse magnetic field B, then an electric field E is induced in the specimen in the direction<br>(a) Parallel to I (b) Perpendicular to B and parallel to I<br>(c) Parallel to I and B (d) Perpendicular to both I and B<br>(iv) The minimum energy of a photon required for intrinsic excitation is equal to<br>(a) The energy of the bottom of the conduction band<br>(b) The energy of the top of the valence band<br>(c) Forbidden gap energy<br>(d) Fermi energy | **4** | **CO1** |
| Q 2 | (i) Atomic number of silicon is<br>(a) 12 (b) 13 (c) 14 (d) 15<br>(ii) The diffusion length for holes Lp, is the<br>(a) Average distance which an injected hole travels before recombining with an electron<br>(b) Maximum distance travelled by a hole before recombining with an electron<br>(c) Length of the region in which diffusion takes places<br>(d) Minimum distance travelled by a hole before it recombines with an electron | **4** | **CO1** |

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| | (iii) When donor atoms are added to the semi-conductor,<br>(a) Increases the energy band gap of the semiconductor<br>(b) Decreases the energy band gap of the semiconductor<br>(c) Introduces a new discrete energy level below the conduction band<br>(d) None of above<br>(iv) Doping intrinsic Silicon with Arsenic as an impurity<br>(a) Produces a semiconductor in which the charge carriers are predominantly electrons, but holes are also present<br>(b) Produces a semiconductor in which the charge carriers are predominantly holes but free electrons also present<br>(c) Produces a semiconductor in which the charge carriers contain a nearly equal number of electrons and holes<br>(d) None of above | | |
| Q 3 | Explain the mechanism of avalanche and Zener breakdown in the p-n junction diode. | **4** | **CO2** |
| Q 4 | The diffusion coefficient of an electron at room temperature, T=300K is 35 $cm^2$/sec. Find the mobility of an electron in Si at room temperature. Give the units of mobility also. | **4** | **CO1** |
| Q 5 | Draw the V-I characteristics of p-n junction photodiode. Does the current correspond to a forward- or reverse- biased diode? | **4** | **CO3** |
| | **SECTION B** | | |
| Q 6 | (i) Draw the energy band diagram of insulator, semiconductor, and insulator.<br>(ii) Explain why a semiconductor acts as insulator at $0^0$K and why its conductivity increases with temperature?<br>(iii) A Si sample is doped with $10^{17}$ arsenic atoms/$cm^3$, what is the equilibrium concentration $p_0$ at 300K? Given that $n_i$=1.5 x $10^{10}$ $cm^3$. | **10** | **CO1** |
| Q 7 | A Si p-n junction with cross-sectional area, A=0.001 $cm^2$ is formed with $N_A$=$10^{15}$ cm-$^3$, $N_D$=$10^{17}$ $cm^{-3}$, calculate the contact potential and space-charge width at zero bias. | **10** | **CO1** |
| Q 8 | Prove that the junction capacitance due to the dipole in the depletion region is given by $C_j = \epsilon A \left[\frac{q}{2\epsilon(V_0-V)}\frac{N_A N_D}{N_A+N_D}\right]^{1/2}$. | **10** | **CO2** |
| Q 9 | (i) Draw the I-V curves of solar cell at different irradiance.<br>(ii) A Si solar cell has a short circuit current of 100 mA and an open circuit voltage of 0.8V under one Sun illumination. The fill factor is 0.7. What is the maximum power delivered to a load by this cell? | **10** | **CO3** |

| SECTION-C | | | |
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| Q 10 | What is the law of junction? Plot the hole current, the electron current, and the total current as a function of distance on both sides of a p-n junction. Prove that the total diode current is given by the following equation:<br>$I = I_o\left[e^{\frac{qV}{kT}} - 1\right]$ where $I_O = Aq\left[\frac{D_p p_{no}}{L_p} + \frac{D_n n_{po}}{L_n}\right]$<br>Given that the current associated with diffusion of minority carriers (holes) is given by $I_p = \frac{AqD_p}{L_p}[p(0) - p_o]e^{-x/L_P}$ | **20** | **CO2** |
| Q 11 | (i) Sketch the basic structure of an n-channel junction field effect transistor. Show the circuit symbol for the JFET.<br>(ii) Define the pinch-of-voltage, $V_P$. Sketch the depletion region before and after the pinch-off.<br>(iii) Show that the pinch-off voltage is given by $V_p = \frac{qa^2N_D}{2\varepsilon}$<br>**OR**<br>(i) Sketch the basic structure of an enhancement type n-channel MOSFET. Show the circuit symbol for it.<br>(ii) Discuss the basic operation of an enhancement type n-channel MOSFET.<br>(iii) Draw the output and transfer characteristics of enhancement type of MOSFET. | **20** | **CO4** |