**Code : 105201**

## B.Tech 2nd Semester Exam., 2019

( New Course )

# PHYSICS

**( Semiconductor Physics and Introduction to Quantum Mechanics )**

*Time* : 3 hours *Full Marks* : 70

*Instructions* :

*(i) The marks are indicated in the right-hand margin.*

*(ii) There are* ***NINE*** *questions in this paper.*

*(iii) Attempt* ***FIVE*** *questions in all.*

*(iv) Question No.* ***1*** *is compulsory.*

*(v) All symbols have their usual meanings as discussed in the class.*

(Dielectric constant of $SiO_2 = 3 \cdot 9$, permittivity of free space $= 8 \cdot 85 \times 10^{-12}$ F/m, charge on electron $= -1 \cdot 6 \times 10^{-19}$ C, Boltzmann constant $k_B = 1 \cdot 38 \times 10^{-23}$ J/K, bandgap of Si at 300 K is 1·1 eV, intrinsic carrier concentration for Si at 300 K is $1 \cdot 5 \times 10^{10}$ cm$^{-3}$, electron affinity of Si at 300 K is 4·1 eV, intrinsic energy for Si can be taken at the middle of the bandgap)

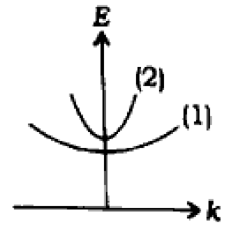
**1.** Answer any *seven* of the following : 2×7=14

*(a)* Explain in brief, what are intrinsic semiconductors.





*(b)* The *E-k* diagram for two materials (1) and (2) have been shown below :




Which one will have larger effective mass?

*(c)* What is the mathematical expression of Fermi function? Make its rough sketches for two temperatures 0 K and 300 K.

*(d)* Write the expressions for drift-diffusion currents for holes.

*(e)* What is radiative recombination?

*(f)* What is Heisenberg uncertainty principle?

*(g)* Explain the difference between luminescence and incandescence.

*(h)* What are phonons?

*(i)* Define the term 'quantum efficiency' for a photodetector.

*(j)* What is phase velocity?

2. Answer the following questions :

(a) What is density of states? Derive an expression for the density of states in 2D.

(b) Explain the variation of carrier concentration with temperature inside a semiconductor. 4

(c) A photodiode is made with *p*-type Ge doped with $10^{23}$ Ga atoms/$m^3$ and *p*-type Ge doped with $10^{22}$ As atoms/$m^3$. The intrinsic carrier concentration and dielectric constant of Ge are $2{\cdot}5 \times 10^{19}$ $m^3$ and 16 respectively. Find out the built-in potential of the junction, the depletion region width and the depletion charges on each side of the junction. 4

3. Answer the following questions :

(a) For a uniformly doped Si sample with $N_A = 10^{16}$ $cm^{-3}$ and $N_D = 2 \times 10^{16}$ $cm^{-3}$, determine the equilibrium electron and hole concentrations at room temperature. 5

(b) An Si sample is doped with $10^{16}$ Boron (B) atoms/$cm^3$. At 300 K, where will be the Fermi energy ($E_F$) relative to the intrinsic energy ($E_i$)? Draw the band diagram also 5





(c) What is avalanche multiplication? Explain with proper diagrams. 4

4. Answer the following questions :

(a) Explain the effects of temperature and doping on carrier mobilities inside a semiconducting material. 5

(b) A 1 cm long bar of Si maintained at 300 K has a cross-sectional area of 100 $\mu m^2$ and is uniformly doped with $10^{15}$ $cm^{-3}$ phosphorus. What current will flow through it, if 10 V is applied across its length? Assume the electron and hole mobilities are 800 $cm^2$/V-s and 400 $cm^2$/V-s respectively. 4

(c) Uniformly doped ($10^{15}$ acceptors/$cm^3$) GaAs sample is exposed to instantaneous flash of light, which generated $10^{14}$ electron hole pairs/$cm^3$ of the sample. How will the carrier concentrations evolve with time? Assume the intrinsic carrier concentration in GaAs is $10^6$ $cm^{-3}$ and the carrier recombination lifetime for both electrons and holes is 10 ns. 5

5. Answer the following questions :

(a) A photodiode has a responsivity of 0·5 A/W at 850 nm. Find the efficiency of the detector. 4

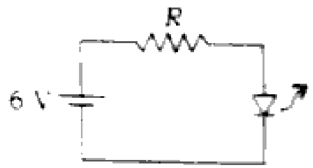
(b) An ideal photodiode is illuminated with 10 mW of optical power at 900 nm. Calculate the current output, when the diode is used in photoconducting mode at 300 K. What is the voltage output, if the diode is used in photovoltaic mode? The reverse bias leakage current is 10 nA. 6

(c) Explain the structure and working of pin photodiode. https://www.akubihar.com 4

6. Answer the following questions :

(a) A GaAs LED radiates at 900 nm. If the forward current in the LED is 20 mA, calculate the power output, assuming an internal quantum efficiency of 2%. 6

(b) In the circuit shown below, the forward biased LED has a voltage drop of 1·5 V :








If the battery voltage is 6 V, then calculate the resistance to be connected to the circuit, if the current through the LED is 15 mA. How much power is dissipated in the resistor? 4

(c) Explain direct and indirect bandgap semiconductors with the help of appropriate diagrams. Which ones are preferred for making LEDs and why? 4

7. Answer the following questions :

(a) Explain the structure and working of a semiconductor laser. 6

(b) What do you mean by relaxation oscillations? Why are they observed? 4

(c) What are input-output characteristics of lasers? 4

8. Answer the following questions :

(a) What is the fill factor of a solar cell? 2

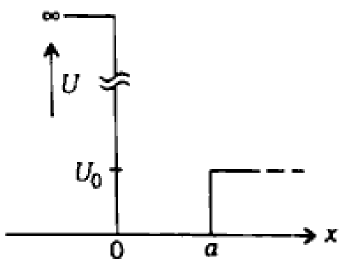
(b) Starting from Planck relation, show that the wavelength of a light (λ) emitted by a semiconductor of bandgap $E_g$ is given by $\lambda(\mu m) = 1 \cdot 24 / E_g(eV)$. 4

(c) Explain population inversion for a *p-n* junction laser diode with the help of a band diagram. 4

(d) What is free electron theory? What are its main assumptions? 4

9. Answer the following questions :

(a) A particle of mass $m$ and energy $E$, where $0 < E < U_0$ is placed in a 1D potential well as shown below :




Obtain the equation which must be solved to determine the allowed particle energies. Rewrite it in terms of $\xi = E / U_0$ and $\alpha_0 = \sqrt{2mU_0 / \hbar^2}$, plot its two sides for cases of $\alpha_0 a = \pi / 4$ and $\alpha_0 a = \pi$ and explain how many solutions you will get. 10

(b) Consider the 1D wave function $\psi(y) = Ae^{-y^2}$. Find $A$ so that it can be normalized. 4

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