**Darbhanga College of Engineering, Darbhanga**

**B.Tech. 2nd Semester (CSE)**

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

**Module 1: Semiconductors**

1. Explain the energy band theory of solids . Differentiate between Conductor, Insulator and Semiconductor.
2. Suppose a pure silicon crystal has 5 X 1028 atom/m3. It is doped by 1 ppm (parts per million) concentration of pentavalent Arsenic. Calculate the number of electrons and holes. Given that ni = 1.5 X 1016/m3.
3. A rod of p-type germanium of 10 mm long and 1 mm diameter has a resistance of 100 **Ω**. What is the concentration of dopant in this rod?

Given μe = 0.46 m2 V-1s-1 and μp = 0.015 m2 V-1s-1

1. What is an intrinsic semiconductor? Discuss its behavior as the temperature increases.
2. Briefly explain how a p-type semiconductor is formed? Give any two differences between a p-type semiconductor and a n-type semiconductor.
3. Explain how p-n junction diode is formed. What are the mechanisms involved in it?
4. Write short notes on diffusion.
5. Write short notes on Fermi level.
6. Write short notes on carrier transport.
7. Write short notes on radiative and non radiative recombination mechanism in semiconductors.
8. Name the dominant charge carrier in P-doped Ge, and specify whether the material is p- or n-type.
9. Explain I-V characteristics of p-n junction diode.
10. You wish to make n-type germanium (i) name a suitable dopant (ii) name the majority charge carrier in the doped material.
11. Write short notes on intrinsic and extrinsic semiconductor.
12. At room temperature, an intrinsic semiconductor has some holes in it due to

a) Doping b) Free electrons c) Thermal energy d) Valence electron

1. An intrinsic semiconductor at room temperature has
2. A few free electrons and holes b) Many holes c) Many free electrons d) No holes
3. What would be a typical proportion of donor atoms added to pure silicon during the

fabrication of P type silicon?

a) 1 donor atom per 100,000 silicon atoms.

b) 1 donor atom per 1,000,000 silicon atoms.

c) 1 donor atom per 10,000,000 silicon atoms.

d) 1 donor atom per 100,000,000 silicon atoms.

1. The most commonly used semiconductor element is

a) Silicon b) Germanium c) Gallium d) Carbon

1. Which of the following could be used as a donor atom used to produce N type

semiconductor material?

1. Aluminium b) Boron c) Phosphorus d) Germanium
2. Discuss the carrier transport mechanisms : Diffusion and Drift.

**Module 2: Electronic Materials**

1. Differentiate between a metallic conductors, semiconductor and insulator basing on the energy band theory of solids?
2. What is direct and In – direct bandgap semiconductor? Explain with examples.
3. Why does the conductivity of a semiconductor change with impurity content? Compare this with the metallic conductors.
4. Draw E-K diagram and explain briefly.
5. Explain Kronig- Penny Model and its significance.
6. Define occupation probability?
7. Discuss free electron theory, density of state and energy band diagram.
8. Derive an expression for effective mass of an electron.
9. Write short notes on types of electronic materials.
10. What do you mean by negative effective mass.
11. Explain the formation of band gap in the solids.
12. Draw schematic band energy diagrams of metals, semiconductor and insulator.
13. Define density of state. Plot density of state versus energy for three dimensional semiconductors.
14. Calculate the density of state of three dimensional semiconductors.
15. Write short notes on phonon.
16. What is effective density of state in semiconductor?
17. Evaluate the Fermi function for energy KT above the Fermi energy.
18. In a solid, consider the energy lying 0.01 eV below Fermi level. What was the probability of this level not being occupied by an electron?
19. Write short notes on Fermi function of electron.
20. Write short notes on Bloch wave function.

**Module 3: Semiconductor Light Emitting Diodes**

1. What is an LED? Briefly explain working principle using a schematic diagram.
2. Write down rate equations for carrier density.
3. What is Internal quantum efficiency, External quantum efficiency and Power efficiency of an LED?
4. Write short notes on Organic LEDs.
5. Discuss the concept of Direct and Indirect Band Gaps
6. 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%.
7. The working voltage of an LED is 1.8 volts. If the desired current flow is 15 mA, how much power is dissipated in a resistor that must be connected to an LED circuit operated on a d.c. voltage of 12 V.(Ans. 0.153 W)
8. Photons of wavelength λ=813 nm are absorbed in InP at room temperature (Eg=1.344eV, me \*=0.08mo , mh \*=0.60mo ) and excites electron-hole pairs (EHP). Calculate the average kinetic energy of the electrons and holes before they relax to the bottom of the bands. [Hint: they will not be the same]
9. Find the peak emission wavelength (λo ) for an Al0.2Ga0.8As LED operating at 400oK, given the band gaps AlAsG =3.03eV, AlAsX =2.15eV, AlAsL =2.36eV, GaAsG =1.43eV, GaAsX =1.73eV, and GaAsL =1.89eV. (assume linear interpolation to be valid)
10. Discuss the concept of Extraction Efficiency of an LED.
11. Calculate the band gap of a Blue LED. What are the materials used for manufacturing Blue LED?
12. Which one of the following is not an advantage of using double-heterostructures for making LEDs? A) Lower reabsorption loss ,

B) Better optical confinement,

C)Higher operating current,

D) Stronger carrier confinement

1. In practical LEDs, increase in the temperature of the LED leads to (mark the correct answer)— A)Increase in the output power

B) Decrease in the linewidth

C) Increase in the peak emission wavelength

D) Increase in the external quantum efficiency

1. A particular LED emitting at 620 nm wavelength has radiative and non-radiative recombination lifetimes in the ratio of 3:2. If the output power of the LED is 10 mW when the applied bias current is 50 mA, the extraction efficiency of the LED is \_\_\_\_\_\_ %.
2. Which one of the following should be chosen for making a red-colour display?

A) A surface-emitting LED using InxGa1–xN ,

B)An edge-emitting LED using AlxGa1–xAs,

C) A surface-emitting LED using GaAs1–yPy ,

D)An edge-emitting LED using In1–xGaxAsyP1–y

1. Which of the following is not a characteristic of LED?  
   a) Fast action  
   b) High Warm-up time  
   c) Low operational voltage  
   d) Long life
2. What is the bandwidth of the emitted light in an LED?  
   a) 1 nm to 10 nm  
   b) 10 nm to 50 nm  
   c) 50 nm to 100 nm  
   d) 100 nm to 500 nm
3. Which process of the Electron-hole pair is responsible for emitting of light?  
   a) Generation  
   b) Movement  
   c) Recombination  
   d) Diffusion
4. Increase in the forward current always increases the intensity of an LED.  
   a) True  
   b) False
5. What should be the biasing of the LED?  
   a) Forward bias  
   b) Reverse bias  
   c) Forward bias than Reverse bias  
   d) No biasing required

**Module 4: Semiconductor LASERS**

1. What is the difference between spontaneous and stimulate emission? Which mechanism is dominant in LED and Semiconductor Laser?
2. What is the need to achieve population inversion?
3. What is stimulated emission? Explain with diagram.
4. Discuss laser dynamics and relaxation oscillations.
5. Discuss input-output characteristics of lasers.
6. Write short notes on semiconductor laser.
7. Classify the different types of lasers based on their active medium.
8. Discuss the role of optical resonators in a laser system.
9. What are the Einstein Relations - A and B Coefficients? Derive their relations.
10. State the differences between laser and normal light.
11. What are the different transition processes involved with lasing action?
12. State some applications of laser.
13. Explain how non degenerate semiconductor is achieved with energy diagram.
14. A semiconductor is said to be degenerate when the Fermi level lies within either the conduction or valence bands. At what doping density is this n-type material degenerate ?
15. Explain output characteristics of semiconductor laser.
16. Discuss the Wien's Displacement Law.
17. Discuss the concept of total internal reflection.
18. With the help of suitable diagrams discuss the types of laser structures, (a) homojunctions, (b) single and (c) double heterostructures.
19. Write short notes on Quantum well, wire and dot lasers.
20. Discuss the Boltzmann Statistics.

**Module 5: Photodetectors**

1. Write short notes on PIN and Avalanche.
2. An APD has a quantum efficiency of 50% at a wavelength of 500 nm in the absence of

multiplication. If the device is operated with a reverse bias to give a multiplication factor of 8, calculate the responsivity.

1. A p-n junction detector has 50% efficiency at nm. What is the responsivity?
2. A photodiode has a responsivity of 0.5 A/W at 850 nm. Find the efficiency of the detector.
3. A photodiode has a responsivity of 0.5 A/W at 850 nm. Find the efficiency of the detector.
4. A p-n junction detector has 50% efficiency at nm. What is the responsivity ?
5. 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. Write short notes on Dark Noise, Shot Noise and Johnson Noise.
7. A photodetector has a quantum efficiency of 80% at 1000 nm. A radiation of optical power 0.01 watt/m at this wavelength is incident on the device which has a receiving area of 1 mm . The detector has a dark current of 5 nA and a shunt resistance of 10 ohms. If the bandwidth of operation is 100 MHz, calculate the power SNR of the detector.
8. Consider an ideal photodiode operating with a bandwidth of 20 MHz. How much optical power is required to get an SNR of 10 ? hfill (Hint : Ideal photodiode has infinite shunt resistance and zero dark current. )
9. What are the Physical Processes in Light Detection?
10. Explain different types of performance parameters of photodetectors.
11. Define Responsivity, Quantum efficiency and spectral response of the photodetectors.
12. Explain the basic working principle of photodetectors.
13. Write short notes on P-N junction, PIN and Avalanche.
14. Explain the working principle of Avalanche Photodetector.
15. Explain the output characteristics of PIN and Avalanche photodetectors.
16. Write short notes on working design of PIN and Avalanche photodetectors.
17. What are the materials used for PIN and Avalanche photodetectors.
18. A photodiode is made with p-type Ge doped with 1023 Ga atoms/m and n-type Ge with 1022 As atoms/m . For Ge, k = 16 . The intrinsic carrier concentration of Ge at 300 K is given by ni = 2.5 X 1019. Calculate the width of the depletion layers and the charge transfer per unit area at 300 K.

**Module 6: Introduction to Quantum mechanics**

1. What is the physical significance of wave function?
2. Define Heisenberg’s uncertainty principle?
3. Define expectation values.
4. What is photoelectric effect?
5. Write short notes on wave and group velocity?
6. Write short noted on Time dependent and independent Schroedinger equation.
7. Define probability current density.
8. Explain briefly the concept of operators in wave mechanics.
9. Briefly explain wave particle duality.
10. Explain blackbody radiation curves and Planck’s quantum hypothesis.
11. Derive Planck’s radiation formula for a blackbody and discuss special case.
12. Calculate the de Broglie wavelength associated with an electron of energy 1.5 eV.
13. Explain in brief Compton effect on the basis of quantum mechanics. What is its physical significance.
14. In Compton experiment, the wavelength of X-ray radiation scattered at an angle of 450 is 0.022 Å.
15. Prove that classical theory does hold in the region of atomic dimension.
16. State the characteristics of black body radiation.
17. What do you mean by matter waves? What is the aim of Davisson Germer experiment?
18. What is Compton effect? Calculate the Compton wavelength for an electron.
19. Prove that Compton shift is independent of the scatter.
20. Using Heisenberg’s uncertainty principle show that electron cannot reside in the nucleus.