POSTAL Book Package 2023

GATE • ESE

Electronics Engineering

Objective Practice Sets

Electronic Devices and Circuits

Contents

MADE EASY Publications

1 CHAPTER Semiconductor Physics

MCQ and NAT Questions

Q.1 A conductor carries a current of 4 A and if magnitude of charge of an electron $e = 1.6 \times 10^{-19}$ Coulomb, then the number of electrons which flow past the cross-section per second is
(a) 2.5×10^{19} (b) 1.6×10^{19}
(c) 6.4×10^{19} (d) 0.4×10^{19}

Q.2 Long wavelength threshold for Si at room temperature is
(a) 1.13 mm (b) 1.73 mm
(c) 1 mm (d) 1.21 mm

Q.3 Given that the band gap of cadmium sulphide is 2.5 eV, the maximum photon wavelength, for electron-hole pair generation will be
(a) 4968 μm (b) 496 μm
(c) 4968 Å (d) 496 Å

Q.4 Doping of semiconductors is
(a) the process of purifying semiconductor materials
(b) the process of adding certain impurities to the semiconductor material
(c) the process of converting a pure semiconductor material into some form of an active device like diode, transistor, FET etc.
(d) one of the processes used in the fabrication of ICs

Q.5 A semiconductor material with impurities added is
(a) an extrinsic semiconductor
(b) an intrinsic semiconductor
(c) an *N*-type semiconductor
(d) a *P*-type semiconductor

Q.6 Boron and Indium are two commonly used trivalent impurities used for doping of semiconductors. Another is
(a) Arsenic (b) Phosphorus
(c) Aluminium (d) none of these

Q.7 The conductivity of a semiconductor crystal due to any current carrier is NOT proportional to
(a) mobility of the carrier
(b) effective density of states in the conduction band
(c) electronic charge
(d) surface states in the semiconductor

Q.8 Consider the following statements for an *n*-type semiconductor:
1. Donor level ionization decreases with temperature
2. Donor level ionization increases with temperature.
3. Donor level ionization in independent of temperature.
4. Donor level ionization increases as E_D (donor energy) moves towards the conduction band at a given temperature.

Which of these statement(s) is/are correct?
(a) 1 only (b) 2 only
(c) 2 and 4 (d) 3 only

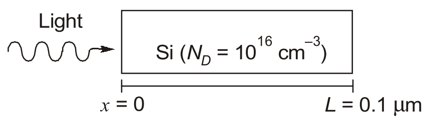
Q.9 Electron mobility and life-time in a semiconductor at room temperature are respectively 0.36 m^2/(V-s) and 340 μs. The diffusion length is
(a) 3.13 mm (b) 1.77 mm
(c) 3.55 mm (d) 3.13 cm

Q.10 The ratio of minority to majority diffusion coefficient D_p / D_n for germanium is approximately
(a) 2 (b) 0.5
(c) 3 (d) 0.33

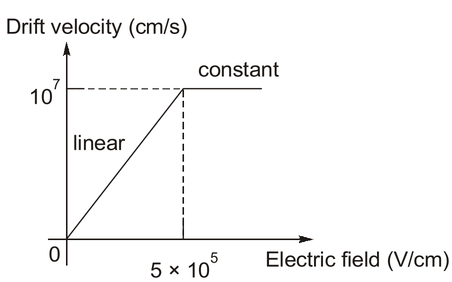
Q.11 The concentration of minority carriers in an extrinsic semiconductor under equilibrium is
(a) directly proportional to the doping concentration
(b) inversely proportional to the doping concentration
(c) directly proportional to the intrinsic concentration
(d) inversely proportional to the intrinsic concentration

$$G_L = G_{L0}\left(1-\frac{x}{L}\right),\ 0 \le x \le L,$$

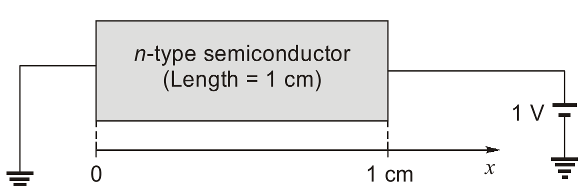
where $G_{L0} = 10^{17}\ \text{cm}^{-3}\ \text{s}^{-1}$. Hole lifetime is 10^{-4} s, electronic charge $q = 1.6 \times 10^{-19}$ C, hole diffusion coefficient $D_p =$ 100 cm²/s and low level injection condition prevails. Assuming a linearly decaying steady state excess hole concentration that goes to 0 at $x = L$, the magnitude of the diffusion current density at $x = L/2$, in A/cm², is ________.



Q.94 The dependence of drift velocity of electrons on electric field in a semiconductor is shown below. The semiconductor has a uniform electron concentration of $n = 1 \times 10^{16}\ \text{cm}^{-3}$ and electronic charge $q = 1.6 \times 10^{-19}$ C. If a bias of 5 V is applied across a 1 μm region of this semiconductor, the resulting current density in this region, in kA/cm², is ________.



Q.95 Consider a uniformly doped n-type silicon semiconductor, which is connected to a DC voltage source as shown in the figure below:



The doping concentration in the sample is $N_D = 10^{16}$ donor atoms/cm³, the intrinsic carrier concentration $n_i = 10^{10}\ \text{cm}^{-3}$ and kT/q = 26 mV. E_C is the lowest energy level of the conduction band and E_F is the Fermi energy level in the sample. The values of E_C and E_F at extreme points of the bar are given by,

at $x = 0$, $E_C = E_{C0}$ and $E_F = E_{F0}$

at $x = 1$ cm, $E_C = E_{C1}$ and $E_F = E_{F1}$

For the given circuit arrangement of the semiconductor, the value of the difference $(E_{F0} - E_{C1})$ will be _______ eV.

[Assume that the energy gap of silicon as 1.1 eV]

Q.96 For a semiconductor having $n_i = 1.5 \times 10^{10}/\text{cm}^3$ and hole mobility = 500 cm²/V.sec while e^- mobility = 1300 cm²/V.sec. Then the value of minimum conductivity will be _______ $\times 10^{-6}$ (Ω-cm).

Multiple Select Questions (MSQs)

Q.97 A p-type silicon sample at room temperature uniformly doped with $N_A = 10^{17}\ \text{cm}^{-3}$ is uniformly illuminated with light, resulting in an optical generation rate $G_L = 10^{20}\ \text{cm}^{-3}\ \text{sec}^{-1}$. Assume spatially uniform conditions, $n_i = 10^{10}\ \text{cm}^{-3}$ and $\tau_n = 10^{-6}$s. Then,

(a) The steady-state excess minority concentration is $10^{11}\ \text{cm}^{-3}$.
(b) The sample is under low-level injection.
(c) Hole Quasi-Fermi level is 0.42 eV below the equilibrium intrinsic Fermi level.
(d) Electron Quasi-Fermi level is 0.42 eV above the intrinsic equilibrium Fermi level.

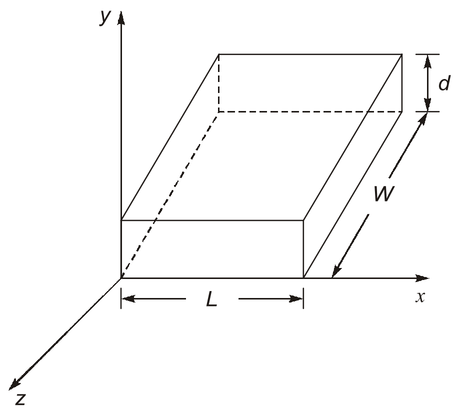
Q.98 Which of the following statement(s) is/are correct in reference to indirect band gap semiconductor?

(a) The minimum energy of conduction band and maximum energy of the valence band have different values of wave vector.
(b) Lifetime of the charge carriers is more.
(c) The recombination is luminative.
(d) These are primarily used to amplify the signals.

Q.99 Which of the below statement(s) is/are correct?

(a) An extrinsic semiconductor behaves as an intrinsic semiconductor at very high temperatures.
(b) The conductivity of an extrinsic semiconductor is always higher than the conductivity of the corresponding intrinsic semiconductor.
(c) The mobility of charge carriers decreases at higher doping concentration.
(d) At very high temperatures, the conductivity of extrinsic semiconductor decreases with temperature.

Q.100 A silicon sample at T = 300 K has the geometry $d = 10^{-3}$ cm, $W = 10^{-2}$ cm, $L = 10^{-1}$ cm. Hall experiment is conducted on the device and following parameters are measured : I_x = 0.8 mA, V_x = 15 V, V_H = 5 mV and B_z = 0.1 T.



Which of the below statement(s) is/are correct?

(a) The silicon-sample is *n*-type.

(b) The majority carrier concentration is 10^{15} cm^{-3}.

(c) The majority carrier mobility is 2000 cm^2/V-s.

(d) The hall coefficient of sample is almost independent of temperature.

Q.101 The concentration of minority carriers in an extrinsic semiconductor under equilibrium

(a) is inversely proportional to the doping concentration.

(b) is directly proportional to the intrinsic concentration.

(c) increases with the temperature.

(d) depends on the bandgap of the semiconductor.

Q.102 Germanium at T = 300K with intrinsic carrier concentration of 2.4×10^{13} cm^{-3} is uniformly doped with Arsenic having concentration of 10^{14} cm^{-3}. Which of the below statement(s) is/are correct?

(a) The thermal equilibrium electron concentration is 1.2×10^{14} cm^{-3}.

(b) The thermal equilibrium hole concentration is 5.46×10^{12} cm^{-3}.

(c) The position of Fermi energy level with respect to intrinsic Fermi level is 0.0383 eV.

(d) With increase in doping concentration, the Fermi energy level moves closer to the intrinsic Fermi level.

Q.103 For a silicon sample (bandgap 1.12 eV) at room temperature 300 K with the Fermi level located exactly in the middle of the bandgap, which of the below statement(s) is/are correct?

(a) The sample is a non-degenerate semiconductor.

(b) The probability that a state located at the bottom of the conduction band is filled is equal to 4.43×10^{-10}.

(c) The probability that a state located at the top of the valence band is empty is 0.005.

(d) The sample can be used as an ohmic contact in ICs.

Q.104 A Hall effect transducer can be used

(a) as magnetometers

(b) for measurement of area of the device

(c) for measurement of power in an electromagnetic wave

(d) for determination of minority carrier concentration.

Q.105 A sample of Germanium is doped to the extent of 10^{14} donor atoms/cm^3 and 5×10^{13} acceptor atoms/cm^3. At 300K, the resistivity of the sample is 60 Ω-cm. The electric field of 2 V/cm is applied to the sample. If $\mu_n = 2\mu_p$, $n_i = 2.5 \times 10^{13}$ cm^{-3}, then

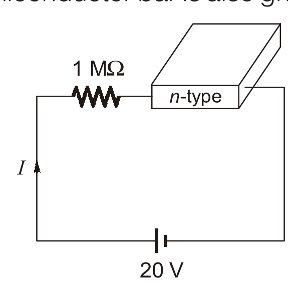
(a) the hole mobility is 1189 cm^2/V-s.

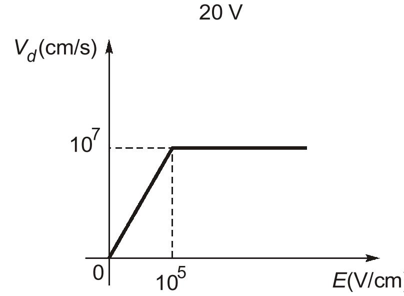
(b) the equilibrium hole concentration is about 1.035×10^{13} cm^{-3}.

(c) the electron current density is 39.2 mA/cm^2.

(d) the hole current density is 4.6 mA/cm^2.

Q.106 A uniformly doped *n*-type semiconductor bar with $N_D = 10^{16}$ cm^{-3} is connected in a circuit as shown in the following figure. The variation of drift velocity of electrons with the electric field across the semiconductor bar is also given in the figure.





Dimensions of the semiconductor bar are :
L = 1 μm & cross-sectional area = (0.5 μm × 0.5 μm)

Which of the below statement(s) is/are correct?

(a) The electron mobility is 2000 cm^2/V-s.

(b) Drift velocity is in the linear region for given supply voltage.

(c) The current flowing through the circuit is 16 μA.

(d) The electric field across the semiconductor bar is 2×10^5 V/cm.

Q.107 A semiconductor has following parameters : $\mu_n = 7500\ cm^2/V$-s, $\mu_p = 300\ cm^2/V$-s and $n_i = 3.6 \times 10^{12}\ cm^{-3}$. Which of the following statements is/are correct?

(a) When conductivity is minimum, the hole concentration is $1.8 \times 10^{13}\ cm^{-3}$.

(b) When conductivity is maximum, the electron concentration is $1.8 \times 10^{13}\ cm^{-3}$.

(c) The minimum conductivity of semiconductor is 1.7 mS.

(d) The semiconductor has minimum conductivity when it has a acceptor doping more than donor doping.

Q.108 Which of the below statement(s) is/are correct?

(a) When GaAs is doped with Magnesium, it becomes a *p*-type semiconductor.

(b) When GaAs is doped with Si, it becomes a *n*-type semiconductor.

(c) GaAs has higher electron mobility than Si.

(d) GaAs have very narrow band gap compared to Si.

■■■■

Answers **Semiconductor Physics**

1. (a)	2. (a)	3. (c)	4. (b)	5. (a)	6. (c)	7. (d)
8. (c)	9. (b)	10. (b)	11. (b)	12. (c)	13. (b)	14. (a)
15. (b)	16. (d)	17. (a)	18. (d)	19. (b)	20. (d)	21. (b)
22. (b)	23. (a)	24. (b)	25. (a)	26. (b)	27. (d)	28. (a)
29. (d)	30. (b)	31. (c)	32. (b)	33. (d)	34. (c)	35. (c)
36. (a)	37. (b)	38. (c)	39. (b)	40. (c)	41. (a)	42. (b)
43. (d)	44. (d)	45. (a)	46. (b)	47. (c)	48. (d)	49. (b)
50. (c)	51. (b)	52. (a)	53. (a)	54. (d)	55. (b)	56. (c)
57. (a)	58. (b)	59. (d)	60. (b)	61. (c)	62. (c)	63. (c)
64. (d)	65. (b)	66. (d)	67. (a)	68. (c)	69. (b)	70. (a)
71. (c)	72. (c)	73. (d)	74. (b)	75. (d)	76. (13)	77. (1.12)
78. (225.2)	79. (0.52)	80. (1.92)	81. (14)	82. (100)	83. (0.27)	84. (500)
85. (500)	86. (16.25)	87. (0.318)	88. (–0.262)	89. (134)	90. (1.048)	91. (1.627)
92. (1.198)	93. (16)	94. (1.6)	95. (0.81)	96. (3.87)	97. (b, c)	98. (a, b, d)
99. (a, c)	100. (b, d)	101. (a, c, d)	102. (b, c)	103. (a, b)	104. (a, c)	105. (b, d)
106. (b, c)	107. (a, c, d)	108. (a, c)				

Explanations — Semiconductor Physics

1. (a)

$$I = ne$$

$$\Rightarrow \quad n = \frac{I}{e} = \frac{4}{1.6 \times 10^{-19}} = 2.5 \times 10^{19}/\text{sec}$$

2. (a)

$$E = \frac{1.24}{\lambda_g(\text{in } \mu\text{m})}\text{eV}$$

$$\therefore \quad \lambda = \frac{1.24}{E}$$

for $E = 1.1$ eV at room temperature

$$= \frac{1.24}{1.1} = 1.127\ \mu\text{m}$$

3. (c)

$$\lambda = \frac{hc}{E_g} = \frac{1.242\ \text{eV-}\mu\text{m}}{2.5\ \text{eV}} = 0.4968\ \mu\text{m} = 4968\ \text{Å}$$

4. (b)

Doping is process of adding impurities to the pure sc. It increases carrier concentration and therefore increases the conductivity.

5. (a)

Semiconductor material with impurities is known as extrinsic semiconductor and without impurities (pure) - intrinsic.

6. (c)

Trivalent/Acceptor impurities - B, Al, Ga, In
Pentavalent / donor - P, As, Sb, Bi

7. (d)

Conductivity, $\sigma = nq\mu_n$

μ_n : mobility of carrier

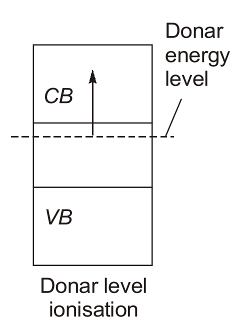
q : electron charge

n : effective density of states in conduction band

8. (c)

Donor energy level is a discrete energy level and is created just below the conduction band.

Donor energy level represents the energy level of all pentavalent atoms added to the pure *sc*.



Donor level ionisation increases with temperature. It also increases if donar energy increases.

Generally, $E_D = 0.01$ eV for Ge
$= 0.05$ eV for si

9. (b)

$$L_n = \sqrt{D_n \tau_n}$$

$$\frac{D_n}{\mu_n} = V_T$$

$$\therefore \quad D_n = \mu_n V_T = 0.36 \times 0.025$$

$$L_n = \sqrt{0.36 \times 0.025 \times 340 \times 10^{-6}} = 1.77\ \text{mm}$$

10. (b)

Since $\frac{D}{\mu}$ α constant

$\therefore D \propto \mu$

For *Ge* $\frac{D_p}{D_n} \propto \frac{\mu_p}{\mu_n} = \frac{1800}{3800} \simeq 0.5$

11. (b)

According to mass action law

$$np = n_i^2$$

$$\therefore \text{ minority carrier conc.} = \frac{n_i^2}{\text{Majority carrier conc.}}$$

$$\propto \frac{1}{\text{Majority carrier conc.}}$$

12. (c)

The bonding in GaAs is covalent bonding.

13. (b)

For Ge: $m = 1.66$ for e^- $\quad m = 2.33$ for holes

For Si: $m = 2.5$ for e^- $\quad m = 2.7$ for holes

14. (a)

Einstein equation,

$$\frac{D}{\mu} = V_T$$

$$\Rightarrow \quad \frac{\mu}{D} = \frac{1}{V_T} = (\text{volt})^{-1}$$