Semiconductor Electronics

Standard difficulty · 20 questions · 40 marks · Time: 38 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. Silicon has an intrinsic carrier concentration of 1×10^{16} m^{-3}. It is doped with 9×10^{20} donor atoms per m^3. The hole concentration is:

(a) 1.11×10^{11} m^{-3} **(b)** 9×10^{20} m^{-3}
(c) 1×10^{16} m^{-3} **(d)** 1.11×10^{-5} m^{-3}

2. Doping pure germanium with indium makes it:

(a) n-type, with electrons as majority carriers
(b) an insulator
(c) p-type, with holes as majority carriers
(d) p-type, with electrons as majority carriers

3. The input to a full-wave rectifier is 1000 Hz AC. The frequency of the output ripple is:

(a) 0 Hz **(b)** 1000 Hz **(c)** 2000 Hz **(d)** 500 Hz

4. A 2 V battery drives current through a forward-biased ideal diode and an 800 Ω resistor in series. The current is:

(a) 2.5 mA **(b)** 0 mA **(c)** 0.25 mA **(d)** 3.375 mA

5. In an intrinsic semiconductor, the number of free electrons is:

(a) equal to the number of holes **(b)** zero
(c) more than the number of holes **(d)** less than the number of holes

6. A solid whose band gap is 0.2 eV is:

(a) a superconductor **(b)** an insulator
(c) a conductor **(d)** a semiconductor

7. The p side of a junction diode is at −4 V and the n side at 3 V. The diode is:

(a) reverse biased **(b)** broken down **(c)** forward biased **(d)** unbiased

8. Assertion (A): In silicon doped with arsenic, the majority carriers are electrons.
Reason (R): Pentavalent impurities make p-type semiconductors.

(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. Pure silicon has $n_i = 1 \times 10^{16}$ m^{-3}. It is doped with 6×10^{23} pentavalent atoms per m^3. Find the electron and hole concentrations, and name the type.

10. Silicon has 5×10^{28} atoms per m^3. It is doped with 1 atom of arsenic for every 10^8 silicon atoms, and $n_i = 1 \times 10^{16}$ m^{-3}. Find the number of donor atoms per m^3 and the hole concentration.

11. A 14 V battery is connected to two branches in parallel: one has an ideal diode (forward biased) and a 950 Ω resistor; the other has an ideal diode that is reverse biased and a 900 Ω resistor. Find the current drawn from the battery.

12. For a silicon diode, the current is 20 mA at 0.61 V and 46 mA at 0.77 V. Find its dynamic resistance in this range.

13. A 100 Hz AC voltage of peak value 28 V is fed to (a) a half-wave rectifier, (b) a full-wave rectifier, each with ideal diodes. Find the output ripple frequency and the peak output voltage in each case.

14. (a) A solid has a band gap of 9 eV. What kind of material is it? (b) Silicon is doped with aluminium. What type does it become, and what are its majority carriers?

15. A silicon diode (0.7 V drop when conducting) and an 850 Ω resistor are in series with a 17 V battery. Find the current when the diode is forward biased and when it is reverse biased (ignore leakage).

16. In a circuit, the p side of a diode is at 6 V and the n side at −10 V. Is the diode forward or reverse biased, and will an ideal diode conduct?

Section C — Word problems — 4 × 4 = 16 marks

17. Silicon with $n_i = 5 \times 10^{15}$ m^{-3} is doped with 3×10^{20} pentavalent atoms per m^3. Find the majority and minority carrier concentrations, name the type, and say what happens to the band diagram.

18. Two silicon diodes (0.7 V drop each) are joined in series, both forward biased, with resistors of 200 Ω and 1000 Ω, across a 19 V battery. Find the current and the voltage across each resistor. What changes if one diode is turned round?

19. A full-wave rectifier with ideal diodes is fed a 60 Hz supply of peak 20 V and drives a 300 Ω load. Explain how it works, and find the ripple frequency and the peak load current.

20. Diode A has its p side at 2 V and n side at −2 V; diode B has its p side at −4 V and n side at 5 V. State the bias of each, which one conducts, and explain what happens to the depletion layer in each case.

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Answer key

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Q	Answer	Working
1	**(a) 1.11×10^{11} m^{-3}**	$n_e n_h = n_i^2$; $n_e \approx N_D$
2	**(c) p-type, with holes as majority carriers**	indium is trivalent
3	**(c) 2000 Hz**	both halves of each cycle give a pulse
4	**(a) 2.5 mA**	I = 2/800
5	**(a) equal to the number of holes**	—
6	**(d) a semiconductor**	small gap → semiconductor; large → insulator; overlap → conductor
7	**(a) reverse biased**	forward bias: p side at the higher potential
8	**(c) A is true, but R is false.**	A is true: arsenic is pentavalent and gives a spare electron. R is false.
9	**$n_e \approx 6 \times 10^{23}$ m^{-3}; $n_h = 1.67 \times 10^{8}$ m^{-3}; n-type**	$n_h = n_i^2/n_e$
10	**5×10^{20} m^{-3}; 2×10^{11} m^{-3}**	$N_D = 5 \times 10^{28} \div 10^{8}$; $n_h = n_i^2/N_D$
11	**14.7 mA**	the reverse-biased branch carries no current
12	**6.15 Ω**	r = ΔV/ΔI
13	**(a) 100 Hz, 28 V; (b) 200 Hz, 28 V**	ideal diodes pass the full peak
14	**(a) an insulator; (b) p-type, holes**	—
15	**19.2 mA; 0 mA**	I = (17 − 0.7)/850
16	**forward biased; it conducts**	conduction needs the p side higher
17	**electrons ≈ 3×10^{20} m^{-3}; holes = 8.33×10^{10} m^{-3}; n-type; a donor level appears just below the conduction band**	minority = n_i^2/majority
18	**14.7 mA; 2.93 V and 14.7 V; with one diode reversed, no current flows**	I = (19 − 1.4)/(200 + 1000)
19	**the two diodes conduct on alternate half-cycles, so current flows through the load the same way in both; 120 Hz; 66.7 mA**	$I_0 = V_0/R$
20	**A: forward biased; B: reverse biased; A conducts; forward bias narrows the depletion layer, reverse bias widens it**	—

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