Department of ECE, Bennett University

EECE105L: Fundamentals of Electrical and Electronics Engineering

Tutorial Sheet-12

Topics Covered: Introduction to semiconductor devices and Diode circuits

Material Constants of Si: $n_i = 1.5 \times 10^{10}$ cm^{-3}, $\mu_n = 1500$ cm^{2}V^{-1}s^{-1}, $\mu_p = 500$ cm^{2}V^{-1}s^{-1}. $E_G = 1.12$ eV.

Universal Constants: Unit charge (q) = 1.6×10^{-19} C, Boltzmann constant (k) = 1.38×10^{-23} JK^{-1}.

If not mentioned, assume non-ideality factor (η) as 1.5, reverse saturation current I_0 as 5 nA.

1. In a piece of silicon semiconductor, Fermi level lies 0.7 eV away from the conduction band. Answer the following questions.
   i) Find electron density and hole density.
   ii) Find conductivity and resistivity.

2. A p-type silicon bar having a resistivity of 0.25 Ω·cm and an n-type silicon bar having a resistivity of 0.1 Ω·cm are used to form a PN Junction. Answer the following questions.
   i) Find majority carrier concentration and minority carrier concentration on each side of the junction.
   ii) What is the built-in potential of the diode?

3. The reverse saturation current for a set of diodes varies between $5 \times 10^{-14} \leq I_O \leq 5 \times 10^{-12}$ A. The diodes are all to be biased at 2 mA. What is the range of forward voltages that must be applied?

4. A PN junction diode having reverse saturation current of 10^{-11} A is forward biased so that the current through the diode is 150 μA. Find the diode voltage.

5. At what reverse bias voltage does the reverse bias current in a PN Junction reaches 90% of its reverse saturation current?

6. What is the ratio of the current for a forward-bias voltage of 0.2 V to the current for a reverse-bias voltage of 0.2 V?

7. For the diode circuit shown in Fig. 1, V_S = 2 V. The silicon diode has a reverse saturation current of 1 nA at 300 K. Given that V = 0.7 V. Find

   i) R_2 when R_1 = 1 kΩ and ii) R_1 when R_2 = 1 kΩ

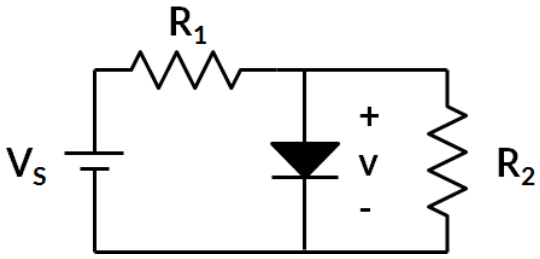

Fig. 1.

8. The diode circuit shown in Fig. 2, D_1 and D_2 are silicon diodes having saturation currents of 5 nA and 10 nA, respectively, at 300 K. Given that both the diodes are forward biased. Find the values of R for which the current is 15 mA.

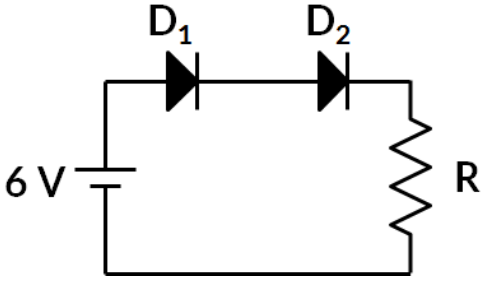

Fig. 2.

9. For the ideal diode circuit shown in Fig. 3, let R_f = 1kΩ and R = 9 kΩ. Find the output voltage V_0 when

   i) $V_1 = V_2 = 0$ V

   ii) V_1 = 10 V, V_2 = 0 V

   iii) $V_1 = V_2$ = 10 V

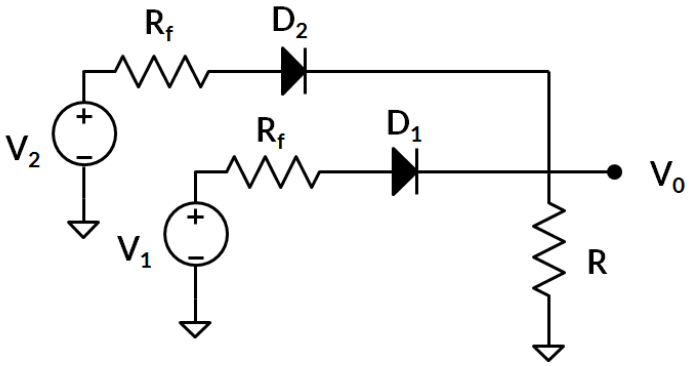

Fig. 3

10. Consider the circuit shown in fig. 4. Determine the current through the diode and voltage across the diode. Assume that the cut-in voltage of the diode is 0.6 V.

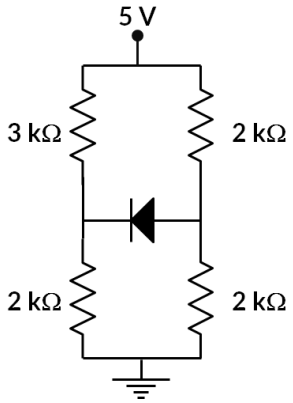

Fig. 4

11. The reverse saturation current of each diode in fig. 5 is 2×10^{-10} A. Determine the input voltage required to produce an output voltage of 0.60 V.

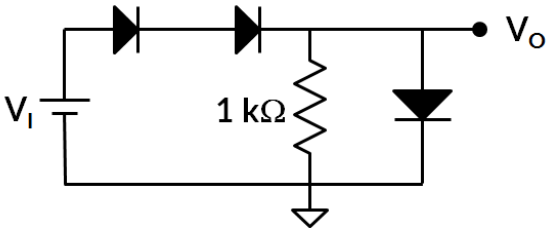

Fig. 5

12. Assume that each diode in the circuit shown in fig. 6 has a cut-in voltage of 0.65 V.

i) If the input voltage is V_I = 5V, determine the value of R_1 such that I_{D1} is one-half of I_{D2}. What are the values of I_{D1} and I_D2?

ii) If V_I = 8V and R_1 = 2 kΩ, determine I_{D1} and I_{D2}.

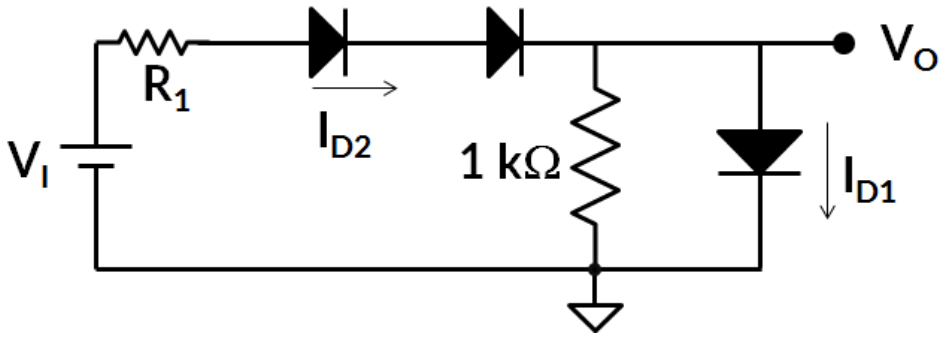

Fig. 6

13. In the circuit shown in fig. 7, find the diode voltage V_D and the supply voltage V such that the current I_D = 0.4 mA. Assume cut-in voltage is 0.7V. What is the power dissipated by the diode?

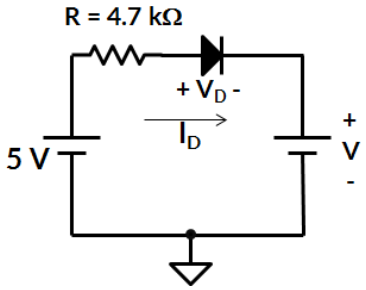

Fig. 7

---------- END OF QUESTIONS ----------

Answers:

1) (i) Electron density = 6.9 x 10^7 cm^3, Hole density = 1.5 x 10^{10}
   (ii) Resistivity = 2.61 $(\Omega\text{-cm})^{-1}$, conductivity = 3.82 kΩ–cm
2) (i) N = 4500 cm^{-3}, p = 5400 cm^{-3}, (ii) 0.78 V
3) 0.515 V – 0.634 V
4) 0.43 V
5) -0.06 V
6) 2193.4
7) i) R_2 = 538 Ω, ii) R_1 = 1.86 kΩ
8) R = 350 Ω
9) i) V_O = 0 V ii) V_O = 8.46 V iii) V_O = 8.91 V

10) $I_D = 0$ A, $V_D = 0.5$ V

11) $V_I = 1.378$ V

12) i) $I_{D1} = 0.65$ mA, $I_{D2} = 1.3$ mA, $R_1 = 2.35$ kΩ ii) $I_{D1} = 2.375$ mA, $I_{D2} = 3.025$ mA

13) V = 2.42 V, P = 0.28 mW