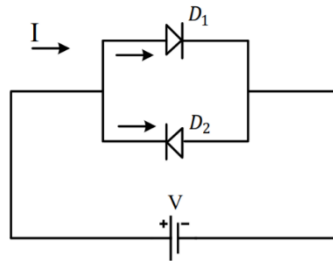


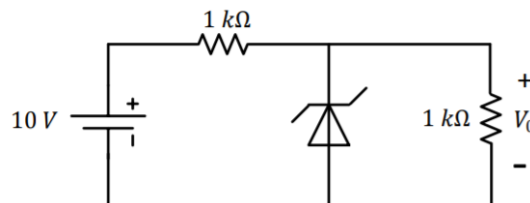
# Introduction to Electronics (Practice paper 1)

## Topic: Basic semiconductor physics & p-n junction diodes and circuits

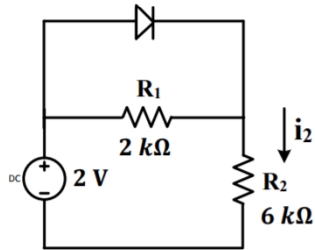
1. 'The maximum resistivity for a silicon sample can be obtained when the sample is slightly p-type' – prove.
2. (a) At room temperature calculate the resistivity of intrinsic silicon. (b) Now doped this Si with  $N_D = 10^{16} \text{ cm}^{-3}$ . Calculate the resistivity of this n-type semiconductor. Given,  $\mu_n = 1350 \text{ cm}^2/\text{V s}$ ,  $\mu_p = 480 \text{ cm}^2/\text{V s}$  and  $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$  at 300 K.
3. An n-type Si material has a resistivity of  $\rho = 0.65 \text{ } \Omega\text{-cm}$ . (i) If the electron mobility is  $\mu_n = 1250 \text{ cm}^2/\text{V-s}$ , what is the concentration of donor atoms? (ii) Determine the required electric field to establish a drift current density of  $J = 160 \text{ A/cm}^2$ .
4. Consider a uniformly doped GaAs pn junction with doping concentrations of  $N_A = 5 \times 10^{18} \text{ cm}^{-3}$  and  $N_D = 5 \times 10^{16} \text{ cm}^{-3}$ . (i) Find the built-in potential ( $V_{Bi}$ ). (ii) Calculate the change in  $V_{Bi}$  if the doping concentration in n-side is increased by 10 times. **Given**, for GaAs bandgap = 1.42 eV and intrinsic carrier concentration =  $1.8 \times 10^6 \text{ cm}^{-3}$  at 300 K. Compare this result with Si p-n diode.
5. At what reverse-bias voltage does the reverse-bias current in a silicon pn junction diode reach 90% of its saturation value?
6. In the circuits shown below, find the relationship between  $V$  and  $I$ .



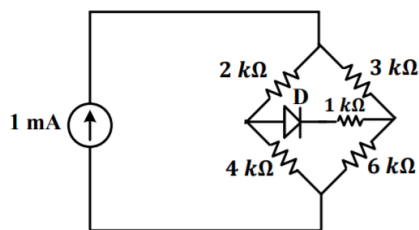
7. A silicon p-n junction under reverse bias has depletion region of width  $10 \text{ } \mu\text{m}$ . The relative permittivity of silicon ( $\epsilon_r$ ) = 11.7 and the free space permittivity ( $\epsilon_0$ ) =  $8.854 \times 10^{-12} \text{ F/m}$ . Estimate the depletion capacitance of the diode (in per square meter).
8. In the circuit shown below, the Zener diode is ideal and Zener voltage is 6 V. Find out the output voltage  $V_0$ .



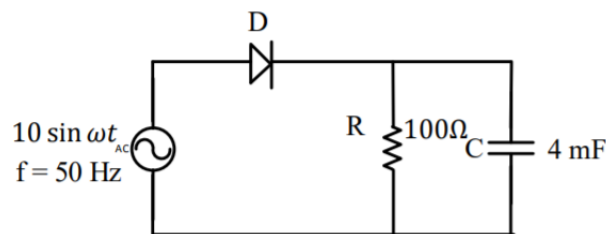
9. Assume that the diode in the following figure has  $V_{on} = 0.7\text{ V}$ , but is otherwise ideal. Find out  $i_2$ .



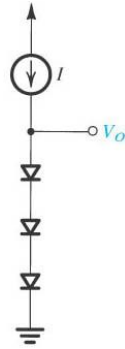
10. The Si diode in the circuit given below has  $V_{\gamma} = 0.7\text{ V}$  but ideal otherwise. Find out the current in the  $4\text{ k}\Omega$  resistor.



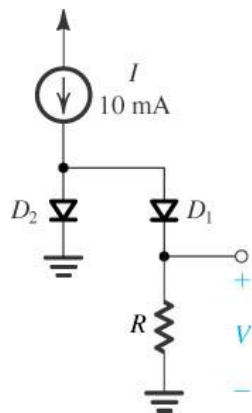
11. The following figure shows a half-wave rectifier. The diode D is ideal. Calculate the average steady-state current through the diode.



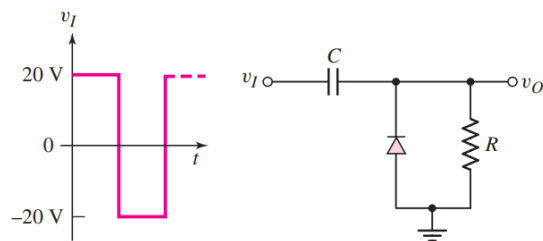
12. A diode, whose internal resistance is  $30\ \Omega$ , is to supply power to a  $990\ \Omega$  load from a  $110\text{ V}$  (rms) source of supply. Calculate (a) the peak load current, (b) the dc load current, (c) the ac load current, (d) the dc load voltage, (e) the total input power to the circuit, and (f) the percentage regulation from no load to the given load.
13. Prove that the regulation of both the half-wave and the full-wave rectifier is given by: Percentage regulation  $= R_f / R_L \times 100\%$ , where,  $R_f$  is the diode resistance and  $R_L$  is the load resistance.
14. The diode current of a p-n junction diode is  $0.5\text{ mA}$  at  $340\text{ mV}$  and again  $15\text{ mA}$  at  $465\text{ mV}$ . Assuming  $kT/q = 25\text{ mV}$  find out the ideality factor.
15. In the circuit shown below, utilizes three identical diodes having  $\eta = 1$  and  $I_s = 10^{-14}\text{ A}$ . Find the value of current  $I$  required to obtain an output voltage  $V_0 = 2\text{ V}$ . If a current of  $1\text{ mA}$  is drawn away from the output terminal by a load, what is the change in output voltage?



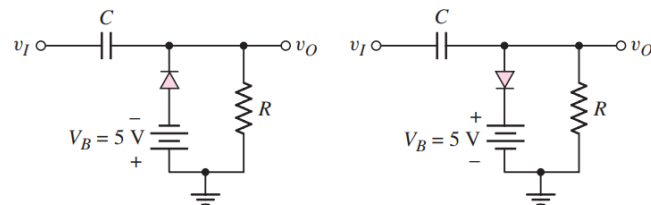
16. For the following circuit both diodes are identical, conducting 10 mA at 0.7 V and 100 mA at 0.8 V. Find the value of  $R$  for which  $V = 80$  mV.



17. Sketch the steady-state output voltage  $V_O$  versus time for each circuits in the following figure for the input voltage shown in Figure. Assume  $V_\gamma = 0$  and the RC time constant is large.



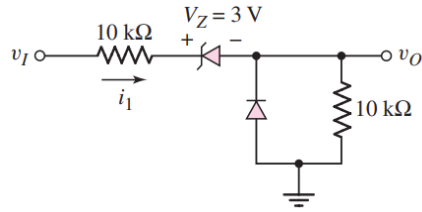
(a)



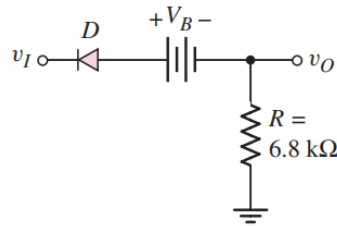
(b)

(c)

18. For the circuit in the following figure, assume  $V_\gamma = 0$ . (a) Plot  $v_O$  versus  $v_I$  over the range  $-10 \leq v_I \leq +10$  V. (b) Also plot the  $i_1$  over the same input voltage range.



19. In the following circuit the diode cut-in voltage ( $V_\gamma$ ) is 0.7 V. The input signal is  $15 \sin \omega t$  and  $V_B = 5$  V. Sketch  $v_O$  versus time.



20. (a) Consider a silicon pn junction diode operating in the forward-bias region. Determine the increase in forward-bias voltage that will cause a factor of 10 increase in current. (b) Repeat part (a) for a factor of 100 increase in current.
21. The reverse-saturation current of a pn junction diode is  $I_S = 10^{-11}$  A. Determine the diode current for diode voltages of 0.3, 0.5, 0.7,  $-0.02$ ,  $-0.2$ , and  $-2$  V. (b) Repeat part (a) for  $I_S = 10^{-13}$  A.
22. The donor concentration in the n-region of a silicon pn junction is  $N_d = 10^{16} \text{ cm}^{-3}$ . Plot  $V_{bi}$  versus  $N_a$  over the range  $10^{15} \leq N_a \leq 10^{18} \text{ cm}^{-3}$  where  $N_a$  is the acceptor concentration in the p-region.
23. In the following voltage regulator circuit, let  $V_I = 6.3$  V,  $R_i = 12$  Ohm and  $V_Z = 4.8$  V. The Zener diode current is to be limited to the range  $5 \text{ mA} \leq I_Z \leq 100 \text{ mA}$ . (a) Determine the range of possible load currents and load resistances. (b) Determine the power rating required for the Zener diode and the load resistor.

