# Exercise Package 2:

## Semiconductor Materials and Diode v-I relationship:

1. In your own words explain the majority carrier and minority carrier in n-type semiconductor materials.
2. What is the difference between p-type and n-type semiconductor materials?
3. What is the band gap energy level of a material to be considered insulator?
4. What is the band gap energy level of Si crystal?
5. For GaAs, the band gap energy level is $E_g$=?
6. Reverse saturation current of a P-N junction is modeled by equation: $I_S = T^{(3+\frac{\gamma}{2})} e^{(-\frac{E_g}{kT})}$ where T is operation temperature in Kelvins, k=1.38x10$^{-23}$ (J/K) Boltzmann constant, $E_g$ is the bandgap energy level of a semiconductor material (eV). γ is a modeling constant.
    a. Given a silicon diode with typical reverse saturation current $I_S$=100pA at 25$^o$C, find the value of modeling constant γ.
    b. Find the reverse saturation current $I_S$ of the above diode at operation temperatures −2$^o$C and 55$^o$C respectively.
    c. Find the corresponding (operation temperatures in −2$^o$C, 25$^o$C, and 55$^o$C) forward biased current using Shockley equation: $I_D = I_S(e^{V_D/nV_T}$-1) where n=2, $V_D$=0.7V and thermal voltage $V_T$=kT/q (q=1.6x10$^{-19}$ (C) is elementary charge unit).
    d. Estimate the dynamic resistor values of a forward biased, $V_D$=0.7V, silicon diode at following operation temperatures (−2$^o$C, 25$^o$C, and 55$^o$C), $r_d = dV_D/dI_D \approx nV_T/I_D$ for n=2.
    e. Using the above results to explain "negative temperature coefficient" of semiconductor.
7. Estimate the resistor values of a forward biased silicon diode at operation temperatures 300K: $r_d \approx nV_T/I_D$ where n=1 and the operation currents $I_D$=10mA, 15mA and 100mA respectively.
8. For a silicon diode with γ=1 and n=2, determine the forward biased voltage $V_D$ such that $I_D$=5mA is maintained at operation temperatures, −20$^o$C, 27$^o$C, and 55$^o$C respectively.

Diode specification sheet (posted on pilot):

9. Find the typical junction capacitor of the diode 1N4001 at reverse biased of 20V. Explain why we only care about the junction capacitor values under reverse biased condition.
10. Find the reverse saturation currents of 1N4004 when reverse biased at 160V at operation temperatures of 25$^o$C, 100$^o$C, and 125$^o$C respectively.
11. What is the maximum forward current rating if the diode 1N4001 is operated at 100$^o$C?