1. In a boron-doped (i.e. p-type) silicon layer with impurity concentration of $10^{16}/\text{cm}^3$, find the hole and electron concentration at 300K and 400K. ($B=5.4 \times 10^{31}$, $E_G=1.12$, $k=8.62 \times 10^{-5}$). From these calculations, explain how the temperature affects the diode.

$$N_A=10^{16}, \quad p_{po}=N_A=10^{16}, \quad n_{po}=n_i^2/N_A$$

$$T=300\text{K}: \quad p_{po}=10^{16}, \quad n_i^2=B T^3 e^{(-E_G/kT)}=(5.4 \times 10^{31})(300)^3 e^{(-1.12/(86.2 \mu)(300))}=2.26 \times 10^{20}$$
\hspace{2cm} \implies n_{po}=2.26 \times 10^4/\text{cm}^3

$$T=400\text{K}: \quad p_{po}=10^{16}, \quad n_i^2=B T^3 e^{(-E_G/kT)}=(5.4 \times 10^{31})(400)^3 e^{(-1.12/(86.2 \mu)(400))}=2.7 \times 10^{25}$$
\hspace{2cm} \implies n_{po}=2.7 \times 10^9/\text{cm}^3

{As $T$ increases: # holes in p-type do not change, The minority carriers ($n_{po}$ increase)}

2. For a forward biased diode:
   a. Explain what happens in the n-type & p-type material when temperature increases.

   **Majority (electrons in n-type, holes in p-type) remain same. Minority (holes in n-type, electrons in p-type) increase.**

   b. Explain what happens in the n-type & p-type material when temperature decreases.

   **Majority (electrons in n-type, holes in p-type) remain same. Minority (holes in n-type, electrons in p-type) decrease.**

   c. Explain in your own words how $I_s$ is created.

   **$I_s$ is created due to the minority carrier drift flow in the diode.**

   i. What happens to this current when the temperature is increased?

   **$I_s$ increases because of the increase of minority carriers due to their dependence on Temperature.**

   ii. What happens to this current when the temperature is decreased?

   **$I_s$ decreases because of the decrease of minority carriers due to their dependence on Temperature.**

   d. Explain in your own words how $I_D$ is created.

   **$I_D$ is created due to the majority carrier diffusion flow in the diode.**

   i. What happens to this current when the temperature is increased?

   **$I_D$ increases because of the increase of $I_s$.**

   ii. What happens to this current when the temperature is decreased?

   **$I_D$ decreases because of the decrease of $I_s$.**
3. Exercise D3.16 (do not need to find the junction area just the resistor R). (Note also that $V_{D0}$ will not be 0.7V).

$$\Delta V_0 / \Delta I_L = 40 \text{mV}/1 \text{mA} = 40 \Omega \quad \text{(This is the resistance across all the diodes)}$$

Therefore, each diode has a resistor, $r_d = 40/4 = 10 \Omega$

$I_D = n V_T / r_d = (1)(25 \text{mV})/10 = 2.5 \text{mA}$

$R = (15 - 3)/I_D = 12/2.5 \text{mA} = 4.8 \text{k}\Omega$

4. Exercise 3.17

$r_z = 50 \Omega \quad V_{zo} = V_z + I_z r_z = 10 - (10 \text{m})(50) = 9.5 \text{V}$

Diode current halved: @ 5m: $V_z = V_{zo} + I_z r_z = 9.5 + (5 \text{m})(50) = 9.75 \text{V}$

Diode current doubled: @20m: $V_z = V_{zo} + I_z r_z = 9.5 + (20 \text{m})(50) = 10.5 \text{V}$