1. (a) \( n = p = n_i = 5.2 \times 10^{15} \gamma^{3/2} \exp \frac{-E_g}{2kT} \)

where \( T = 300^\circ K \), \( E_g = 0.82 \text{eV} = 0.82 \times 1.6 \times 10^{-19} \text{J} \)
\( k = 1.38 \times 10^{-23} \text{J/}^\circ \text{K} \)

\( \Rightarrow n = p = 3.549 \times 10^{12} \text{ electrons (or holes)/cm}^3 \)

(b) \( n \approx N_D = 10^{18} \text{cm}^{-3} \)
\( p \approx \frac{n_i^2}{N_D} \Rightarrow p = 1.26 \times 10^7 \text{cm}^{-3} \)

2. (a) \( n_i(T = 300^\circ K) = 1.08 \times 10^{10} \text{cm}^{-3} \) (Eq 2.2, page 16 of Reader)
\( n = 10^{17} \text{cm}^{-3} \Rightarrow p = \frac{n_i^2}{n} = 1.1664 \times 10^3 \text{cm}^{-3} \) (which is very small)
\( I = \text{Area} \times J_{tot} \), \( J_{tot} = q \left( \mu_n n + \mu_p p \right) E \)
\( \text{Area} = 0.05 \mu m \times 0.05 \mu m, \; \mu_n = 1350 \text{cm}^2/\text{Vs}, \; \mu_p = 480 \text{cm}^2/\text{Vs} \)
\( E = \frac{V}{L} = \frac{1 \text{ volt}}{0.1 \mu m} = 10 \frac{V}{\mu m} \)

\( \Rightarrow I = (0.05 \mu m)^2 \times 1.6 \times 10^{-19} \text{C} \times \left( 1350 \frac{\text{cm}^2}{\text{Vs}} \times 10^{17} \text{cm}^{-3} + 480 \times 1.1664 \times 10^3 \text{cm}^{-3} \right) \times 10 \frac{V}{\mu m} \)

\( \Rightarrow I = 54 \mu A \)

(b) \( n_i(T = 400^\circ K) = 5.2 \times 10^{15} (400)^{3/2} \exp \frac{-1.12 \times 1.6 \times 10^{-19}}{2 \times 400 \times 1.38 \times 10^{-23}} = 3.7126 \times 10^{12} \text{cm}^{-3} \)

\( \Rightarrow p = 1.3783 \times 10^8 \text{cm}^{-3} \) (still it is way smaller than 'n')

\( \Rightarrow I = 54 \mu A \)
3. (a) \[ V_o = \frac{kT}{q} \ln \left( \frac{N_A N_D}{n_i^2} \right) \approx (26 \text{ mV}) \ln \frac{5 \times 10^{15} \times 3 \times 10^{16}}{(1.08 \times 10^{10})^2} \]
\[ \Rightarrow V_o \approx 725 \text{ mV} \]

(b) \[ V_o \approx (26 \text{ mV}) \ln \frac{5 \times 10^{15} \times 3 \times 10^{16}}{(3.549 \times 10^{12})^2} \Rightarrow V_o \approx 423.6 \text{ mV} \]

"from problem 1"

4. We know from basic physics and Ohm's law that a material can conduct current in response to a potential difference and hence an electric field. The field accelerates the charge carriers in the material, forcing some to flow from one end to the other. Movement of charge carriers due to an electric field is called "drift." (from Reader, pages 196, 20)

5. (a) \[ \frac{i}{+} \rightarrow \text{p} \rightarrow \text{n} \rightarrow \text{p} \rightarrow \text{n} \rightarrow \frac{i}{-} \]
\[ + V_1 \rightarrow \text{n} \rightarrow \text{p} \rightarrow \text{n} \rightarrow - V_2 \]
\[ V_1 = V_T \ln \frac{i}{I_s} \]
\[ V_2 = V_T \ln \frac{i}{I_s} \]
\[ V = V_1 + V_2 = 2V_T \ln \frac{i}{I_s} \]
\[ \Rightarrow i = I_s \exp \left( \frac{V}{2V_T} \right) \]

(b) when \( i \) becomes \( 10i \), amount of increase in \( V \)
\[ \text{IS: } \Delta V = 2V_T \ln 10 \Rightarrow \Delta V \approx 120 \text{ mV} (@300^\circ K) \]

(c) \[ I_X = \frac{V_X - V_D}{R_1} \text{, Assume } V_D = 1.5V \Rightarrow I_X = \frac{3 - 1.5}{1k\Omega} = 1.5 \text{ mA} \]
\[ \Rightarrow V_D = 2V_T \ln \frac{I_X}{I_s} = 52 \text{ mV} \ln \frac{1.5 \text{ mA}}{5 \times 10^{16}} = 1.4939 \approx 1.5 \quad \Rightarrow I_X = 1.5 \text{ mA} \]
6. Diode is a two-terminal device which allows the current flow through it only in one direction and blocks the flow of current in the opposite direction. These terminals are called "anode" and "cathode". Current can only flow from anode to cathode.

7. (a) \[ V_{\text{in}} \rightarrow -\infty : D_1 \& D_2 \text{ are both OFF} \Rightarrow V_{\text{out}} = V_{\text{in}} \]
\[ I_{R1} = 0, I_{R2} = 0, I_{D2} = 0 \]
\[ V_{\text{in}} = 0 \Rightarrow D_1 \& D_2 \text{ both become ON} \]
\[ \Rightarrow V_{\text{out}} = 0, I_{R1} = \frac{V_{\text{in}}}{R_1}, I_{R2} = 0, I_{D2} = \frac{V_{\text{in}}}{R_1} \]
and \( D_1 \& D_2 \) stay on for all \( V_{\text{in}} \geq 0 \).

So, this circuit with ideal model for diodes looks like:

(b) \[ V_{\text{in}} \rightarrow +\infty : D_1 \& D_2 \text{ are both ON} \Rightarrow V_{\text{out}} = 2V_{D,\text{on}} \]

Let's write the current for each diode:
\[ I_{D1} = \frac{V_{\text{in}} - 2V_{D,\text{on}}}{R_1}, \ I_{D2} = \frac{V_{\text{in}} - 2V_{D,\text{on}} - V_{D,\text{on}}}{R_1} \]

So while sweeping \( V_{\text{in}} \) from \( +\infty \) to \( -\infty \), first \( I_{D2} \) becomes zero at \( V_{\text{in}} = 2V_{D,\text{on}} + \frac{R_1}{R_2}V_{D,\text{on}} \) and \( D_2 \) becomes OFF and \( V_{\text{out}} = V_{D,\text{on}} + \frac{R_2}{R_1 + R_2} (V_{\text{in}} - V_{D,\text{on}}) \). Now \( I_{D1} = \frac{V_{\text{in}} - V_{\text{out}}}{R_1} \) which
becomes zero at \( V_{in} = V_{D, on} \) and since then till \( V_{in} \to -\infty \),
we have \( V_{out} = V_{in} \).

8. For example, let's find input-output characteristic of this circuit:

For \( V_{in} \to -\infty \): \( D_1 \): ON & \( D_2 \): OFF

\[ V_{out} = \frac{2V_{in} - 1}{3} \]

\[ i_{D_1} = \frac{V_{out} - V_{in}}{R} = -\frac{1}{3R} (V_{in} + 1) \]

So at \( V_{in} = -1 \): \( D_1 \) turns OFF and \( V_{out} = V_{in} \), \( V_{D_2} = V_{in} - 2 \)

So at \( V_{in} = 2 \): \( D_2 \) turns ON and \( V_{out} = \frac{V_{in} + 1}{2} \)
so, the characteristic looks like:

\[ \text{Slope} = \frac{1}{2} \]

\[ \text{Slope} = \frac{2}{3} \]