ECE 320 - Quiz #2 - Name ____________________

Semiconductors, pn Junction, ideal diodes - Spring 2022

1a) What are holes and electrons?

Electrons: negatively charged particles that form covalent bonds and move around to carry current.

Holes: A missing electron in a covalent bond. A missing negative charge behaves like a positive charge.

1b) The voltage drop across a silicon diode is about 0.7V.

- Does this voltage go up or down as temperature goes up?
- Why does this happen?

Voltage goes down.

The voltage across a pn junciton is a funciton of the doping level / the intrinisic carrier concentration level

$$V_d = V_T \cdot \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

As temperature goes up, the number of thermal holes and electronics (ni) goes up. This makes the doping level less significant, making the diode pn-junction less distinct, reducing the voltage.

2) An 0603 resistor has the following dimensions

- L = 0.06cm
- W = 0.03cm
- H = 0.02cm

Determine the doping required to make a resistance of R ohms where

- R = 1200 + 100*(your birth month) + (your birth date).
- For example, May 14th would give R = 1714 Ohms

R 1200 + 100*(your birth month) + (your birth date)	Required Doping of Boron atoms / cc
1714	**7.29e14**

$$R = \left(\frac{\rho L}{A}\right)$$

$$1714\Omega = \left(\frac{\rho \cdot 0.06cm}{(0.03cm)(0.02cm)}\right)$$

$$\rho = 17.14\ \Omega \cdot cm$$

$$\sigma = \frac{1}{\rho} = 0.0583 = n_n \cdot q \cdot \mu_n$$

$$0.0583 = n_n \cdot (1.6 \cdot 10^{-19}) \cdot (500)$$

$$n_n = 7.29 \cdot 10^{14}\ \frac{\text{atoms}}{cc}$$

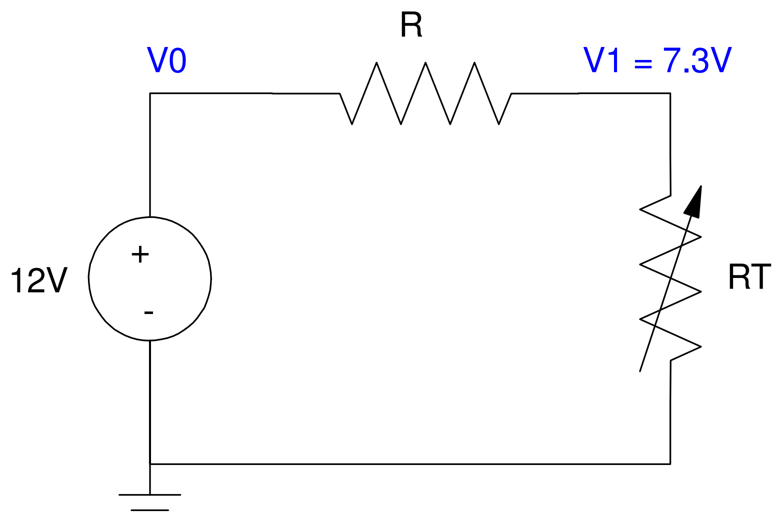
3) Thermistors: Assume the VI characteristics of a thermistor are

$$R_T = 2000 \exp\left(\frac{4350}{T+273} - \frac{4350}{298}\right)\Omega$$

where T is the temperature in degrees C. Determine RT and the temperature if V1 = 7.3V

- Let R be 1200 + (your birth month) * 100 + your birthday. (March 14th would give R = 1714 Ohms)

R 1200 + 100*Month + Day	R_T (Ohms) Thermistor	Temperature (C)
1714 Ohms	**2662 Ohms**	**19.27 C**



$$V_1 = 7.3V = \left(\frac{R_T}{R_T+1714}\right)12V$$

$$R_T = \left(\frac{7.3V}{12V-7.3V}\right)1714\Omega$$

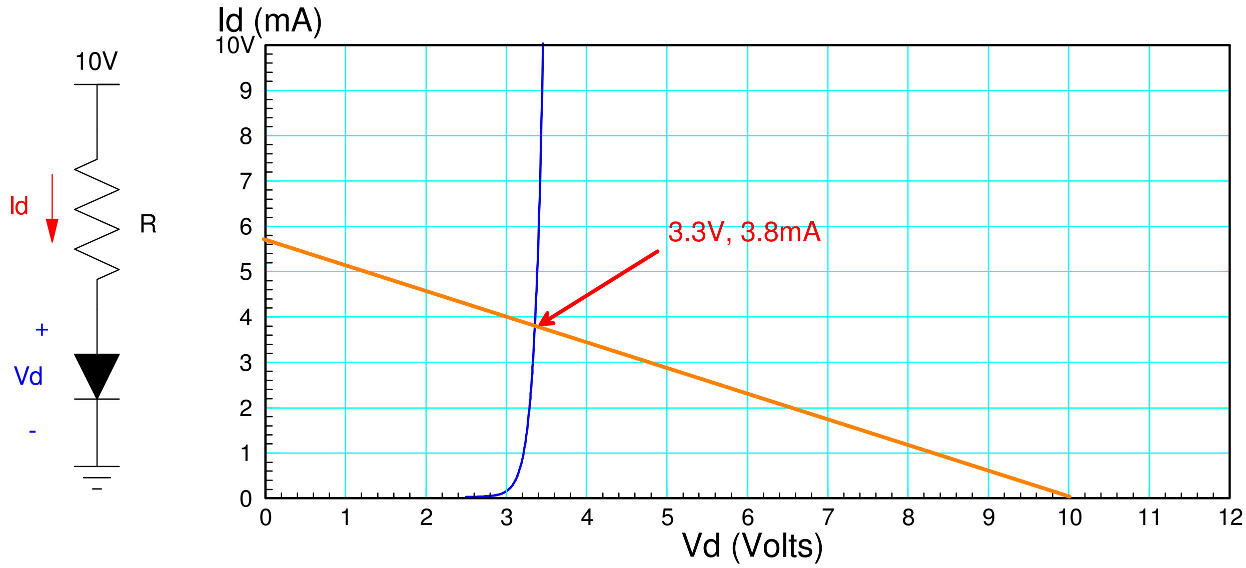
$$R_T = 2662.17\Omega$$

$$T = 19.27^0 C$$

4) Load Lines: The VI characteristic for a diode is show on the graph below. Draw the load line for the following circuit and from the graph, determine Vd and Id

- Let R be 1200 + 100*(Birth Month) + (Birthday)

R 1200 + 100*Month + Day	Load Line x-intercept	Load Lie y-intercept	Vd	Id
1714	**10V**	**5.83mA**	**3.3V**	**3.8mA**



5) Diodes (nonlinear equations): Assume

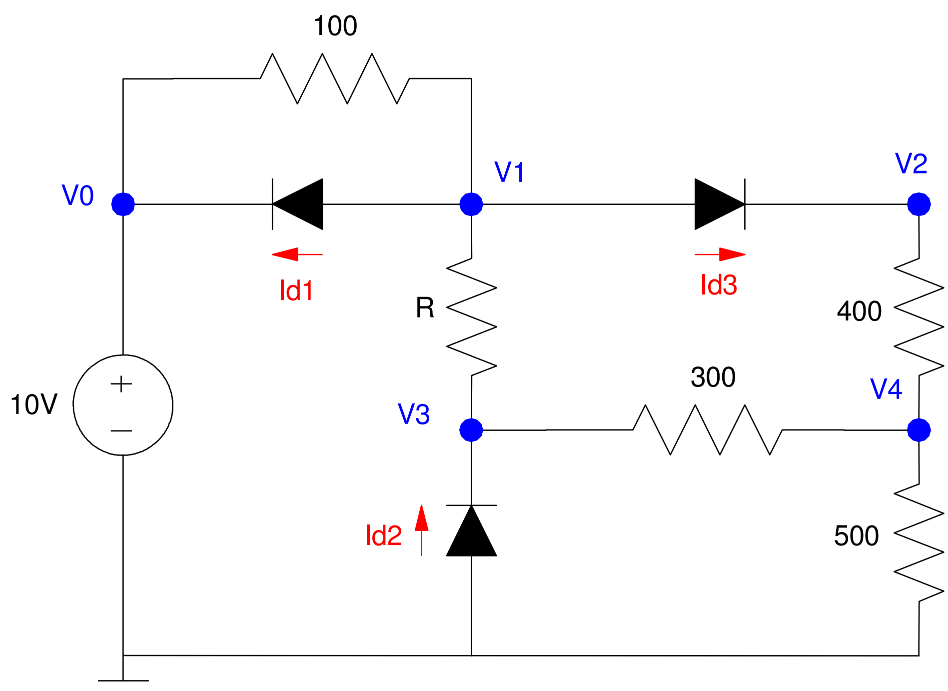
- The VI characteristics of a diode are

$$I_d = 10^{-11} \cdot \left(\exp\left(\frac{V_d}{0.038} \right) - 1 \right)$$

- R = 1200 + 100 * (your birth month) + (your birth date).

Write 7 equations so solve for 7 unknowns: V1, V2, V3, V4, Id1, Id2, Id3

- note: don't solve.



$$I_{d1} = 10^{-11} \cdot \left(\exp\left(\frac{V_1 - V_0}{0.038} \right) - 1 \right)$$

$$I_{d2} = 10^{-11} \cdot \left(\exp\left(\frac{0 - V_3}{0.038} \right) - 1 \right)$$

$$I_{d3} = 10^{-11} \cdot \left(\exp\left(\frac{V_1 - V_2}{0.038} \right) - 1 \right)$$

$$\left(\frac{V_1 - 10}{100} \right) + I_{d1} + \left(\frac{V_1 - V_3}{R} \right) + I_{d3} = 0$$

$$-I_{d3} + \left(\frac{V_2 - V_4}{400} \right) = 0$$

$$\left(\frac{V_3 - V_1}{R} \right) - I_{d2} + \left(\frac{V_3 - V_4}{300} \right) = 0$$

$$\left(\frac{V_4 - V_2}{400} \right) + \left(\frac{V_4 - V_3}{300} \right) + \left(\frac{V_4}{500} \right) = 0$$

6) Diodes (nonlinear equations): Assume

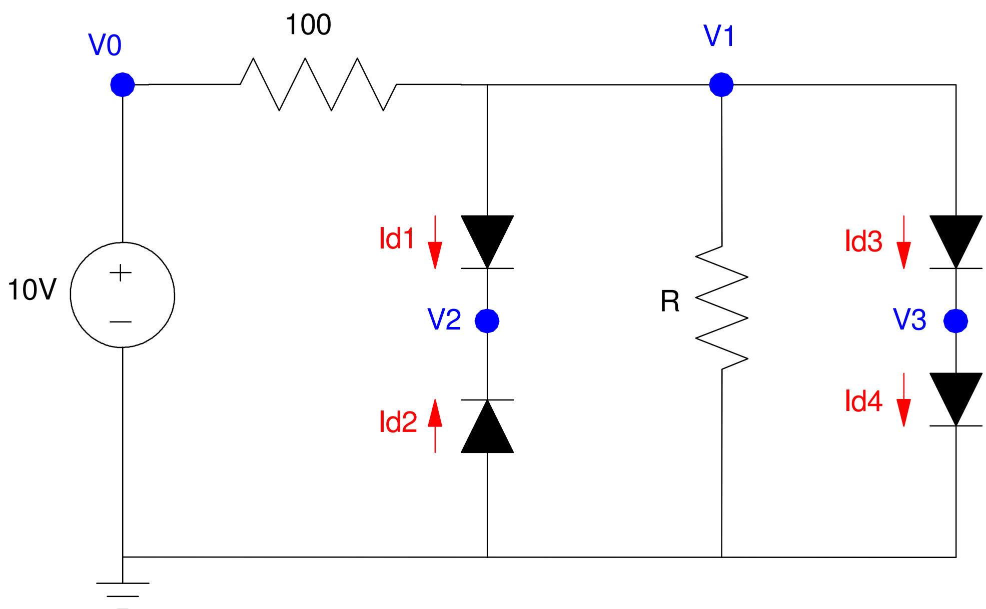
- The VI characteristics of a diode are

  $$I_d = 10^{-11} \cdot \left(\exp\left(\frac{V_d}{0.038}\right) - 1\right)$$

- R = 1200 + 100 * (your birth month) + (your birth date).

Write 7 equations so solve for 7 unknowns: V1, V2, V3, Id1, Id2, Id3, Id4

- note: don't solve.



$$I_{d1} = 10^{-11} \cdot \left(\exp\left(\frac{V_1 - V_2}{0.038}\right) - 1\right)$$

$$I_{d2} = \left(\exp\left(\frac{0 - V_2}{0.038}\right) - 1\right)$$

$$I_{d3} = 10^{-11} \cdot \left(\exp\left(\frac{V_1 - V_3}{0.038}\right) - 1\right)$$

$$I_{d4} = 10^{-11} \cdot \left(\exp\left(\frac{V_3 - 0}{0.038}\right) - 1\right)$$

$$\left(\frac{V_1 - 10}{100}\right) + I_{d1} + \left(\frac{V_1}{R}\right) + I_{d3} = 0$$

$$I_{d1} = -I_{d2}$$

$$I_{d3} = I_{d4}$$