ECE 320 - Quiz #2 - Name _____

Semiconductors, pn Junction, ideal diodes - Spring 2023

1a) What are holes and electrons?

holes: A covalent bond which is missing an electron. Holes act as positive charge carriers.

electrons: Negatively charged particles that form covalent bonds. Free electrons carry current.

note: we actually don't know what electrons are. It is thought that they are fundamental particles (quarks).

1b) Why does the resistance of a semiconductor go down as temperature goes up?

as opposed to metals where the resistance goes up with temperture

As temperature goes up, you get more and more thermal holes/electrons. More charge carriers means less resistance.

2) An 0805 resistor has the following dimensions

- L = 0.02cm
- W = 0.013cm
- H = 0.005cm

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

- R = 800 + 100*(your birth month) + (your birth date).
- For example, May 14th would give R = 1314 Ohms

R 800 + 100*(your birth month) + (your birth date)	Required Doping of Boron atoms / cc
1314	**2.927e15**

Useful Equations (units cm):

$$R = \frac{\rho L}{A}$$

$$\sigma = \frac{1}{\rho} = n_p \cdot q_p \cdot \mu_p = n_p \cdot (1.6 \cdot 10^{-19}) \cdot (500)$$

$$1314\Omega = \frac{\rho \cdot 0.02cm}{(0.013cm)(0.005cm)}$$

$$\rho = 4.271\Omega \cdot cm$$

$$\sigma = \frac{1}{\rho} = n_p \cdot (1.6 \cdot 10^{-19}) \cdot 500$$

$$n_p = 2.927 \cdot 10^{15}$$

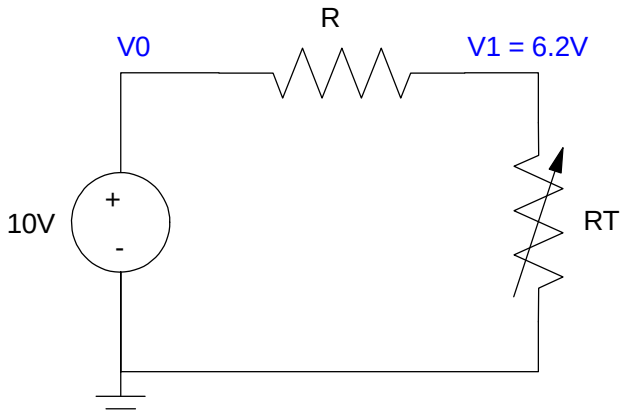
3) Thermistors: Assume the VI characteristics of a thermistor are

$$R_T = 1500 \exp\left(\frac{4000}{T+273} - \frac{4000}{298}\right)\Omega$$

where T is the temperature in degrees C. Determine RT and the temperature if V1 = 6.2V

- Let R be 800 + (your birth month) * 100 + your birthday. (March 14th would give R = 1314 Ohms)

R 800 + 100*Month + Day	RT (Ohms) Thermistor	Temperature (C)
1314	**2143.9**	**17.276C**



$$V_1 = \left(\frac{R_T}{R_T+1314}\right)V_0$$

$$R_T = \left(\frac{6.2V}{10V-6.2V}\right)1314\Omega = 2143.895\Omega$$

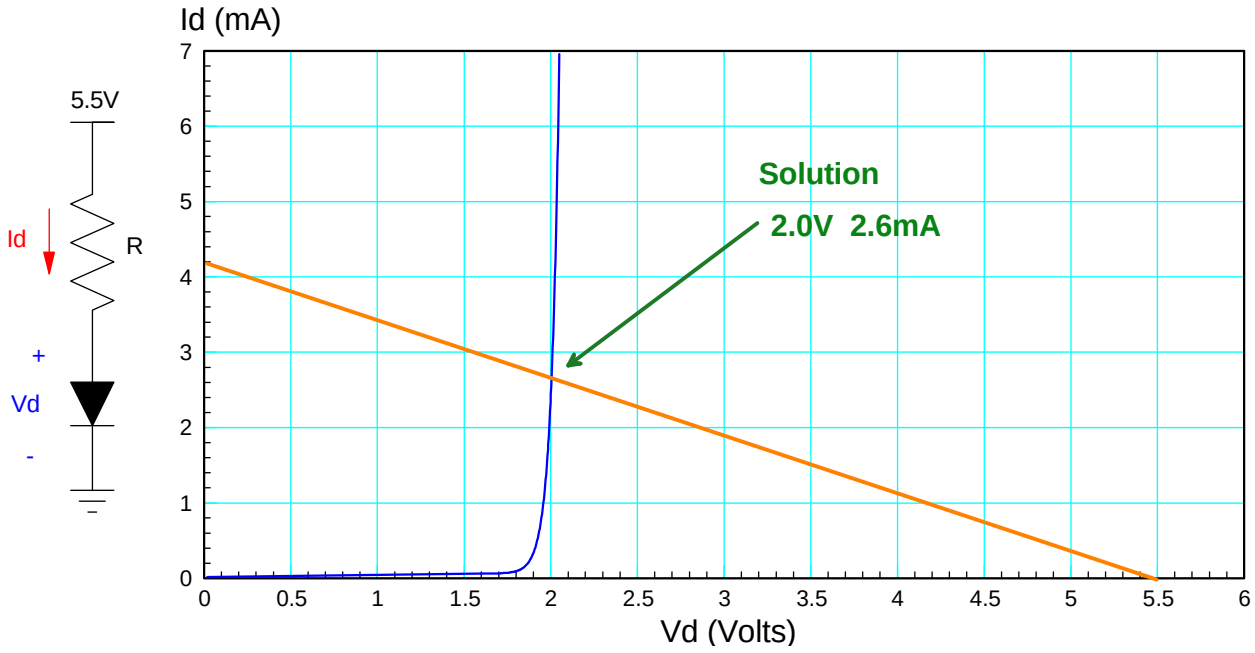
$$2143.895\Omega = 1500 \exp\left(\frac{4000}{T+273} - \frac{4000}{298}\right)\Omega$$

$$T = 17.276^0 C$$

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 800 + 100*(Birth Month) + (Birthday)

R 800 + 100*Month + Day	Load Line x-intercept	Load Lie y-intercept	Vd	Id
1314	**5.5V**	**4.186mA**	**2.4V**	**2.6mA**

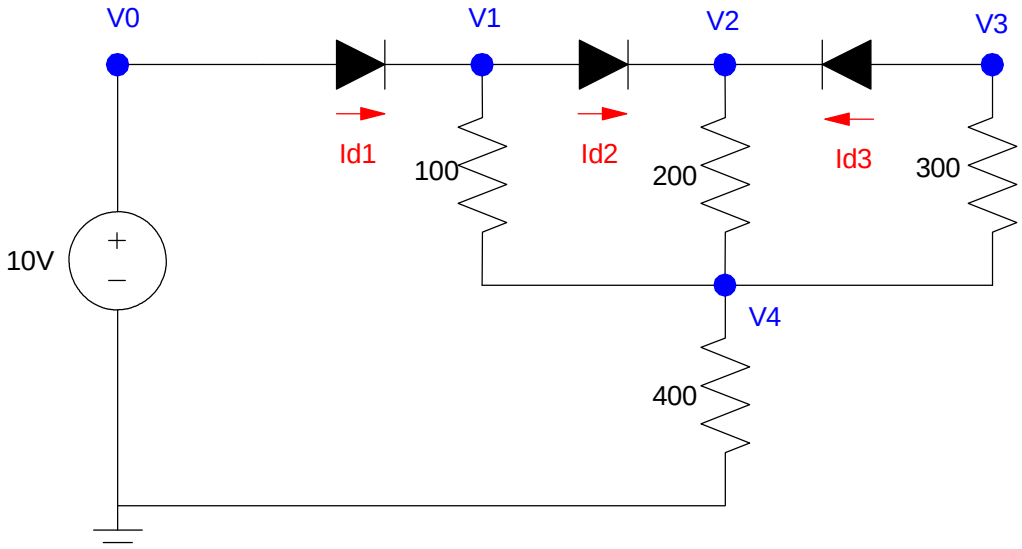


5) Diodes (nonlinear equations): Assume the VI characteristics of a diode are

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

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

- note: don't solve.



Write the diode equations

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

$$I_{d2} = 10^{-11} \cdot \left(\exp\left(\frac{V_1 - V_2}{0.038} \right) - 1 \right)$$

$$I_{d3} = 10^{-11} \cdot \left(\exp\left(\frac{V_3 - V_2}{0.038} \right) - 1 \right)$$

Write the node equations

$$V_0 = 10$$

$$-I_{d1} + I_{d2} + \left(\frac{V_1 - V_4}{100} \right) = 0$$

$$-I_{d2} - I_{d3} + \left(\frac{V_2 - V_4}{200} \right) = 0$$

$$I_{d3} + \left(\frac{V_3 - V_4}{300} \right) = 0$$

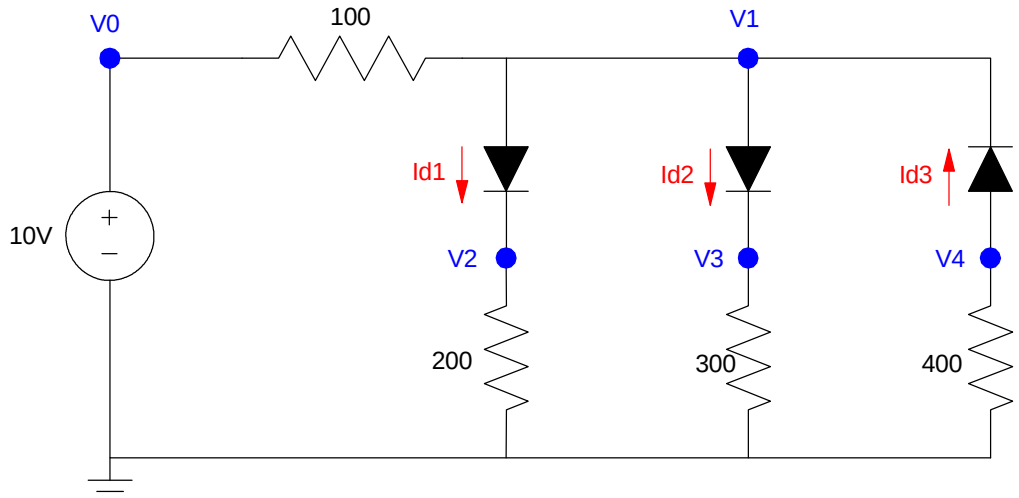
$$\left(\frac{V_4 - V_1}{100} \right) + \left(\frac{V_4 - V_2}{200} \right) + \left(\frac{V_4 - V_3}{300} \right) + \left(\frac{V_4}{400} \right) = 0$$

6) Diodes (nonlinear equations): Assume the VI characteristics of a diode are

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

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

- note: don't solve.



Start with the diode equations

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

$$I_{d2} = 10^{-11} \cdot \left(\exp\left(\frac{V_1 - V_3}{0.038} \right) - 1 \right)$$

$$I_{d3} = 10^{-11} \cdot \left(\exp\left(\frac{V_4 - V_1}{0.038} \right) - 1 \right)$$

Write the node equations

$$V_0 = 10$$

$$\left(\frac{V_1 - V_0}{100} \right) + I_{d1} + I_{d2} - I_{d3} = 0$$

$$-I_{d1} + \left(\frac{V_2}{200} \right) = 0$$

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

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