ECE 320 - Solution to Homework #2

Semiconductors, PN Junctions, Diode VI Characteristics. Due Wednesday, September 9th

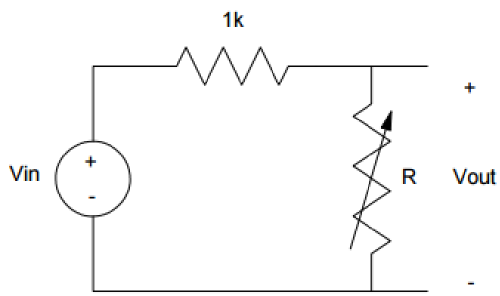
Assume a thermistor has the temperature - resistance relationship of

$$R \approx 1000 \cdot e^{-0.04(T-25)}$$

1) Explain why the resistance drops as temperature goes up.

As temperature goes up, more and more electrons get enough energy to escape their covalent bonds. This creates more charge carriers at higher temperatures - resulting in lower resistance.

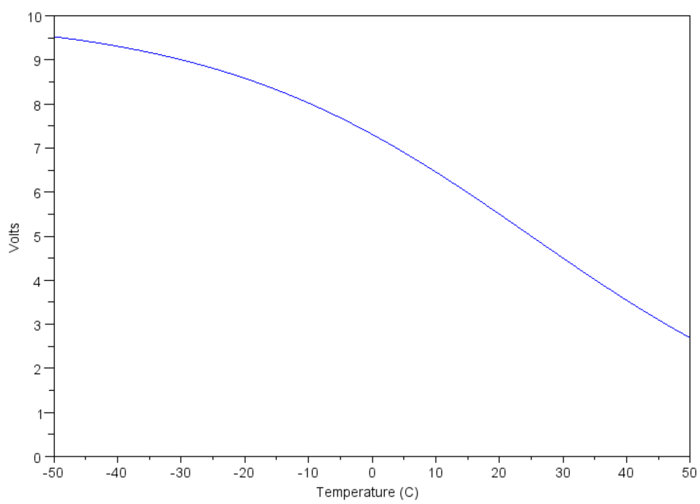
2) Assume you have a thermistor with a voltage divider:



Use MATLAB, plot the voltage vs. temperature for -50C < T < 50C

```
-->T = [-50:0.1:50]';
-->R = 1000 * exp(-0.04*(T-25));
-->V = R ./ (1000 + R) * 10;

-->plot(T,V);
-->xlabel('Temperature (C)');
-->ylabel('Volts');
```



3) Explain what is meant by 'n-type' and 'p-type' material.

n-type: Most of the charge carriers are electrons traveling in the conduciton region.

 # electrons >> # holes

p-type: Most of the charge carriers are holes (electrons hopping from hole to hole)

 # holes >> # electrons

4) Assume the temperature was very high. Would this still be a PN junction? Why or why not?

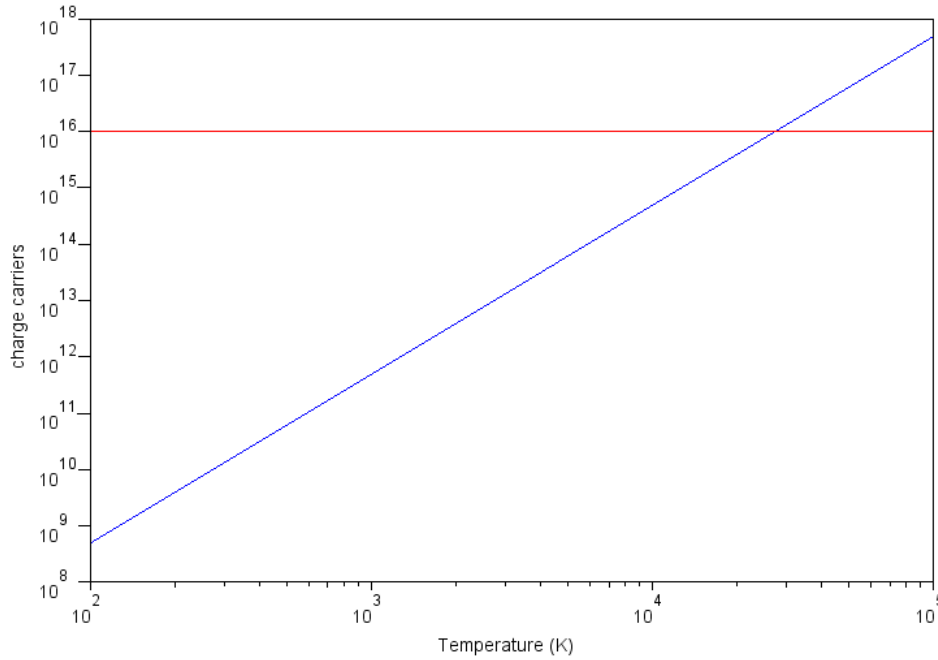
The total number of charge carriers is equal to

The number of doping atoms, plus

The number of thermal electrons / holes

At low temperatures, the number of thermal electrons / holes is very small. This results in the number of charge carriers being determined predominantly by the number of doping atoms.

At high temperatures, the number of thermal electrons / holes becomes very large. This makes the doping less and less significant - changing the p-type and n-type material into intrinisc sillcon (essentially no doping)

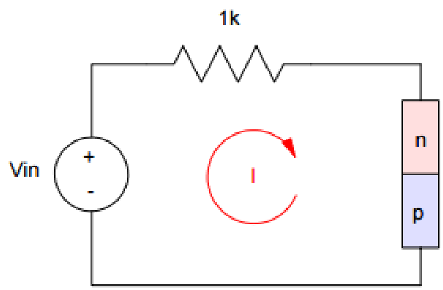


Number of thermal electrons / holes vs. temperature (blue) vs. doping level (red)

5) Assume the temperature was very low. Would this still be a PN junction? Why or why not?

Yes. As you get colder and colder, the number of thermal electrons / holes becomes smaller and smaller. The silicon becomes more 'pure' n-type or p-type.

6) Assume Vin = +5V. Explain why current does / does not flow in this circuit.



Current does not flow due to ...

a) using minority carriers in the p and n regions - resulting in very high impedance.

b) the depletion region being increased by Vin

c) the potential energy barrier being increased by Vin

7) Assume Vin = -5V. Explain why current does / does not flow in this circuit.For the following circuits, write N equations to solve for N unknowns. You do not need to solve - just

Current does flow due to...

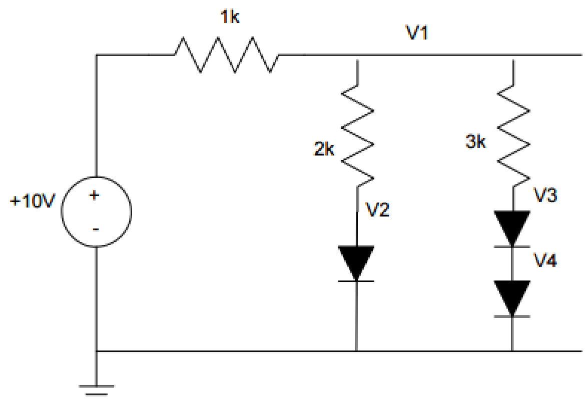
a) using majority carriers in the p and n regions - resulting in very low impedance.

b) the depletion region being reduced to zero, allowing current to flow

c) the potential energy barrier being reduced to zero, allowing current to flow

Write the equations.

8) Diode circuit



Current Loops (KCL)

$$-10 + 1k \cdot I_1 + 2k(I_1 - I_2) + nV_T \ln\left(\frac{I_1 - I_2}{I_{dss}}\right) = 0$$

$$-nV_T \ln\left(\frac{I_1 - I_2}{I_{dss}}\right) + 2k \cdot (I_2 - I_1) + 3k \cdot I_2 + nV_T \ln\left(\frac{I_2}{I_{dss}}\right) + nV_T \ln\left(\frac{I_2}{I_{dss}}\right) = 0$$

Voltage Nodes

$$\left(\frac{V_1 - 10}{1k}\right) + \left(\frac{V_1 - V_2}{2k}\right) + \left(\frac{V_1 - V_3}{3k}\right) = 0$$

$$\left(\frac{V_1 - V_2}{2k}\right) = I_{dss}\left(\exp\left(\frac{V_2}{nV_T}\right) - 1\right)$$

$$\left(\frac{V_1 - V_3}{3k}\right) = I_{dss}\left(\exp\left(\frac{V_3 - V_4}{nV_T}\right) - 1\right)$$

$$I_{dss}\left(\exp\left(\frac{V_3 - V_4}{nV_T}\right) - 1\right) = I_{dss}\left(\exp\left(\frac{V_4}{nV_T}\right) - 1\right)$$

9) Use a thermistor in the lab has the voltage-resistance relationship of

$$R \approx 1000 \cdot e^{-0.04(T-25)}$$

	R	Computed Temperature	Actual Temp
Dry Ice (-70C):	202k	-107C	-78C (Wikipedia)
Room (+25C):	1k	25C	25C (thermometer)
60W Incandescent:	40 Ohms	105C	
60W Halogen:	37 Ohms	107C	
9W CFL:	410 Ohms	47C	

The temperature of dry ice is pretty certain - so the equation is probably off. A more accurate equation would be

$$R \approx 1000 \cdot e^{-0.0515(T-25)}$$

	R	Computed Temperature	Actual Temp
Dry Ice (-70C):	202k	-78C	-78C (Wikipedia)
Room (+25C):	1k	+25C	25C (thermometer)
60W Incandescent:	40 Ohms	87C	
60W Halogen:	37 Ohms	89C	
9W CFL:	410 Ohms	42C	