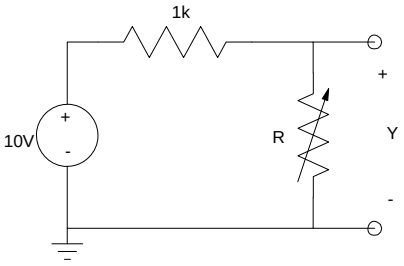
ECE 320 - Solution to Homework #1

Semiconductors, PN Junction, Diode VI Characteristics. Due Monday, Jan 26th

Assume the resistance of a thermistor is

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

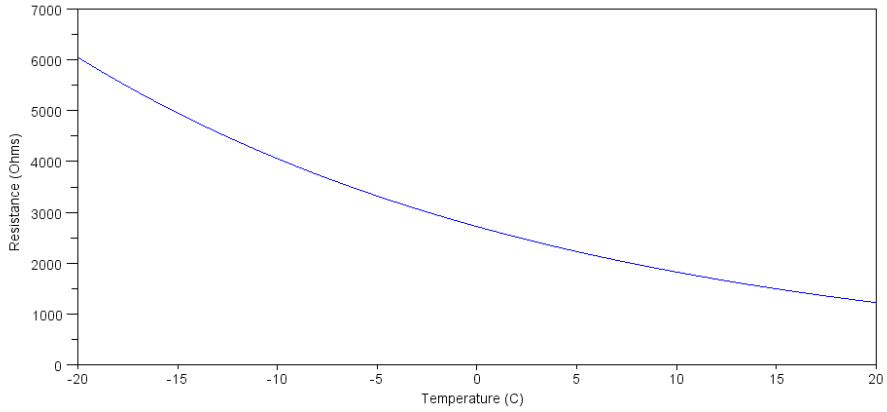


1) Using MATLAB (or like program),

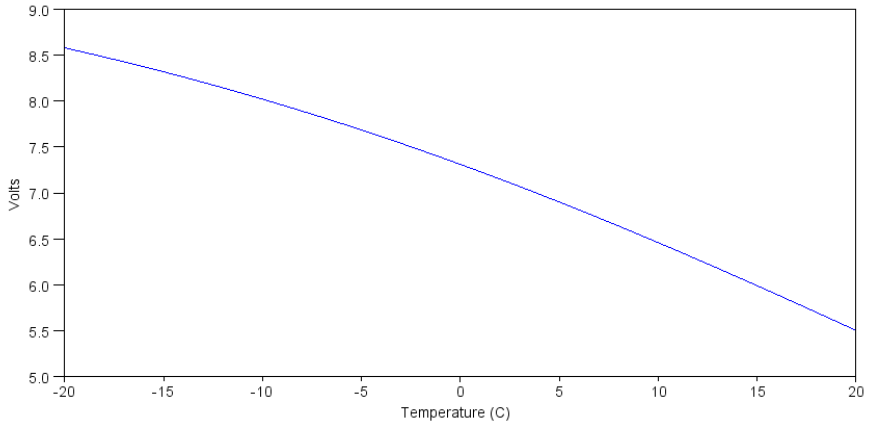
- Plot the resistance of a thermistor vs. temperature from -20C to +20C
- Plot the voltage at Y from -20C to +20C

SciLab Code:

```
-->T = [-20:20]';
-->R = 1000 * exp(-0.04*(T-25));
-->plot(T,R)
-->xlabel('Temperature (C)');
-->ylabel('Resistance (Ohms)');
```




```
-->V = R ./ (1000+R) * 10;
-->plot(T,V);
-->plot(T,V);
-->xlabel('Temperature (C)');
-->ylabel('Volts');
```



2) Determine the temperature if the voltage at Y is 2.00V, 4.00V, and 6.00V

Solving backwards:

$$V = \left(\frac{R}{R+1000}\right)10V \qquad R = \left(\frac{V}{10-V}\right)1000\Omega$$

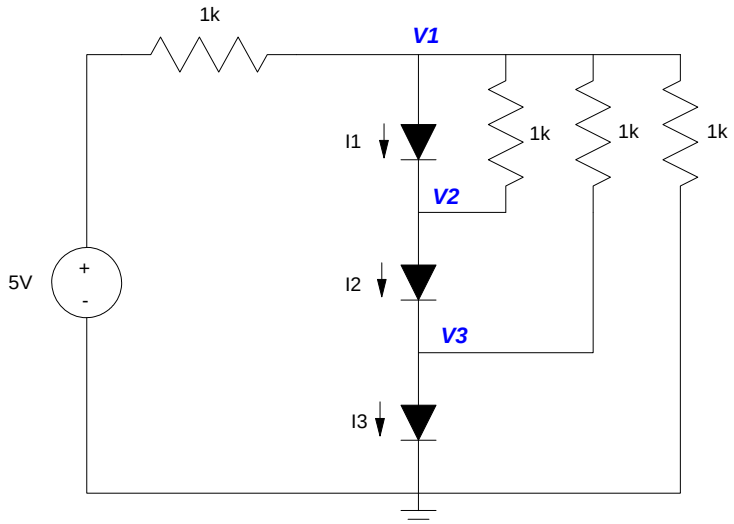
$$R = 1000 \cdot e^{-0.04(T-25)}\Omega \qquad T = 25\left(1 - \ln\left(\frac{R}{1000}\right)\right)$$

V (Volts)	R (Ohms)	Teperature (C)
2V	250	59.6
4V	666	35.1
6V	1,500	14.8

PN Junction:

3) Write N equations to solve for the currents I1, I2, and I3. Assume for each diode

$$I_d = I_{dss} \cdot (e^{20V_d} - 1)A \qquad I_{dss} = 1.66 \cdot 10^{-8}A$$



Writing votlage node equations

$$\left(\frac{V_1-5}{1k}\right) + \left(\frac{V_1-V_2}{1k}\right) + \left(\frac{V_1-V_3}{1k}\right) + \left(\frac{V_1}{1k}\right) + I_{dss} \cdot (e^{20(V_1-V_2)} - 1) = 0$$

$$\left(\frac{V_2-V_1}{1k}\right) + I_{dss} \cdot (e^{20(V_2-V_3)} - 1) - I_{dss} \cdot (e^{20(V_1-V_2)} - 1) = 0$$

$$\left(\frac{V_3-V_1}{1k}\right) + I_{dss} \cdot (e^{20(V_3)} - 1) - I_{dss} \cdot (e^{20(V_2-V_3)} - 1) = 0$$

4) Solve for I1, I2, and I3 (not easy....)

Create a function in SciLab which

- You guess V1, V2, V3
- It computes the error in the three equations (currents should sum to zero)
- Returns the sum square error

```
function J = cost3(z)
// y = cost(z)
// ECE 320 homework set #1
// JSG - 1/22/15

V1 = z(1);
V2 = z(2);
V3 = z(3);

Idss = 1.66e-8;

E1 = (V1-5)+(V1-V2)+(V1-V3)+1000*Idss*(exp(20*(V1-V2)-1));
E2 = (V2-V1)+1000*Idss*(exp(20*(V2-V3)-1))-1000*Idss*(exp(20*(V1-V2)-1));
E3 = (V3-V1)+1000*Idss*(exp(20*(V3)-1))-1000*Idss*(exp(20*(V2-V3)-1));

J = E1*E1 + E2*E2 + E3*E3;


endfunction
```

Callin it:

```
-->[a,b] = leastsq(cost3,[2.1,1.4,0.7])
b  =

   1.8994883    1.2881626    0.6568849
a  =

   4.853D-17
```

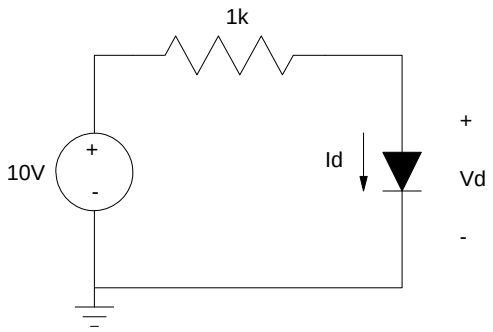
The answer is approximately:

V1 = 1.8994883

V2 = 1.2881626

V3 = 0.6568849

5) Give 2 equations to solve for 2 unknowns: Vd and Id



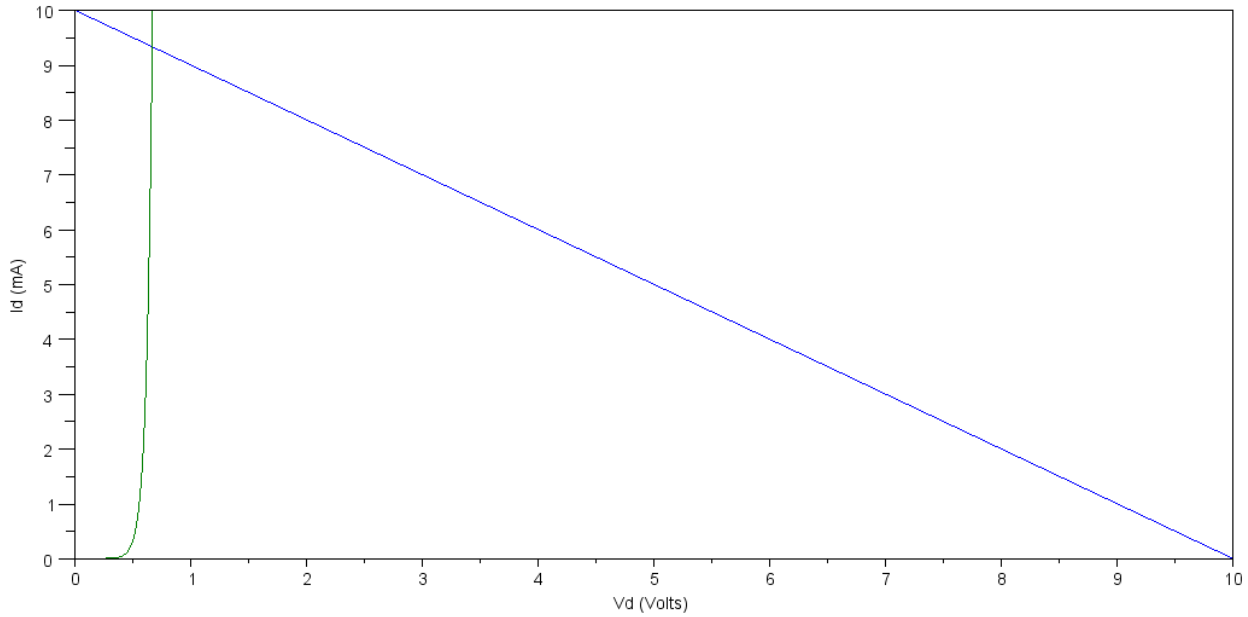
$$I_d = \left(\frac{10 - V_d}{1k}\right)$$

$$I_d = I_{dss} \cdot (e^{20V_d} - 1)A$$

6) Use load-line analysis to determine Id and Vd (graphical solution)

```
-->Idss = 1.66e-8;
-->Id = [0:0.01:10]' * 0.001;
-->Vd1 = 10 - 1000*Id;
-->Vd2 = log(Id/Idss+1)/20;

-->plot(Vd1,Id*1000,Vd2,Id*1000)
-->xlabel('Vd (Volts)');
-->ylabel('Id (mA)');
```



7) Find Id and Vd numerically

- Guess Id
- Compute Vd using the first equation
- Compute Vd using the second equation
- Iterate until the two match

Iterating until the difference is zero

Id = 9.338 mA

Vd = 0.6620 V

ECE 321 - Lab (Thrusday open lab: room 235)

(note: The TA and/or instructor will be in lab from 11AM - 3PM if you need help. You should have 24/7 access to room 235 and 237, however, so you can do the lab any time it works for you and your lab partners)

8) Build the circuit from problem 1 and measure the voltage of three items. (snow, ice water, your hands, room 235, etc).

Fom your voltage measurement, compute

- The resistance of the thermistor, and
- The temperature of that item

9) Build the circuit from problem 3 and measure the actual voltage across the diodes and resistors. From the voltages, compute the actual I1, I2, and I3