ECE 320 - Solution to Homework #2

Semiconductors, PN Junction. Due Monday, January 22, 2018

Semiconductors

1) What is the difference between n-type, p-type, and intrinsic silicon?

n-type silicon: *# electrons >> # holes*
p-type silicon: *# holes >> # electrons*
intrinsic: *# holes ≈ # electrons*

2) An 0805 resistor is made out of silicon with dimensions

- Width & height: 1.25mm x 1.25mm
- Length: 2mm

What does the doping level need to be to make this a 10k resistor using Boron (p-type semiconductor)?

Going backwards

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

$$10k\Omega = \left(\frac{\rho \cdot 0.2cm}{0.125cm \cdot 0.125cm}\right)$$

$$\rho = 781.25\ \Omega \cdot cm$$

$$\sigma = \frac{1}{\rho} = 0.0001280\ \frac{1}{\Omega \cdot cm}$$

From the lecture note,

$$\sigma = q(n_p \mu_p + n_n \mu_n)$$

For p-type silicon

$$\sigma = q n_p \mu_p$$

$$0.0001280\ \frac{1}{\Omega \cdot cm} = (1.6 \cdot 10^{-16} C) \cdot n_p \cdot \left(500\ \frac{cm^2}{Vs}\right)$$

$$n_p = 1.6 \cdot 10^{10}\ \frac{\text{atoms}}{cc}$$

3) A thermistor (i.e. a piece of silicon) has the following temperature - resistance relationship:

$$R = 1000 \cdot \exp\left(\frac{3903}{T} - \frac{3903}{298}\right)\ \Omega$$

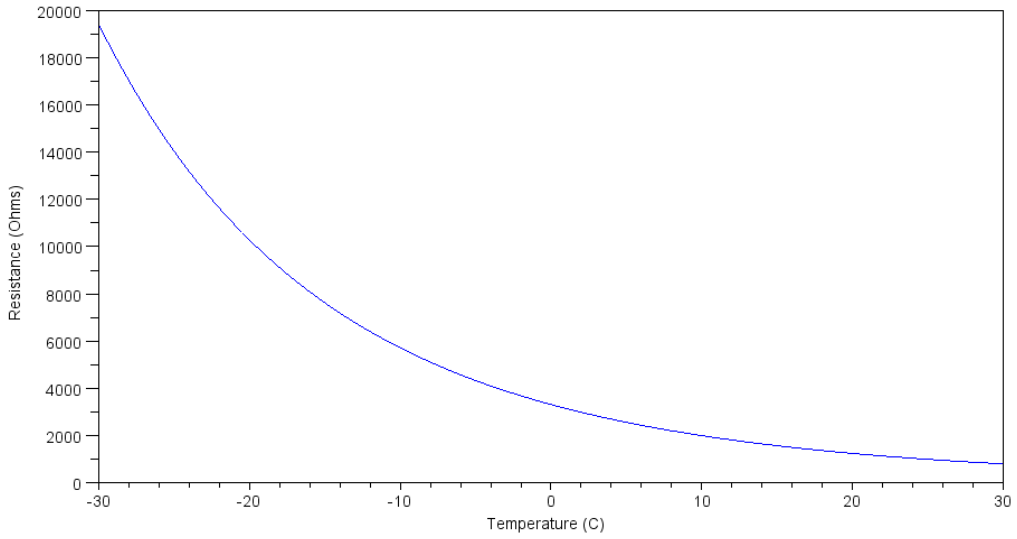
where T is the temperature in degrees Kelvin. In Matlab (or similar program),

- Plot the resistance vs. temperature from -30C to +30C (243K to 303K)
- Plot the voltage for the voltage divider shown below

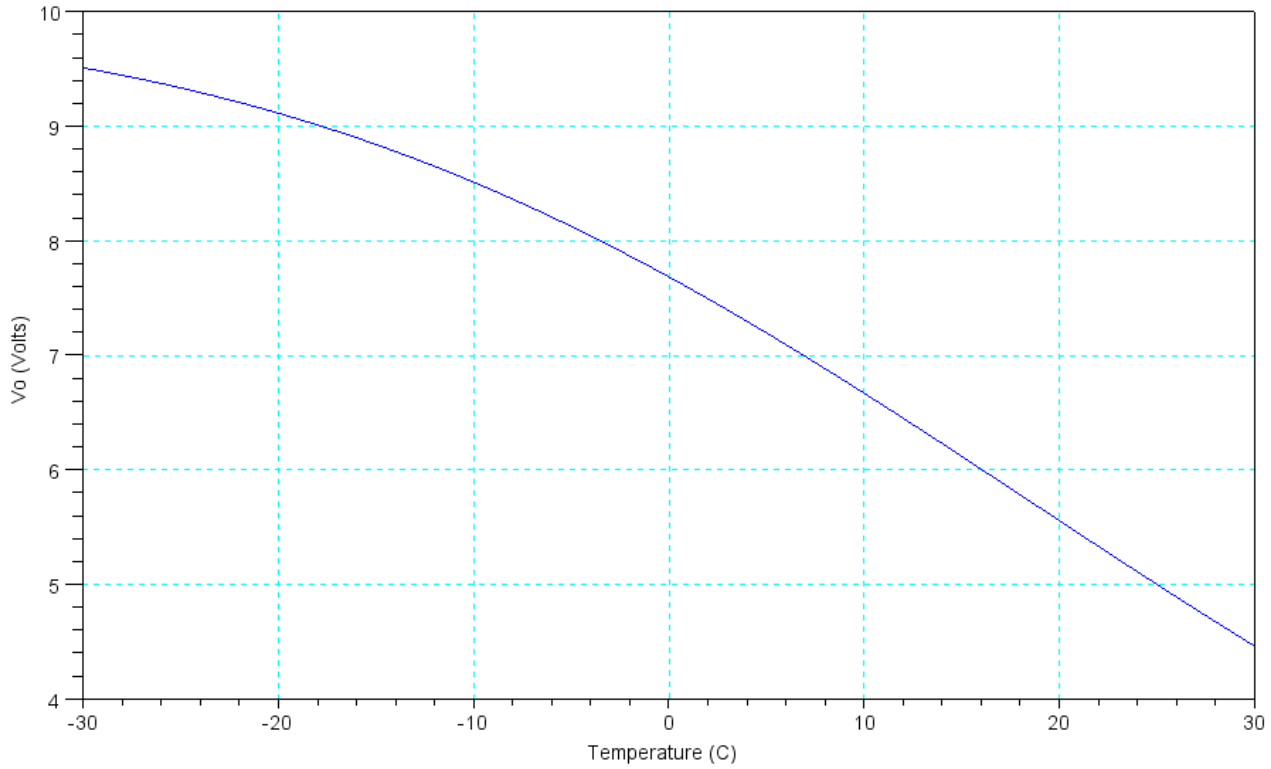
```
-->C = [-30:0.1:30]';
-->K = C + 273;

-->R = 1000 * exp(3903 ./ K  - 3903/298);

-->plot(C,R);
-->xlabel('Temperature (C)');
-->ylabel('Resistance');
```




```
-->V = ( R ./ (R + 1000) ) * 10;
-->plot(C,V);
-->xlabel('Temperature (C)');
-->ylabel('Vo (Volts)');
```



4) If the voltage at the voltage divider is 6.00V, what is the temperature?

From the graph

T = 16C

PN Junction

5) Will current flow in the following circuit if

Vin = +3V? Why?

Yes, current will flow

- *You are using majority carriers when current flows p to n. This results in the resistance being very small.*
- *3V is enough to overcome the potential energy barrier, allowing current to flow*
- *3V is enough to squeeze the depletion zone to zero, allowing current to flow.*

Vin = -3V? Why?

No, current will now flow (or is very very small)

- *You are using minority carriers when current flows n to p. This results in the resistance being very large.*
- *-3V increases the potential energy barrier, blocking current flow*
- *-3V increases the depletion zone to zero, blocking current flow.*

6) Does this behave like a pn junction if

The temperature is really low (say, -100C)? Why?

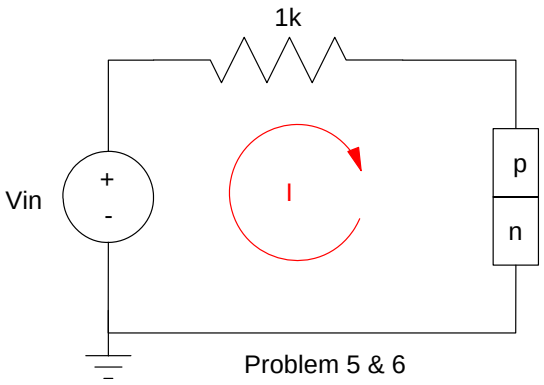
Yes. When the temperature drops, the number of thermal electron / holes produced drops. This makes the doping more significant relative to the thermal electrons / holes.

In the limit, as T = 0 Kelvin, the pn junction starts to behave as a 'perfect' diode with no thermal noise. (Semiconductors like cold. Really really cold is good.)

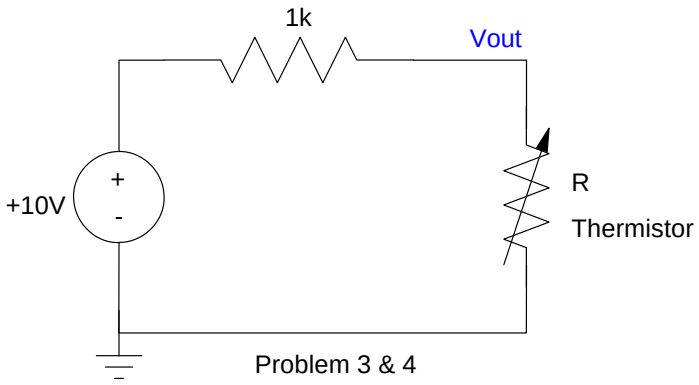
The temperature is really high (say, +300C)? Why?

No - when the temperature increases, the number of thermal electron / hole pairs produced increases. This makes the number of holes (electrons) due to doping less significant.

In the limit, eventually the number of thermal electron / hole pairs becomes more significant than the number of doping electrons (holes). At that point, the silicon reverts to behaving like intrinsic silicon.



Problem 5 & 6



Problem 3 & 4