# ECE 320 - Quiz #2 - Name _____

Semiconductors, pn junction. January 25, 2017

1a) What is meant by the term *n-type semiconductor*?

#electrons >> #holes

almost all of the charge carriers are electrons (vs holes)

1b) Why does the resistance of silicon drop as temperature increases?

As temperature goes up, the number of thermal hole/electron pairs increases.

As the number of charge carriers increases resistance decreases.

2) What doping level is required to make a 3.3k resistor?

| ~~R (Ohms)~~ $\rho$ $\Omega \cdot cm$ | $n_n$ (atoms / cc) |
|---|---|
| 103 $\Omega \cdot cm$ | $4.66 \cdot 10^{13}$ |

Assume the dimensions of the resistor are (0805 surface mount resistor)

- L = 2.0 mm
- Area = 1.25mm x 0.5mm

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

$\sigma = \frac{1}{\rho} = (1.6 \cdot 10^{-19}) \cdot n_n \cdot 1300 \ \frac{1}{\Omega \cdot cm}$ *conductivity*

$n_n$ *doping concentration* $\frac{\text{atoms}}{cc}$

$$3300 = \frac{\rho(0.2cm)}{(0.125cm)(0.05cm)}$$

$$\rho = 103 \ \Omega \cdot cm$$

$$\sigma = \frac{1}{\rho} = .0097 \ \frac{1}{\Omega \cdot cm} =$$

$$n_n = 4.66 \cdot 10^{13}$$

3) Assume you measure 2.0V with the following circuit. Determine the resistance and the temperature.

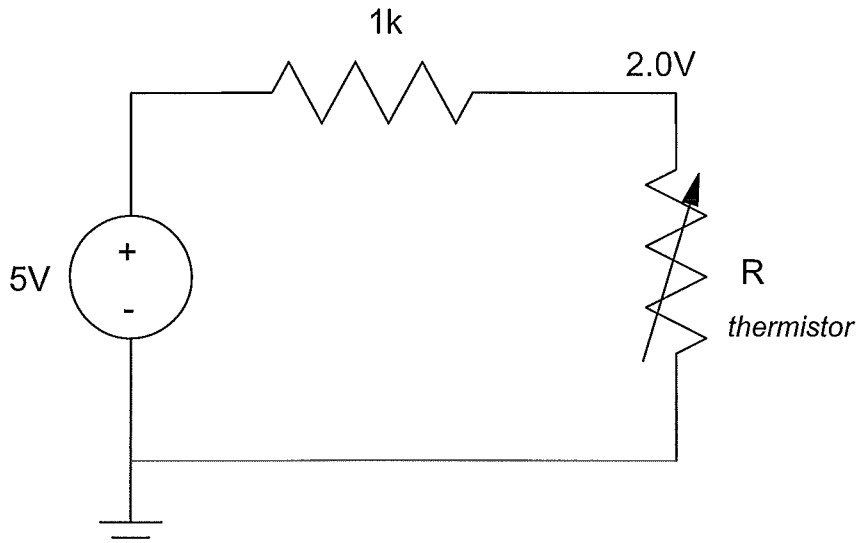
Assume the temperature - voltage relationship of the resistor are:

$$R = 1000 \cdot \exp\left(\frac{3905}{T} - \frac{3905}{298}\right)\ \Omega$$

where T is the temperature in degrees Kelvin ( 273K = 0C )

| R (Ohms) | T (Kelvin) |
|---|---|
| 666.7 Ω | 307 K |

(34.5C)




$$R = \left(\frac{2}{5-2}\right) \cdot 1000\ \Omega = 666.7$$

$$666.7 = 1000 \cdot \exp\left(\frac{3905}{T} - \frac{3905}{298}\right)$$

$$T = 307\ K$$

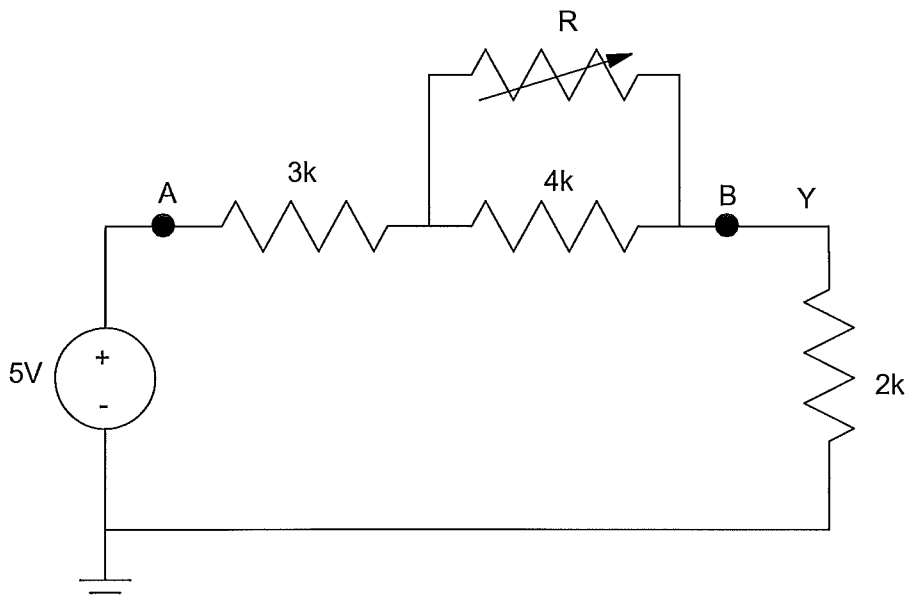
4) The Voltage - Resistance for a thermistor is

$$R = 1000 \cdot \exp\left(\frac{3905}{T} - \frac{3905}{298}\right)\ \Omega$$

where T is the temperature in degrees Kelvin ( 273K = 0C ). Determine the resistance and voltage at Y when

T = 0C (273K)

| R<br>resisance of the thermistor | RAB<br>Combine 3k / 4k / R to find the resisance between A and B | Y<br>Voltage across 2k |
|---|---|---|
| 3320 Ω | 4814 | 1.46V |




R =

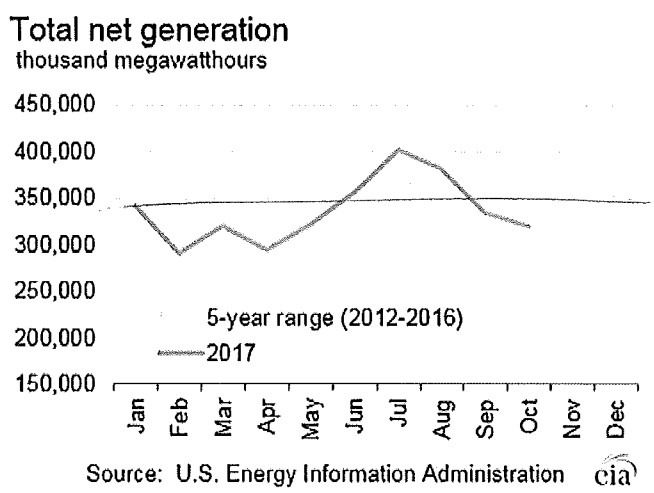
5) Why does current flow in the direction of p to n for a pn junction (diode) but not n to p?

- p to n uses majority carriers (low R)
  n to p uses minority carriers (high R)

- Voltage p to n squeezes the depletion zone to zero, allowing current to flow
  Voltage n to p just increases the size of the depletion zone

- Voltage p to n (more than 0.7v) is enough to overcome the potential energy barrier

BONUS! The total electrical energy generation of the United States on a monthly basis is shown to the right. How much electricity does the U.S. generate each year in killo-watt hours? (approxmately equal to how many pounds of coal we'd have to burn each year to keep the lights on if we used nothing but coal)




350,000,000 mwh /mo

$4.2 \cdot 10^9$ mwh /year

$4.2 \cdot 10^{12}$ kwh /year

$4.2 \cdot 10^{12}$ pounds of coal

$4.2 \cdot 10^{12}$ lb coal

$= 1.9 \cdot 10^{12}$ kg coal $\left(\frac{12g}{mole}\right)$ $\left(\frac{.012kg}{mole}\right)$

$= 1.59 \cdot 10^{14}$ moles/cole $(22.4\ l/m)$ gas constant

$= 3.55 \cdot 10^{15}$ litres

$= 3.55 \cdot 10^{12}$ $m^3$ of $CO_2$

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atmosphere of Earth

$r = 6371$ km

surface area $= \frac{4}{3}\pi r^2 = 1.699 \cdot 10^{14}\ m^2$

assume atmosphere is 50,000 ft thick (10 miles) 16 km

volume of the atmosphere $= (1.699 \cdot 10^{14}\ m^2)(16000\ m)$

$= 2.73 \cdot 10^{18}\ m^3$

$$\frac{3.55 \cdot 10^{12}\ m^3 \text{ of } CO_2}{2.73 \cdot 10^{18}\ m^3 \text{ atmosphere}} = 1.29 \text{ ppm}$$

$CO_2$ is going up by 1.29 ppm/year just from the US (assuming all electricity came from coal)