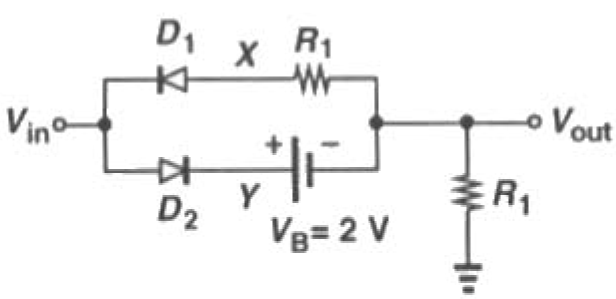
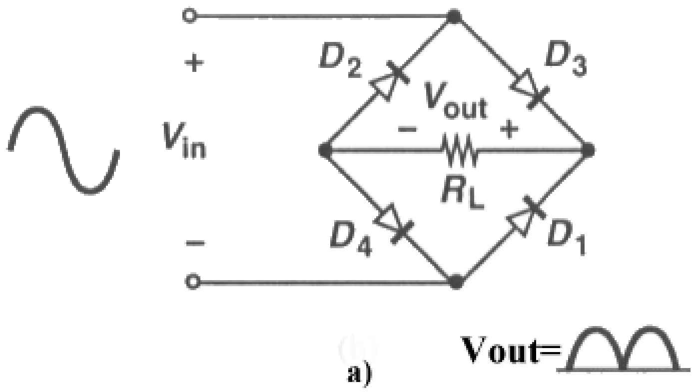
Homework 4

A silicon p-n diode maintained at 300K has a doping of N_a=3x10^{18} cm^{-3} and N_d=1.0x10^{16} cm^{-3} and mobilities in the two regions of μ_n=1000 cm^2/V-Sec, μ_p=200 cm^2/V-Sec, minority carrier lifetimes in the two regions of τ_n=10 μS τ_p=1.2 μS.

1) What is the built in voltage?
2) What is the depletion width (total, W) and width on each side of the junction (x_n and x_p)?
3) Why is the value of x_p different from x_n (i.e. why is the depletion region asymmetric)?
4) What is the leakage current density, Jo (not Io)?
5) Write out the J-V equation of the diode explaining which part is due to diffusion current and which part is due to drift current.
6) What is the capacitance per unit area and the small signal diode resistance at 0 volts? (Assuming the diode area is 2.0e-5 cm^2 when solving problems 6-8)
7) What is the capacitance per unit area and the small signal diode resistance at -3 volts (i.e. reverse bias)?
8) What is the capacitance per unit area and the small signal diode resistance at +0.5 volts (i.e. forward bias)?
9) The diode is to be used in a 3GHz oscillator circuit for a cell phone and thus is placed in parallel with a 12 nH inductor. If the device is intended to be biased at -3 V (see results from problem above), what diode area is required?
10) If the bias voltage is changed to -1V, what is the shift in frequency that results?
11) Using the Ideal Diode Model for the circuit below, draw a graph of the Output voltage (y- axis) vs Input voltage (x-axis) for all voltage inputs between -10 and +10 V. Repeat with the CVD model using a turn on voltage of 0.6 V.





12) The circuit above is called a full wave bridge rectifier and is so common in power supply applications that you can buy the diode sets as one single part. The resistor R_L is not part of the rectifier but instead is the load you are trying to deliver power to (it could represent a computer or any other appliance that consumes DC power). The input voltage is a sin wave (120 Volts, 60 Hz voltage for our example here but in general can have any amplitude or frequency). The output is the absolute value of the input or a "Fully Rectified" waveform as shown in the figure.
   a. Using the Ideal diode model, draw the equivalent circuit for the positive ½ cycle of the input waveform (i.e. 1^{st} ½ cycle) indicating the direction of current flow through the load resistor, R_L.
   b. Using the Ideal diode model, draw the equivalent circuit for the negative ½ cycle of the input waveform (i.e. 2^{nd} ½ cycle) indicating the direction of current flow through the load resistor, R_L.
   c. Explain the advantage this circuit offers in terms of efficiency of the power used compared to our ½ wave rectifier we discussed in class.
   d. Discuss the advantage this circuit offers in regards to the direction of current flow delivered to the load.
   e. How could we "smooth out" the voltage waveform to make it look more like a DC voltage?

13) Shown below is the voltage regulator with V_i=27V, the breakdown voltage of the zener diode is V_z=9V, R1=15 KΩ. Assume the zener diode is perfect.

a. What is the minimum value of our load resistor, R, that can be used and still have a regulated output voltage?

b. What is the maximum load current that can be drawn from the regulator?

c. What is the output voltage for R=5 KΩ?