EECS 40, Fall 2007
Prof. Chang-Hasnain
Test #4

December 3, 2007
Total Time Allotted: 50 minutes
Total Points: 100

1. This is a closed book exam. However, you are allowed to bring **four** pages (8.5" x 11"), single-sided or one double-sided page notes.
2. No electronic devices, i.e. calculators, cell phones, computers, etc.
3. SHOW all the steps on the exam. Answers without steps will be given only a small percentage of credits. Partial credits will be given if you have proper steps but no final answers.
4. Draw BOXES around your final answers.
5. **Remember to put down units. 1 point will be taken off per missed unit.**

Last (Family) Name:____

First Name: ____

Student ID: _____________________________ **LAB Session** : _________________

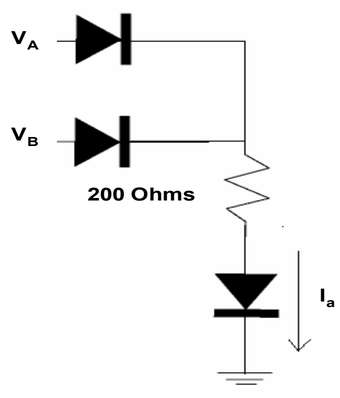
Signature: ____

Score:	
Problem 1 (40 pts)	
Problem 2 (30 pts):	
Problem 3 (20 pts):	
Problem 4 (10 pts):	
Total	

1. (40 pts) Diode Circuits
For the diodes in this problem, use the “0.6V ON-OFF” model:

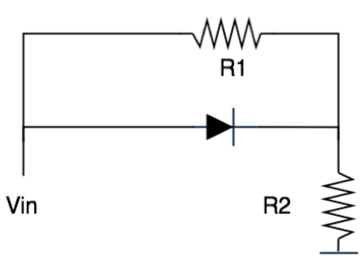
If $I_D < 0$, then the diode is open or OFF
If $I_D >= 0$, then the diode is a 0.6V source or ON

a. (10 pts) Find I_a for the circuit on the right and a range of values of V_A and V_B. Remember to show the steps.



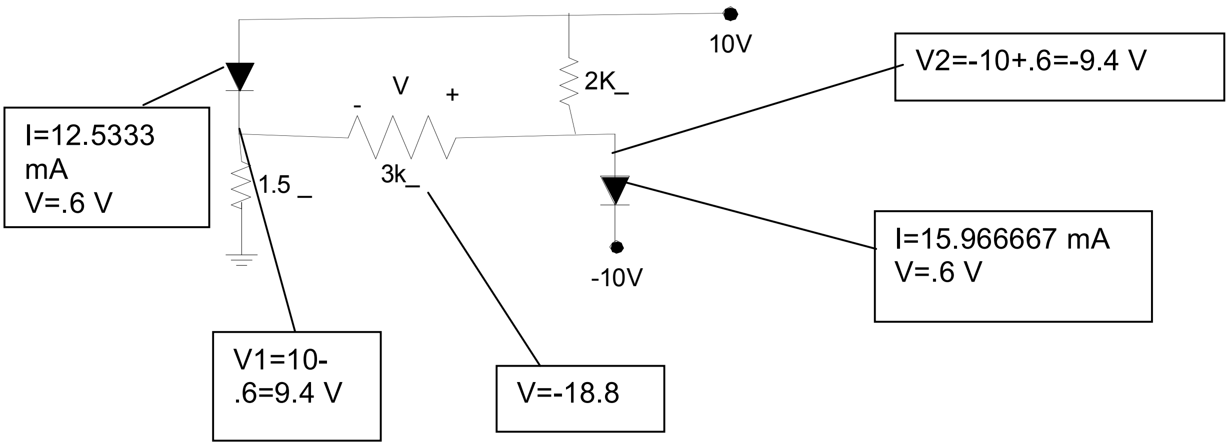
V_A (V)	V_B (V)	I_a (mA)
0	0	0
5	0	19
0	5	19
5	5	19

b. (10 pts) The resistors below are 1 Ohm, and the diode has threshold voltage 0.6V (ON-OFF model). What is the current across the resistor R1 if Vin = 30V? What if Vin = 3V? What about Vin = 0.3 V ?

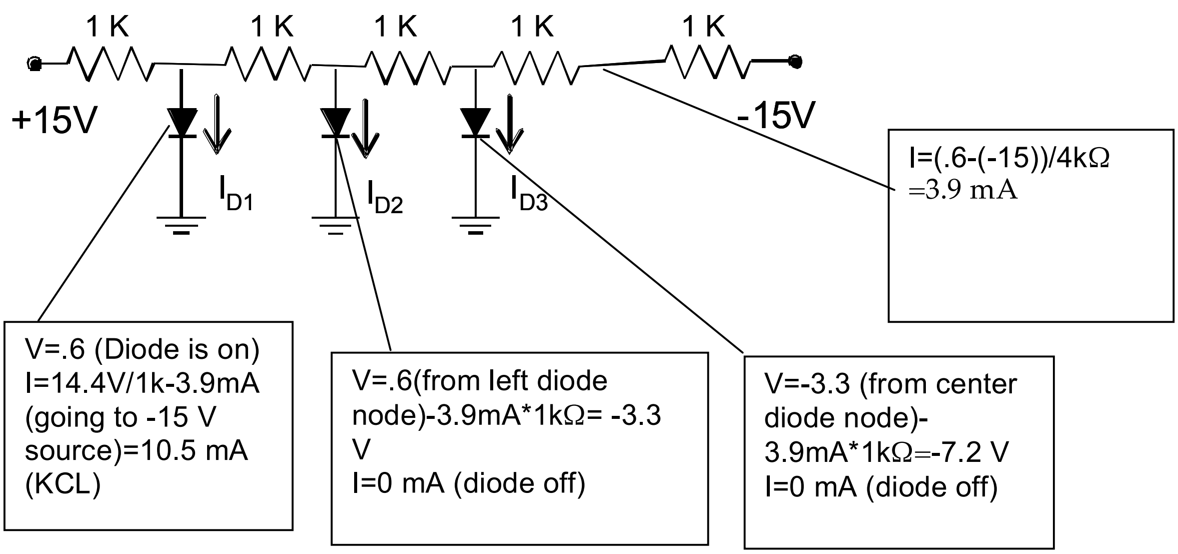


For the first two cases, the diode is on and there is a .6 V drop across the diode and thus the resistor has a .6 V drop across it.
Vin=30 I=.6V/1Ω=.6 A
Vin=3 I=.6V/1Ω=.6 A
Vin=.3 The diode is off thus you can use Ohm’s law: I=.3V/2Ω=.15 A

C. (10 pts) Find the current and voltage of each diode, and the value V (you can leave your answers in fractions; no need to do the arithmetic out):



D. (10 pts) All resistors are 1 K Ohm. Assuming ideal diodes (using the .6V ON-OFF model), find the voltage and current across each diode.



Since all three of these diodes are attached to ground, they must be at a voltage of at least .6 V to be on. The diode on the left we can guess to be on (it's close to a +15 voltage and there is only a resistor between it and the voltage). If this is the case, the voltage at it's top must be .6 V. If this voltage is .6, then it follows that the other two diodes must be off, since the -15 V source implies that the voltage nodes must be less as you move to the right (Intuitively there must be some current flowing from the +15 V to the -15 V regardless of the diodes).

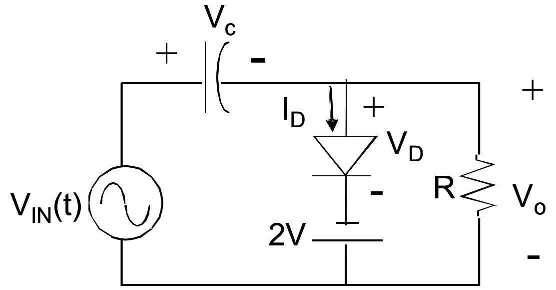
To solve this problem then we just solve for the voltages across the other diodes using the voltage divider equation. After solving for the voltages across all three diodes, we see that our guess that the left diode is on and the right two are off is correct.

2. (30 pts) diode application circuits
Consider the circuit shown below and the capacitance is large. Use large signal diode model:

If $V_D < 0.6$, then the diode is OFF and does not pass current (I_D=0)

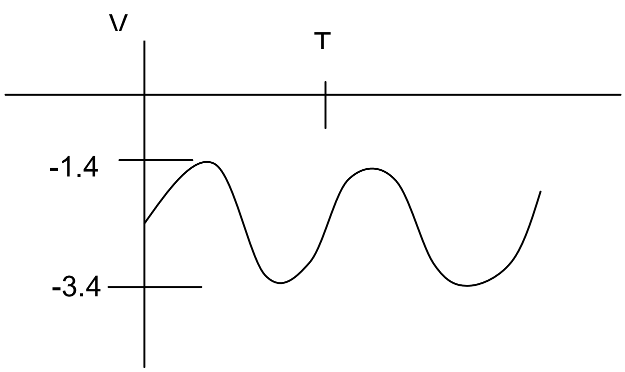
If $I_D >= 0$, then the diode is ON and V_D=0.6

V_D is the voltage drop across the diode and I_D is current through the diode.
The AC source is an alternating voltage source, call it Vin, and let the top side be (+) and the bottom side be (-).

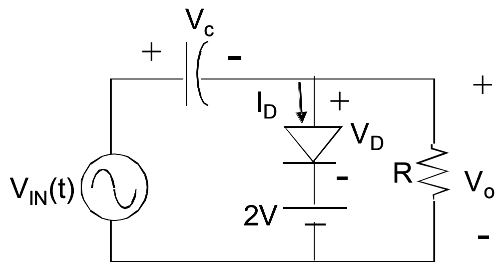


(a) (14 pts) Suppose $V_{IN}(t)= sin(2\pi t/T)$. Assume the circuit has been operating for some time.
What is V_o? Write down the function.
What is V_c?
Sketch V_o, labeling maxima and minima (don't worry about the period or any other details).

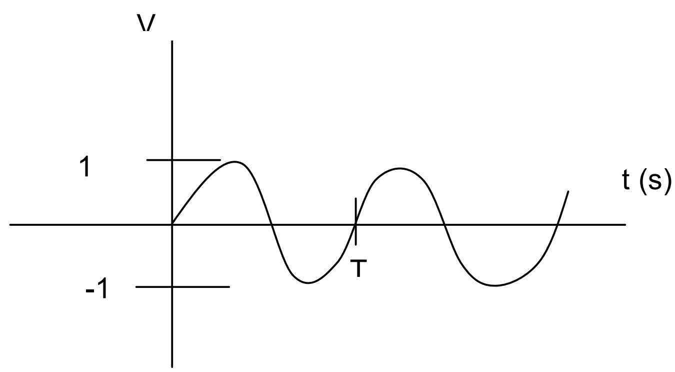
This is a clamp circuit clamping the top of the output of the circuit at -1.4 V (if Vin=0, V0=-1.4V).
$V_o=\sin(2\pi t/T)-2.4$ V
Vc=2.4 V (the average of V_o)



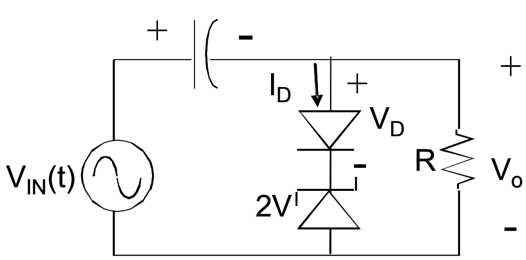
(b) (8 pts) Now switch the direction of the 2V battery. Sketch V_o again just labeling maxima and minima.



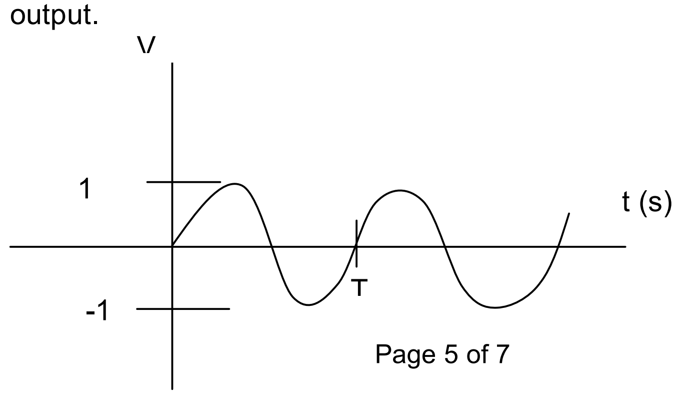
This is tricky. This clamp circuit is improperly designed. If you consider Vin=0, you see that the circuit's output will have a steady state voltage of 0 V instead of the 2.6 V that you might expect. Since the input maximum never hits the clamp, the capacitor will never charge (the diode needs to be on for this to happen). Thus in this case the input will be seen across the output



(c) (8 pts) Replace the 2V battery (in b) by a Zener diode with breakdown voltage of 2V. Sketch V_o once more.



There is no power source in this circuit, thus the capacitor never charges. The input voltage also never gets high enough for the diodes to both turn on, so the input is simply reflected across the output.



3. (20 pts) Semiconductor Diode problem

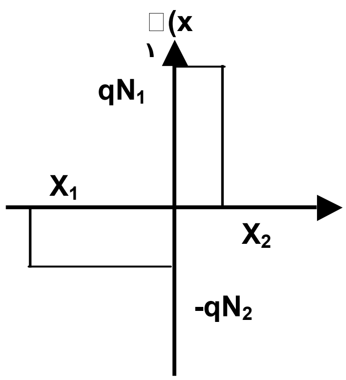
a) (6 pts) Consider a Si wafer doped with Selenium (Group VI) at a concentration of 1.25×10^{18} cm^{-3}. What is the majority carrier (holes or electrons)? Calculate the majority and minority carrier concentrations. Given that $n_i^2 = 10^{20}$ cm^{-3}.

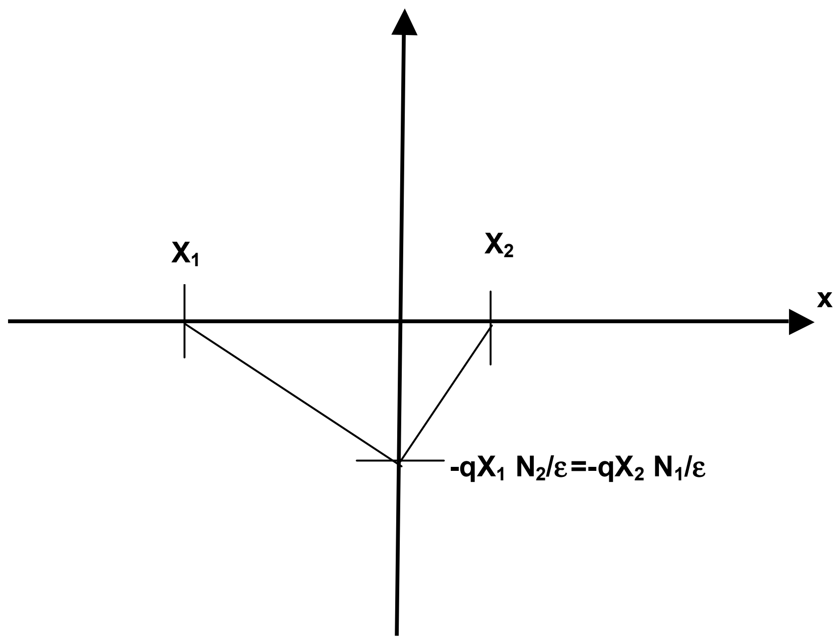
Majority Carrier is electrons

Majority Concentration = $2 \times 1.25 \times 10^{18} = 2.5 \times 10^{18}$ cm^{-3}. (Group VI donors have two extra electrons!)

Minority Concentration = $p = n_i^2/n = 10^{20}/2.5 \times 10^{18} = 40$ cm^{-3}.

b) (10 pts) Now consider the space-charge diagram for a P-N junction below. The permittivity of the junction is □. **Plot E(x) vs. x.** Given E(-∞)=0. Label important points.





c) (2 pts) Which side above is the n-side and which the p-side?

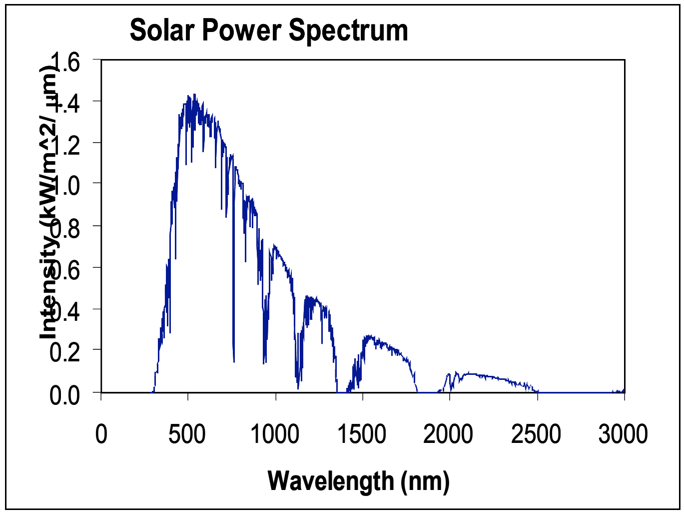
p-side is the left side

n-side is the right side

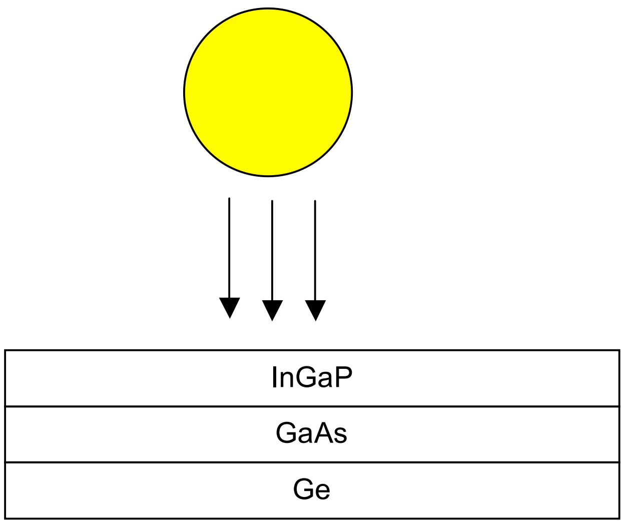
d) (2 pts) Under forward bias, is the maximum value (in magnitude) of electric field greater or less than under no bias?

less

4. (10 pts) Semiconductor Physics problem
I am interested in building a solar cell that can absorb as much solar spectrum as possible. The solar spectrum is shown on the right. I know the following facts:
(1) a GaAs solar cell has a bandgap of 1.4 eV and hence absorb photons with energy larger than 1.4 eV and deliver a voltage close to 1.4 V.
(2) a InGaP solar cell has a bandgap of 1.8 eV and can deliver a voltage close to 1.8V.
(3) a Ge solar cell has a bandgap of 0.66 eV and can deliver a voltage close to 0.66V.



How do I arrange the cells to maximize the photovoltaic power?



This design maximizes the energy captured from the high energy (short wavelength) photons by capturing them in the material with the largest band gap.