HW 4

ECE250 Test 1 (100 Pts Max) Fall Quarter 2006 (KEH)

You must show key steps on the test form to clearly document your solution!

Name: ______________________ CM #__________

1. (14 Pts) Assume that diode D1 is characterized by

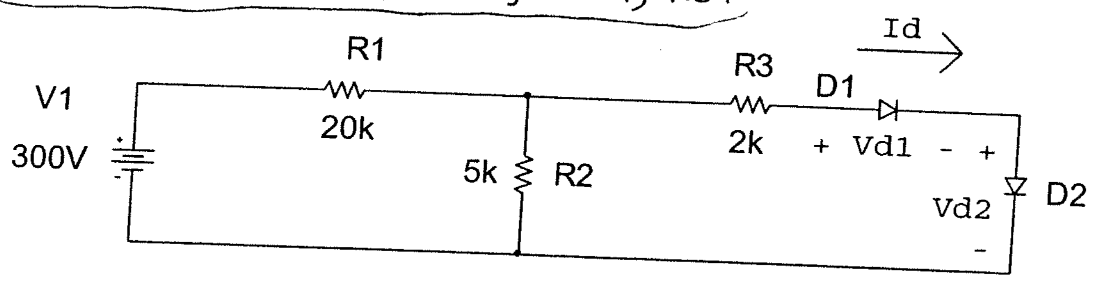
$Is1 = 1$ ***nanoAmpere*** $= 1*10^{-9}$ ***Amperes*** and $n1 = 1$.

and assume that diode D2 is characterized by

$Is2 = 10$ ***nanoAmperes*** $= 10*10^{-9}$ ***Amperes*** and $n2 = 2$.

Use the ideal diode equation to find Id, Vd1, and Vd2 for the circuit below Assume the diodes are at room temperature.

Scrambled Ans: 9.77, 0.419, 0.717, 9.81



Id = __________ mA

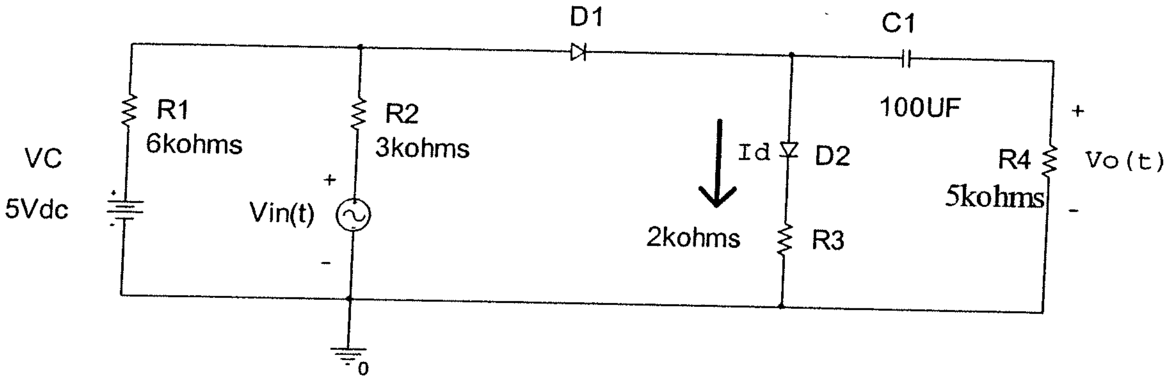
Vd1 = __________ v

Vd2 = __________ V

B. Now find Id using the piecewise-continuous diode model for each diode, with $Rf = 0$ Ω and $V\gamma = 0.70$ V. (Your two answers should be reasonably close to each other!)

Id = __________ mA

2. (20 pts) In the circuit below, assume that the peak amplitude of the small signal Vin(t) is 0.1 V, and that the 100 μF capacitor acts like a short circuit at the source frequency. Assume that both of the diodes have a forward junction drop of ***$V\gamma = 0.7V$***. (a) With control voltage **Vc = 5 V**, construct the ***dc*** circuit model, and then "Theveninize" the source. (b) Find the dc current through the diodes, ***Idq.*** (c) Assuming that both the diodes have a junction grading coefficient of **n = 2,** and that the diodes are at ***room temperature,*** find the small-signal ac diode resistance "***rd***" of each of the diodes. (d) Find the ac model of the circuit, and then Theveninize the ac source (e) Finally, predict the small-signal gain **Av** = v***o(t)/vin(t)*** when the dc control voltage ***Vc = 5 V***, (f) Find **Av** when the dc control voltage is changed to ***Vc = -5 V.***



(a) *dc model*

Theveninized dc model

(d) *ac model*

Thevenized ac model

(b)Idq = ______________ μA

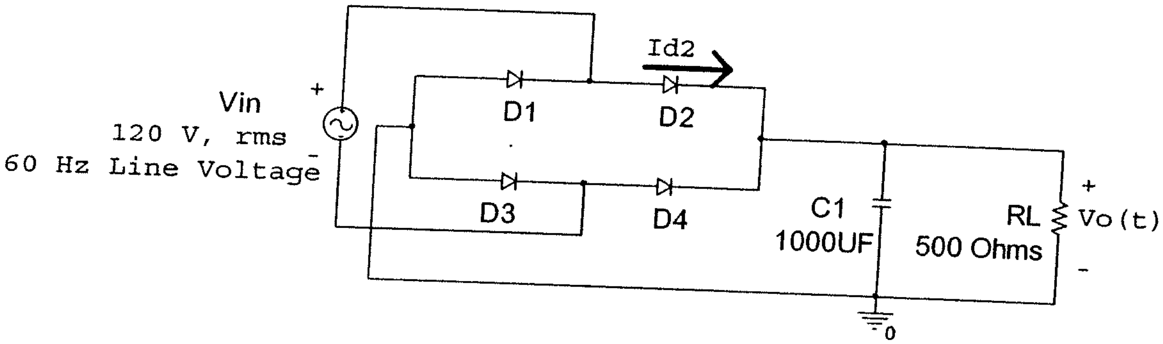
(c) rd = ______________ Ω

(e) For Vc = +5 V, $Av = \frac{Vo(t)}{Vin(t)}$ = ______________

(f) VC = -5 V, $Av = \frac{Vo(t)}{Vin(t)}$ = ______________

Scrambled Ans: 0, 780, 66.66, 0.261

3. (10 pts) In the circuit below Vin corresponds to a standard ***120 V rms (NOT PEAK!)***, 60 Hz household AC power line. Assume each diode has ***$V\gamma = 0.7$ V*** Find: (a) the dc (average) output voltage Vodc. To be as accurate as possible, please take $V\gamma$ and Vr into account when calculating Vodc. (b) the peak-to-peak output (ripple) voltage variation, Vr, and its frequency "fr" (c) the minimum allowable peak reverse voltage (PIV) rating of each of the diodes (d) the new value of C1 that will make the ripple voltage (Vr) approximately 0.5 V.



a) Vodc = ________ V

b) Vr = ________ V

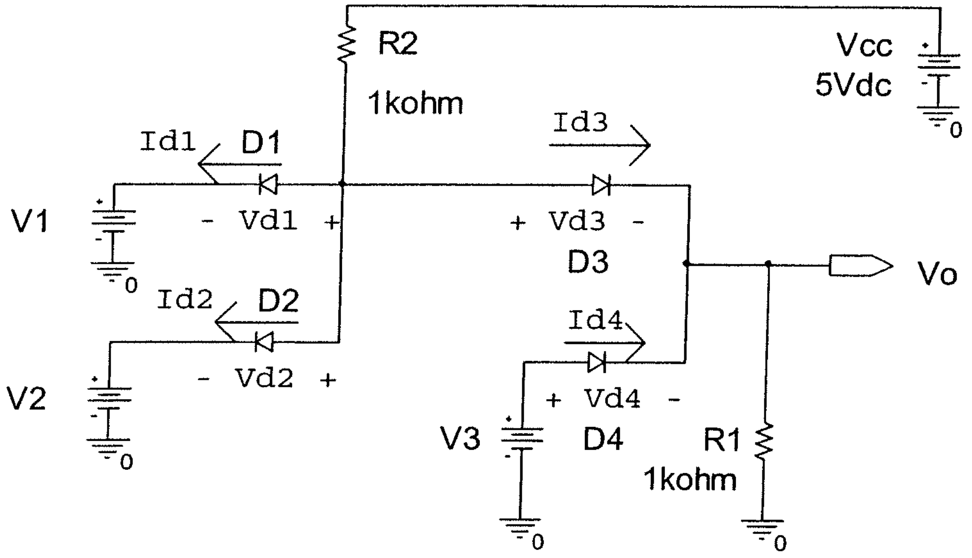
fr = ________ Hz

c) PIV = ________ V

d) New C1 = ________ μF

Scrambled Ans: 120, 166.91, 169, 5602, 2.782

4. (16 pts) Assume the piecewise linear model for each of the diodes below, with ***Rf* = *0 Ω*** and ***Vγ* = *0.7 V***. Calculate the diode currents Id1, Id2, Id3, and Id4 (the diode current must be 0 if the diode is OFF, and it must be positive if the diode is ON), the diode voltages Vd1, Vd2, Vd3, and Vd4 (the diode voltage must be 0.7 V if the diode is ON, and it must be less than 0.7 V if the diode is OFF.) *Diode voltages can NEVER exceed 0.7 V --- unless they are burned out diodes!*) Also find the resulting value of Vo. You may have to make several trial guesses about which diodes are on, and then check for consistency... so I suggest that you work this problem in pencil so you can erase!



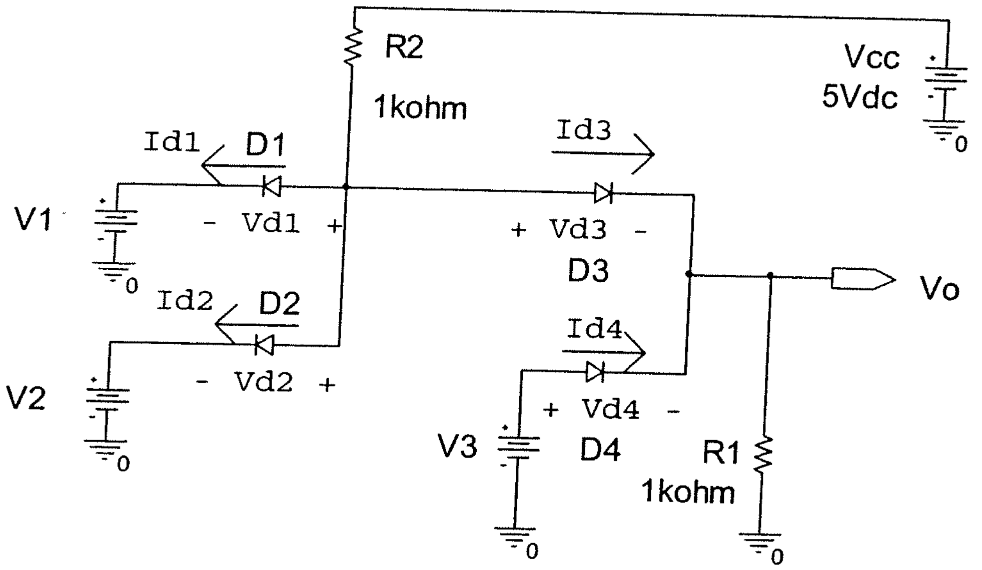
4A. V1 = 5 V, V2 = 0 V, V3 = 2 V

Id1 = _____mA Vd1 = _______ V
Id2 = _____mA Vd2 = _______ V
Id3 = _____mA Vd3 = _______ V
Id4 = _____mA Vd4 = _______ V

Vo = ________ V

Scrambled Answers : 0, -4.3, 4.3, 0.7, 0, -0.6, 0.7, 1.3, 1.3

4B. The circuit on the previous page has been redrawn below for your convenience!



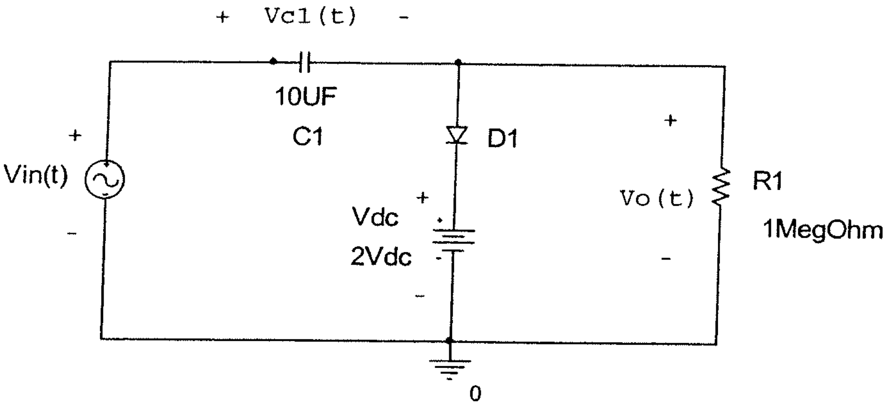
Repeat your analysis for V1 = 3 V, V2 = 4 V, V3 = 2 V

Id1 = ______mA Vd1 = _______ V
Id2 = ______mA Vd2 = _______ V
Id3 = ______mA Vd3 = _______ V
Id4 = ______mA Vd4 = _______ V

Vo = ________ V

Scrambled Ans: 0, -0.15, 0, 0.7, -1.15, 2.15 -0.15, 2.15, 0

5. (10 pts) For the 3 situations below, find the ***dc*** steady-state value of Vc1(t), and then write an expression for Vo(t) in the steady-state. Also find the maximum and minimum value of Vo(t) once the circuit has reached steady-state. Assume the period of the source is much shorter than the time constant R1*C1. Assume the piecewise linear model of the diode, with ***Rf = 0 Ω*** and ***Vγ = 0.7 V***



A. Vin(t) = 5cos(ωt) Volts $Vc_{1\_dc\_steady\text{-}state}$ = ________ Vdc,

Vo(t) = ____

$Vo(t)_{MAX}$ = ______________ V $Vo(t)_{MIN}$ = ____________ V

B. Vin(t) = {5cos(ωt) + 5} Volts. $Vc_{1\_dc\_steady\text{-}state}$ = ________ Vdc,

Vo(t) = ____

$Vo(t)_{MAX}$ = ______________ V $Vo(t)_{MIN}$ = ____________ V

C. Now diode D1 is ***reversed*** (it now points ***UP***). Everything else remains the same.

Vin(t) = 5cos(ωt) Volts. $Vc_{1\_dc\_steady\text{-}state}$ = __________ Vdc,

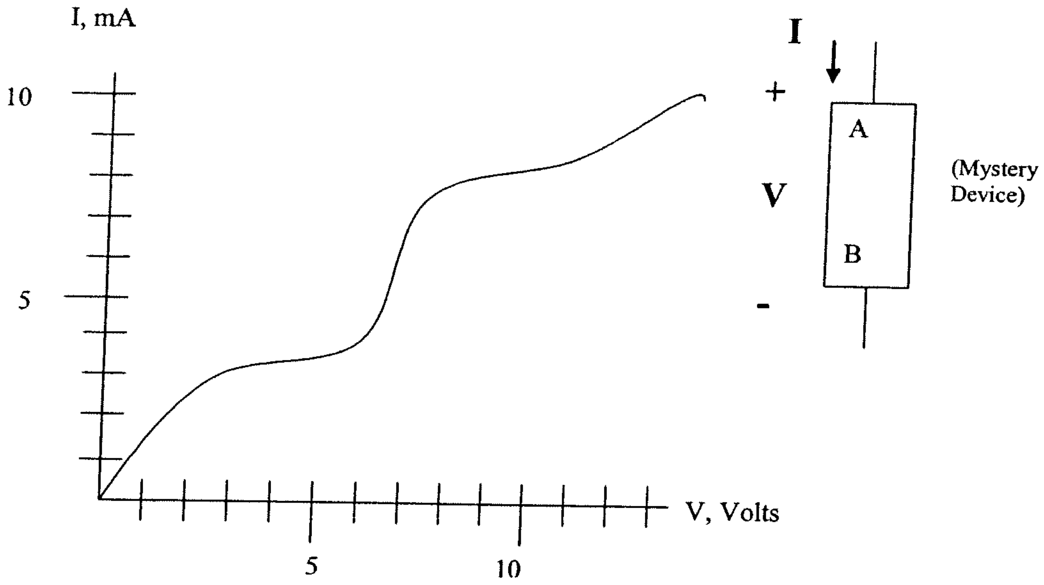
Vo(t) = ____

$Vo(t)_{MAX}$ = ______________ V $Vo(t)_{MIN}$ = ____________ V

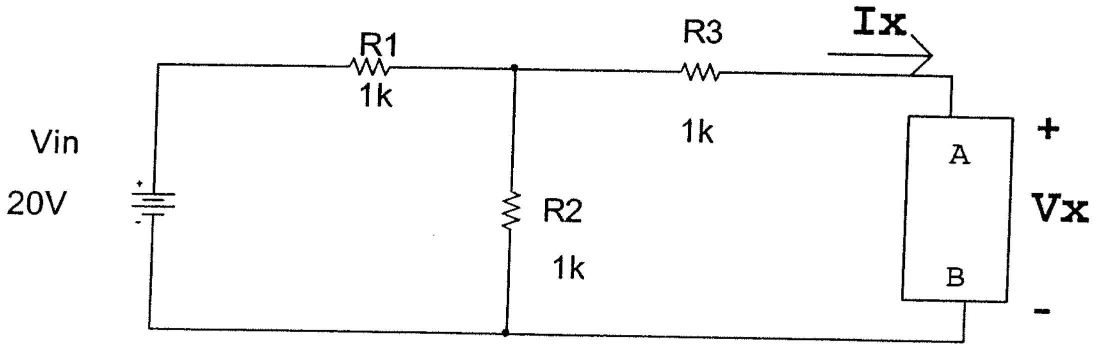
Scrambled Ans: $V_{C1\,ss}$ = -6.3V, 2.3, 7.3 Vo_{Min} = -7.3, -7.3, 1.3

Vo_{Max} = 2.7, 11.3, 2.7

6. (10 Points) A nonlinear "mystery device" has the I vs. V curve shown below:



Use graphical load line analysis (draw the load line over the nonlinear I-V curve above) to determine Vx and Ix in the circuit below.



Vx = ____________

Ix = ____________

(Scrambled Ans: $V_x = 4.7$, $I_x = 3.4$,)

7. (14 points) *Semiconductor Physics Concept Questions*

--- Circle one answer to each of the 14 questions below

A. Which one of the following materials has a crystal lattice structure that is most likely to be the most tightly packed?
(a) Copper (b) Silicon (c) Gallium Arsenide (d) Silicon Dioxide (glass)

B. The mean time between collisions between a free electron and a lattice atom in a conductor __?__ increasing temperature.
(a) increases with (b) decreases with (c) does not depend on

C. A free electron in a conductor drifts _?_ the direction of an applied electric field.
(a) along (b) against (c) perpendicular to

D. The number of free electrons per cubic meter that are present in a pure (intrinsic) semiconductor becomes constant (= n_i) when the rate of thermal generation equals the rate of _?_
(a) diffusion (b) drift (c) adiabatic synergy (d) recombination

E. If a semiconductor is doped with a "donor" impurity, it becomes _?_ type.
(a) p (b) n (c) intrinsic (d) insulator

F. If silicon (which is found in Column 4 of the periodic chart) is doped with an impurity that comes from Column 3 of the periodic chart, the silicon becomes _?_ type.
(a) p (b) n (c) intrinsic (d) insulator

G. (i) A pn junction with no external bias voltage has an internal E field across the junction that is directed
(a) from the p side to the n side (b) from the n side to the p side

(ii) When the pn junction has an external voltage applied across it that makes the p side more positive than the n side
(a) more diffusion current flows than drift current
(b) more drift current flows than diffusion current

(iii) The capacitance of a reverse-biased pn junction _?_ as the magnitude of the cathode-to-anode voltage is increased.
(a) increases (b) decreases (c) remains the same

H. (i) A photodiode requires the light photons that it detects to have an energy that
(a) is ***less than*** the bandgap of the material the diode is made from
(b) is ***greater than*** the bandgap of the material the diode is made from

(ii) Thus the wavelength of the light that is detected by a photodiode must be sufficiently
(a) short (b) long

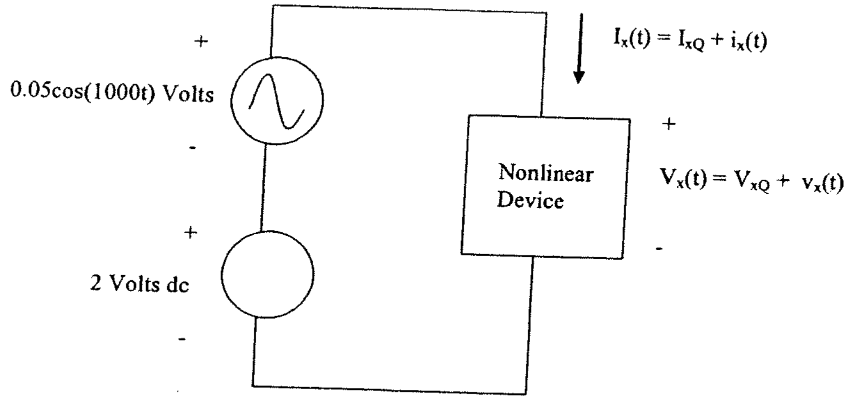
I. (i) A light bulb filament's resistance _?_ with increasing temperature
(a) increases (b) decreases (c) remains the same

(ii) The resistance of a doped semiconductor (either p or n type) _?_ with increasing temperature
(a) increases (b) decreases (c) remains the same

(iii) For this reason (as discussedin class) a doped semiconductor (thermistor) may be placed in series with a light bulb in order to:
(a) prolong bulb life (b) make the bulb more efficient (c) increase the bulb's brightness

Scrambled answ: a b a a b b a b a b d b b a

8. (6 pts) A nonlinear device obeys a "square law" characteristic, where $\mathbf{V_x = 8(I_x^2)}$ **Volts**



(a) Draw the dc model of this circuit, and then determine the dc component of the current through this device, I_{xQ}.

DC Model

I_{xQ} = __________ A

(b) Determine the small-signal resistance of this device (r_x) at the dc bias current level fou in Part (a). *Hint: Recall that for small ac variations, rx = $v_x(t)/i_x(t)$. Use calculus just as we derived "rd" for the ac small-signal diode model in class.*

r_x = __________ Ω

(c) Draw the ac small-signal model of this circuit, and use the value of r_x to find $i_x(t)$.

AC Model

$i_x(t)$ = ______________________ mA

Scrambled Ans.: 8, 1/2, 6.25cos(1000t)