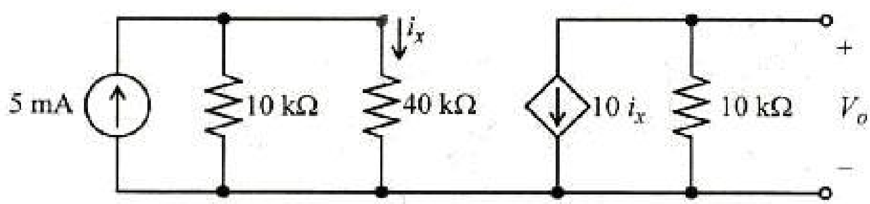
EECS 40, Spring 2000
Midterm 2
Professor King

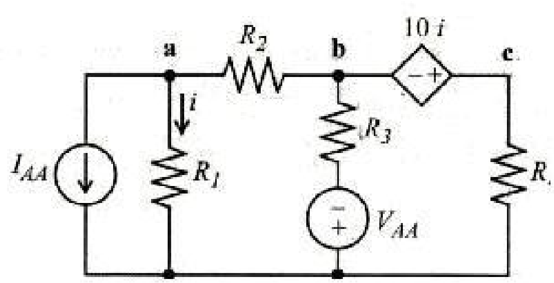
Problem #1: Circuits with Dependent Sources [20 points]

a) Find V_0. [4 pts]



b) In the circuit below, the independent source values and resistances are known. Use the **nodal analysis technique** to write **3 equations sufficient to solve for V_a, V_b, and V_c**. To receive credit, you must write your answer in the box below. [6 pts]

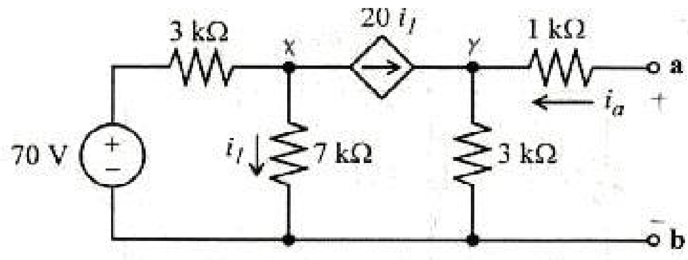
DO NOT SOLVE THE EQUATIONS!



Write the nodal equations here:

1.
2.
3.

c) Consider the following circuit:



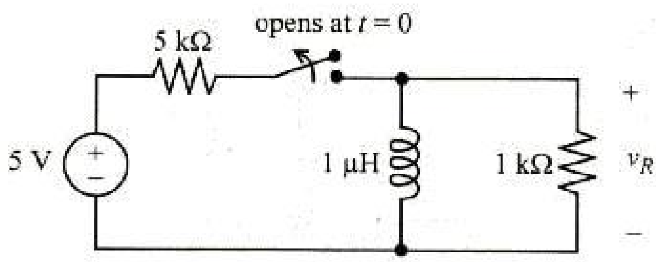
i) Find the voltage V_{ab}. [5 pts]

ii) What is the current i_a when the terminals **a** and **b** are shorted together? [3pts]

iii) Draw the Thevenin Equivalent Circuit. [2pts]

Problem #2: Transient Response [30 pts]

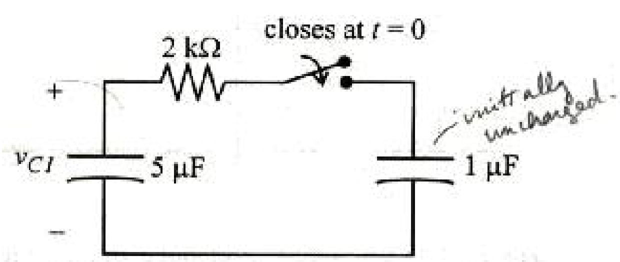
a) In the circuit below, the switch has been in the closed position for a long time.



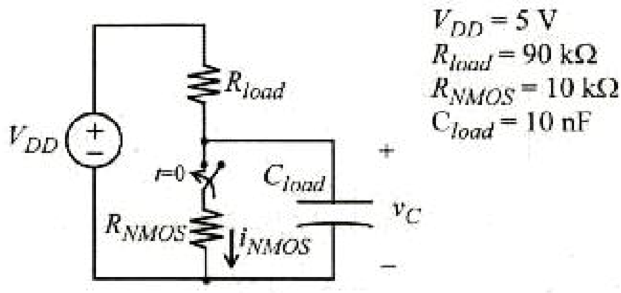
i) Find the value of v_R just after the switch opens ($t = 0+$). [3 pts]

ii) How much energy is dissipated in the 1 k-ohm resistor after the switch is opened? [2 pts]

b) In the circuit below, the 5 micro-farad capacitor is initially charged to 5 V ($v_{C1}(0^-) = 5$ V). The switch is then closed at time t = 0. What is the final value of v_{C1}? [5 pts]



c) The following is a circuit model for an NMOS inverter, in which the transistor is turned on at time t = 0:



i) What is the value of v_C at $t = 0^-$? [3 pts]

ii) What is the value of i_{NMOS} at $t = 0^+$? [3 pts]

iii) What is the final value of v_C? [3 pts]

iv) Neatly sketch the graph of i_{NMOS} **for all t**, labelling the axes. [5 pts]

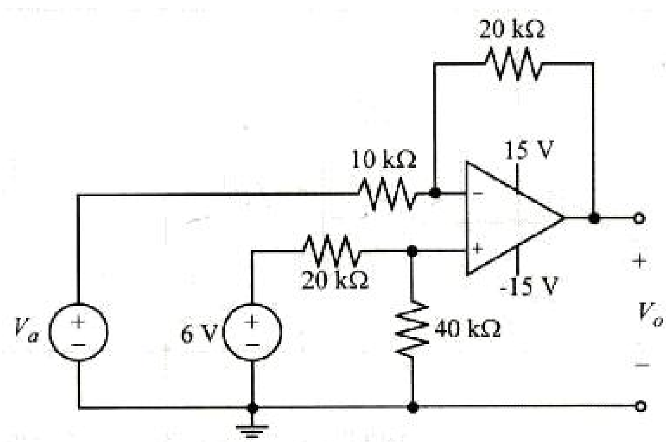
v) Write an equation for i_{NMOS} as a function of time, for $t>0$. [6 pts]

Equation for i_{NMOS}: ____

Problem #3: Op-Amp Circuits [25 pts]

Assume the op=amps in this problem are ideal.

a) Consider the following circuit:

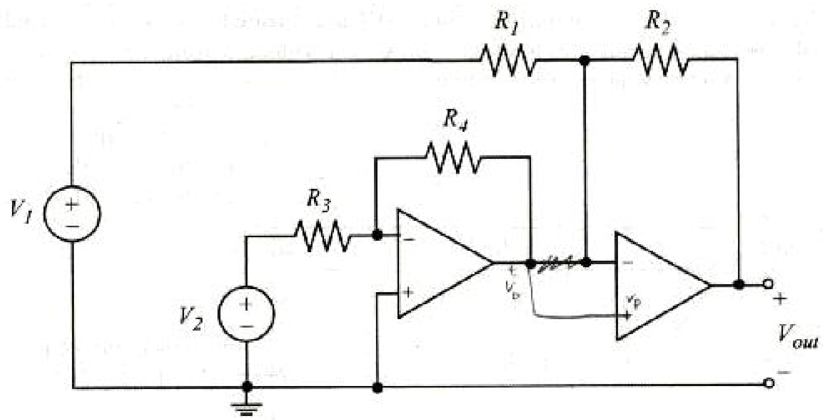


i) Find an expression for V_0 as a function of V_a. [6 pts]

ii) Find V_0 for V_a=2V. [3 pts]

iii) For what values of V_a will the op-amp be saturated? [6 pts]

b) In the following circuit, the op-amps are operating linearly.

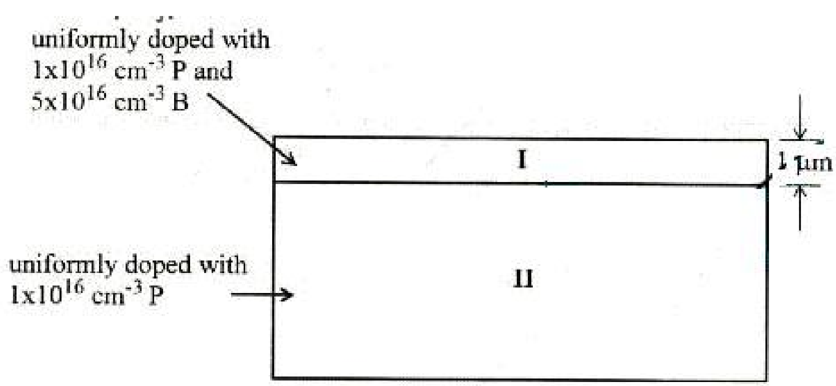


Find V_{out} in terms of V1, V2, R1, R2, R3, F4. [10 pts]

(Hint: The superposition method might be helpful here.)

Problem 4: Semiconductor properties; p-n diodes [25 pts]

a) Consider a silicon sample maintained at 300K under equilibrium conditions, uniformly doped with $1x10^{16}$ cm^{-3} phosphorus atoms. The surface region of the sample is additionally doped uniformly with $5x10^{16}$ cm^{-3} boron atoms, to a depth of 1 micron, as shown in the figure below.



Schematic cross-sectional view of silicon sample

i) In the figure above, indicate the type of the regions (I and II) by labelling them as "n" or "p" type. [2 pts]

ii) What are the electron and hole concentrations in Region I? [5 pts]

n = _______________ cm^{-3}

p = _______________ cm^{-3}

iii) What is the sheet resistance of Region I? [5 pts]

iv) Suppose any voltage between 0 V and 5 V can be applied to Region I. What fixed voltage ("bias") would you apply to Region II, to guarantee that no current would ever flow between Region I and Region II? **Briefly explain your answer**. [3 pts]

b) If a diode is operated only within a small range of forward-bias voltages, its behavior can be accurately modelled by a resistor, whose value is dependent on the bias voltage. Device an expression for the diode "small-signal" resistance:

$$R_{diode} = \left(\frac{\partial I}{\partial V}\right)^{-1}$$

in terms of the saturation current I_S, the bias voltage V, and the absolute temperature T. [5 pts]

R_{diode} = ________________________

c) Plot v_L vs. V_{IN} for **-10 V < V_{IN} < 10 V** on the axes provided, for the circuit below, Note that the diode is a perfect rectifier. **Label the axes.** [5 pts]