NAME:____________________________________ **HUID:**_________________________.

THE QUIZ

Engineering Sciences 50

Harvard School of Engineering and Applied Sciences

Instructors: Chris Lombardo & Marko Loncar November 3, 2014

There are 9 questions worth of total of 67 points, and 2 Bonus question worth of total of 8 points.

You have 80 minutes to complete the quiz. Unjustified answers receive little credit, so use the space provided to show all work.

Good luck! ☺

1 (5pts)	2 (5pts)	3 (6pts)	4 (9pts)	5 (6pts)	6 (3pts)	7 (9pts)	8 (14pts)	9 (10pts)	B1 (4pts)	B2 (4pts)	Σ (67+8pts)

Question 1. Simple Circuits (5 points)

You are given three resistors with resistances $R_1=100\Omega$, $R_2=10\Omega$, $R_3=1\Omega$, and one current source outputting current $I_s=1A$.

a) **(3 points)** How would you connect these four elements so that the current source generates as much power as possible? Show your circuit.

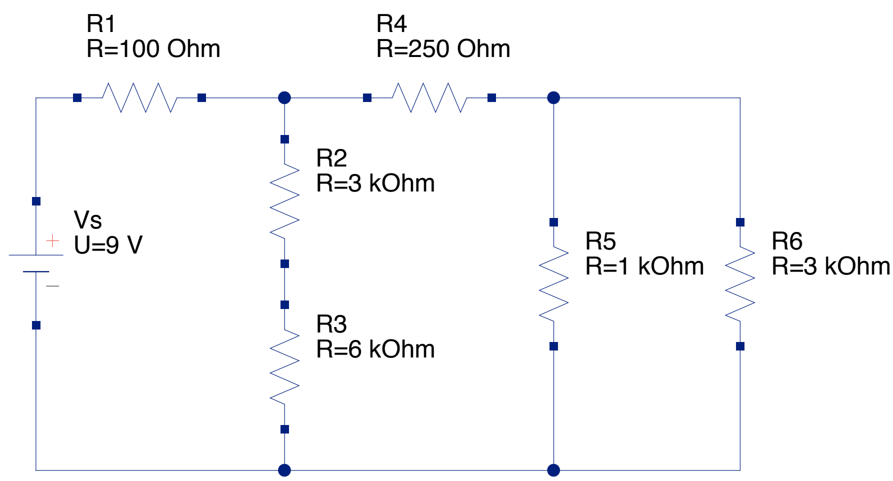
b) **(2 points)** For your answer in a), how much power does each resistor dissipate? How much power is generated by the current source?

Question 2: Equivalent circuits, resistor combinations (5 points)

Consider the circuit shown below:

a) **(4 points)** Find the expression for the overall resistance of the resistive network "seen" by the voltage source. (That is, combine all of the resistors into one net resistance.) What is the value of this net resistance?
Note: if you resistors R_A and R_B are in parallel, for example, their combined resistance can be written using short notation as $R_A||R_B$.

b) **(1 point)** Calculate the current flowing out of the voltage source.

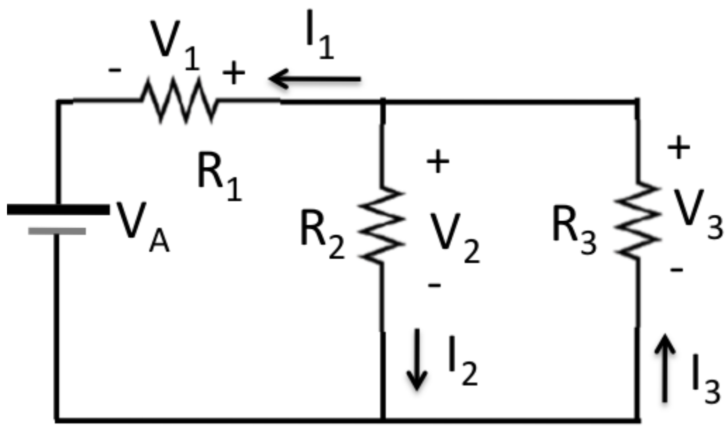


Question 3: KCL, KVL and Ohm's Law (6 points)

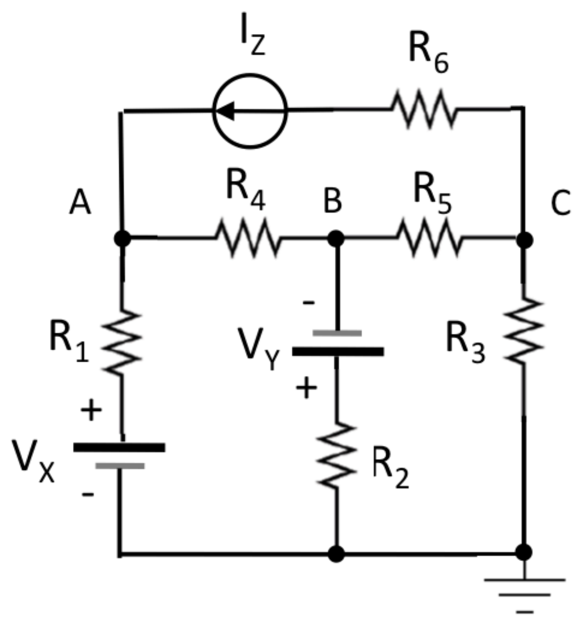
In the circuit below, $R_1 = 30\Omega$, $R_2 = 20\Omega$, and $R_3 = 30\Omega$. $I_3 = -0.5A$, and voltage V_A is unknown.

a) **(3 points)** Find V_3, V_2, and I_2 , with respect to reference directions indicated;

b) (**3 points**) Find I_1 , V_1 and V_A with respect to reference directions indicated

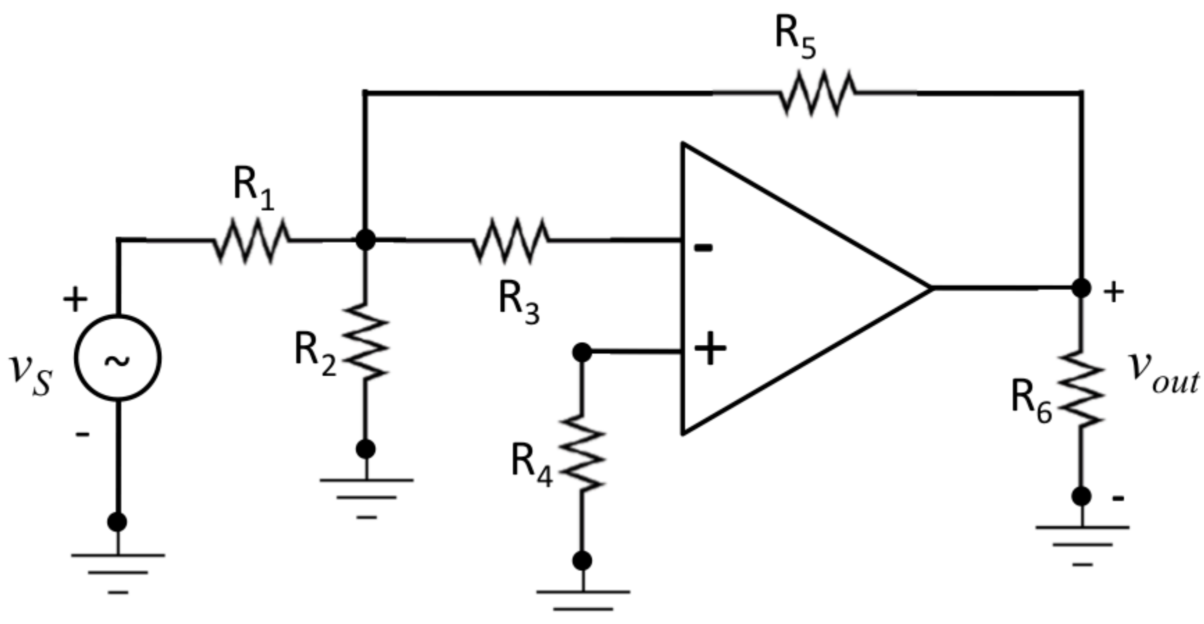


Question 4: Nodal Voltages (9 points)
For circuit shown below write the complete set of nodal voltages equations that can be used to find potentials V_A, V_B and V_C with respect to ground. You do not need to solve the system of equations.



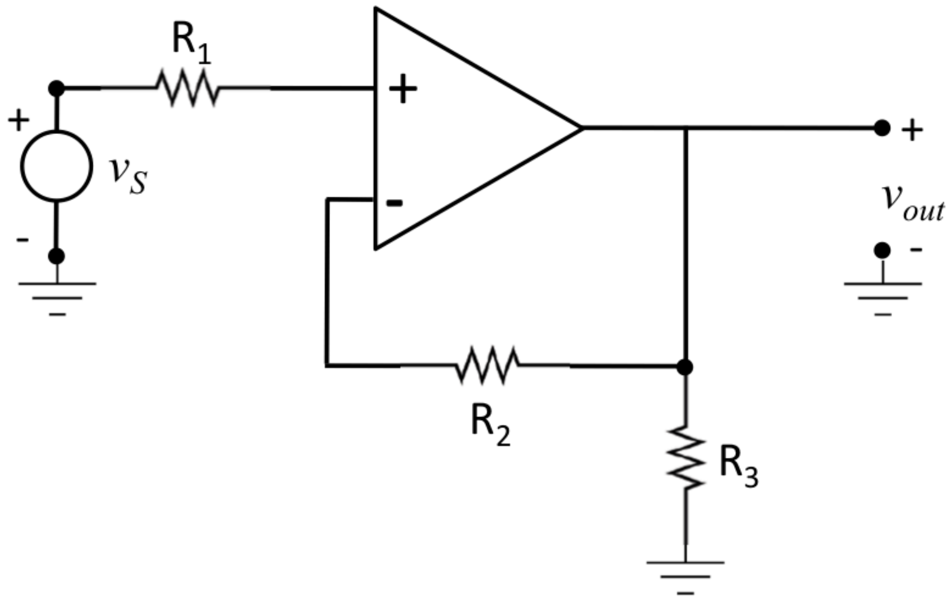
Question 5: Op Amp Analysis (6 points)

For the Op Amp circuit shown below, find gain G=v_{out}/ v_S in terms of other circuit elements.



Question 6: Op Amp Analysis (3 points)

For the Op Amp circuit shown below, find gain G=v_{out}/ v_S in terms of other circuit elements.



Question 7: Combinatory Logic (9 points)

Realize combinatory logic circuit that has following properties:

- input to the circuit is a 3-bit number $A_2A_1A_0$
- output is an one-bit number O
- O=1 only if decimal number represented by $A_2A_1A_0$ can be evenly divided by 2 or 3 (e.g. if $A_2A_1A_0$=010, O=1); O=0 in all other cases;
    - A restatement of this is if the result of the decimal represented by $A_2A_1A_0$ when divided by 2 or 3 is has integer value, O=1

a) **(3 points)** show a truth table for this circuit;

b) **(2 points)** using the table come up with a logic equation for this circuit;

c) **(2 points)** simplify the equation if possible;

d) **(2 points)** draw a logic circuit (either simplified or non simplified)

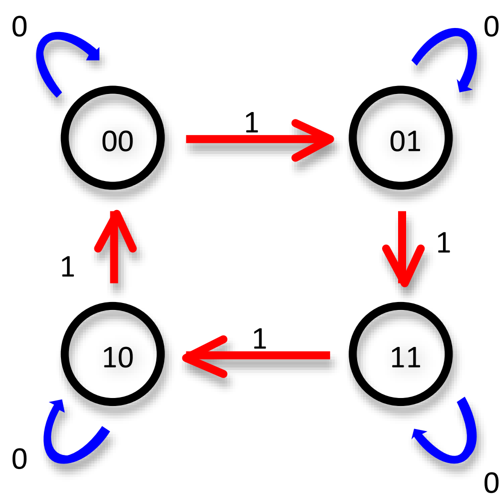
Question 8: Finite State Machine Implementation (14 points)

The diagram of a finite state machine is shown below:

a) **(4 points)** Using the state diagram, construct a truth table to describe the dependence of the 'next state' on the 'present state' and inputs. Notice that the machine does not have outputs.

b) **(4 points)** Find the logic expressions for 'next state'. Simplify if possible.

c) **(6 points)** Construct the finite state machine using flip flops of your own choice, and any number of logic gates with as many inputs as you wish. You have to implement the outputs as well.



Question 9: Finite State Machine (10 points)

Seeing the higher-than-ever enrollment for ES 50, a greedy TF decides to be entrepreneurial (aka, make some money). People have to sign up for office hours which are of two types: 'ordinary' and 'empowering' (where you also get correct answers to pset problems!).

The TF wants to have a machine designed, working and installed at the entrance to the office hour local – but being lazy, wants YOU to design that machine.

You have to design and draw the diagram for a Finites State Machine (FSM), giving the following details:

1. 'Ordinary' office hours cost 2 token-coins and 'Empowering' office hours cost 4 token-coins.
2. The machine gives you a receipt for either 'ordinary' or 'empowering' office hours, depending on your choice.
3. You can insert tokens one at a time.
4. There should be two buttons: 'ordinary' and 'empowering', which a person can select.
5. If you do not put in enough tokens, the machine displays a message, '*Insert more tokens, NOW!* ' Machine displays the same message even if you are not doing anything (not providing any input), and just standing in front of it .
6. If you put enough tokens for 'ordinary' then machine displays 'push 'ordinary' or insert more tokens for 'empowering!'.
7. Once you put in enough tokens for 'empowering', receipt for 'empowering' is automatically printed, and machine is ready for another customer.
8. Once receipt for 'ordinary' or 'empowering' is printed, extra tokens (if any) are "eaten" by the machine (not returned back) and machine is ready for another customer.

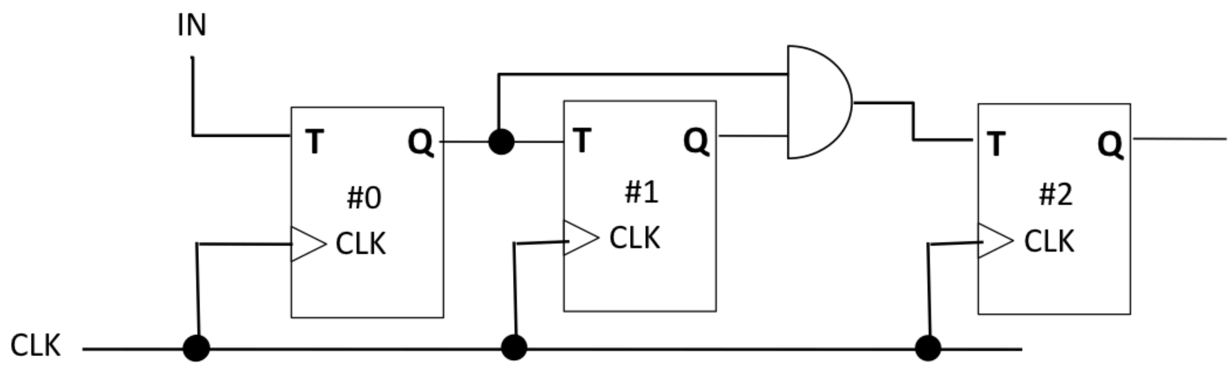
a) **(8 points)** Draw the state diagram for this machine – you do not have to encode your states, inputs and outputs. Indicate clearly your states, inputs and outputs to this machine?

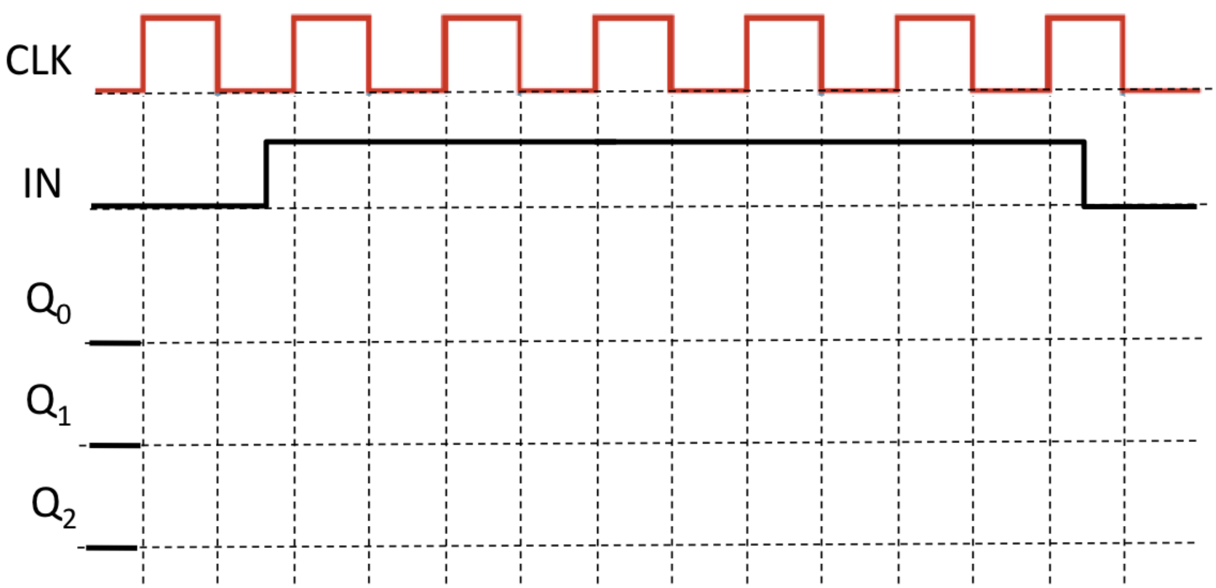
b) **(2 points)** How many flip-flops would you need to represent this machine?

B1: EASIER BONUS - Flip-Flops and Sequential Logic (4 points)
Consider the sequential logic circuit shown below.

a) **(3 points)** In the area provided below show the outputs of Q_2, Q_1, and Q_0 as a function of time. All flip-flops start n state 0 (as indicated)

b) **(1 points)** What does this circuit do? That is, what does the combination of output wires $Q_2Q_1Q_0$ encode?





B2: HARDER BONUS – for those who want to impress us ☺ (4 points)

Find gain $G=V_{out}/V_{in}$