NAME:_____ **HUID:**_____.

THE QUIZ

Engineering Sciences 50
Harvard School of Engineering and Applied Sciences

Instructors: Evelyn Hu & Marko Loncar March 10, 2014

There are 6 questions worth of total of 50 points and 2 bonus question worth of total of 21 points. One of the Bonus questions is easy, the other one is hard.

You have 70 minutes to complete the quiz. Unjustified answers receive little credit, so use the space provided to show all work.

Good luck! ☺

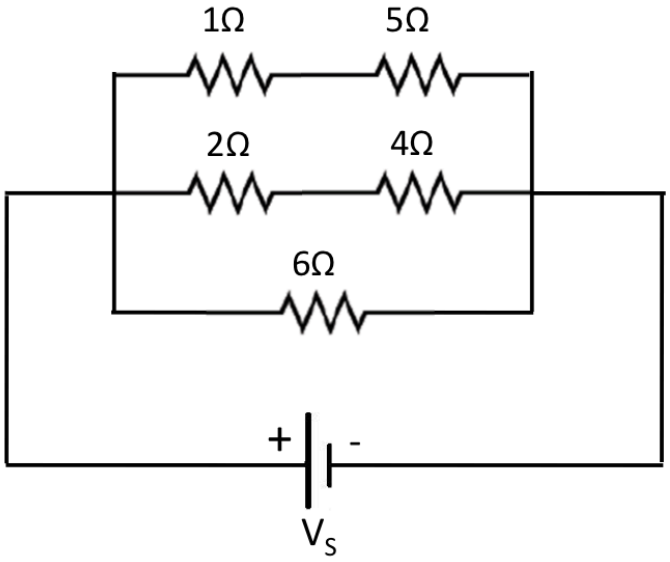
1 (8pts)	2 (10pts)	3 (8pts)	4 (8pts)	5 (10pts)	6 (6pts)	B1 (6pts)	B2 (15pts)	Σ (50pts + 21pts)

Question 1: Simple Circuits with Resistors; Power; (8 points)

Note: Parts a) and b) can be done without writing any equations.

Consider the circuit below, with V_S=6V.

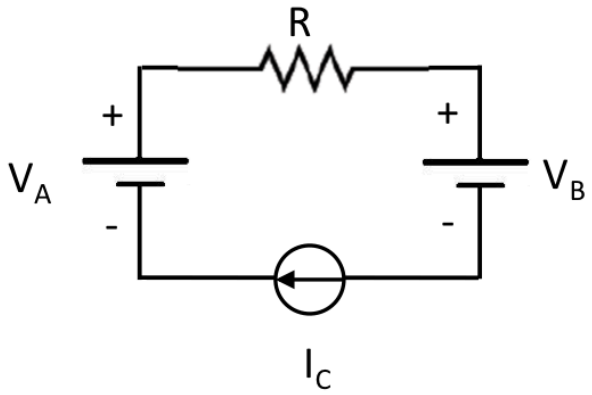
- **a) (2 points)** Which of the resistors dissipates the most power?
- **b)** (**2 points**) Which of the resistors dissipates the least power?
- **c) (2 points)** What is the equivalent resistance seen by the voltage source?
- **d) (2 points)** How much power does the voltage source generate?



Question 2: Current and Voltage Sources; Power; (10 points)

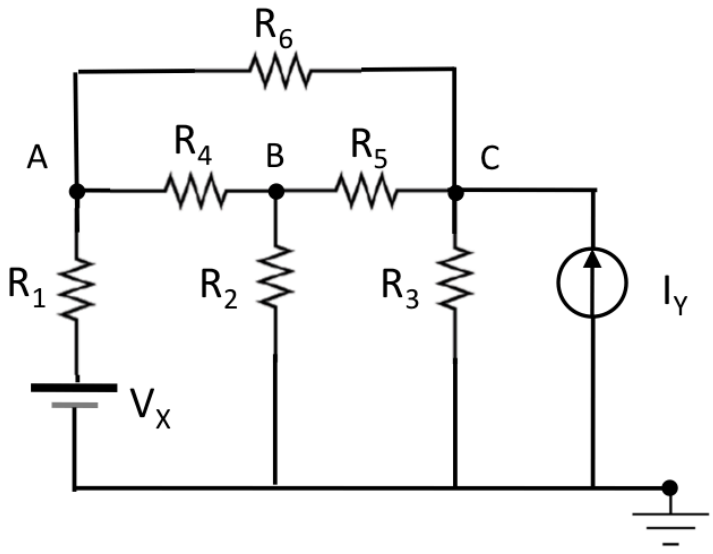
Consider the circuit below with V_A=1V, V_B=5V, I_C=1A, R=5Ω.

a) **(4 points)** Find currents through voltage sources V_A and V_B , as well as voltages on the current source I_C and resistor R.
b) (**3 points**) What is the total power generated in the circuit?
c) **(3 points)** What is the total power dissipated in the circuit?



Question 3: Nodal Voltages (8 points)

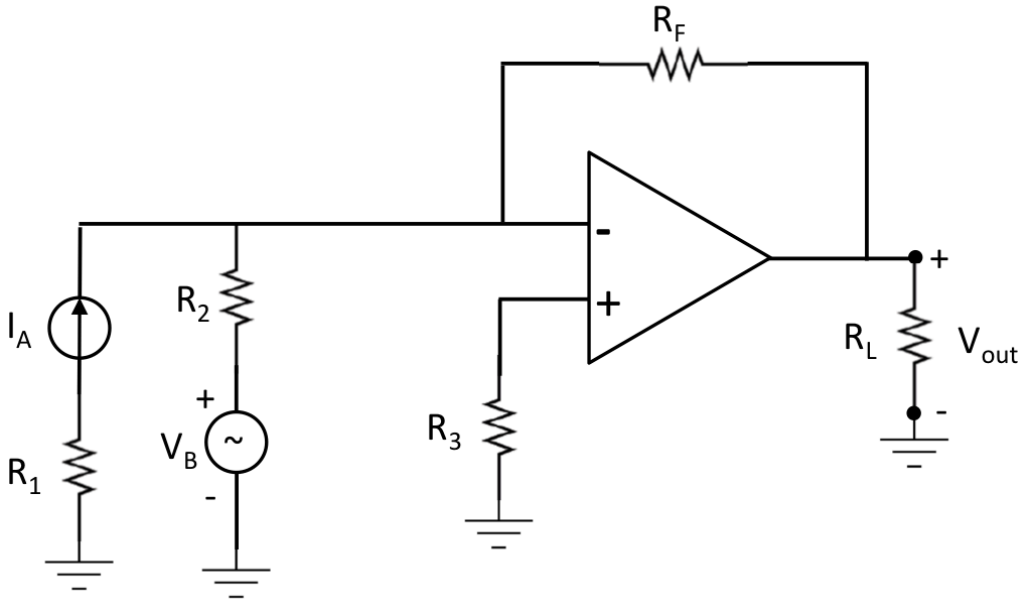
For the circuit shown below write the complete set of nodal voltage equations that can be used to find potentials (voltages) V_A, V_B, V_C with respect to ground. You do not need to solve the system of equations.



Question 4: Op Amp Analysis (8 points)

(Note: this is not hard! Do not panic! In fact, it is similar to problem on PSet 4 that you just turned in ☺).

Consider the Op Amp circuit shown below. Find V_{out} as a function of I_A ,V_B, and resistor values.



Question 5: Useful Circuits with Op Amps (10 points)

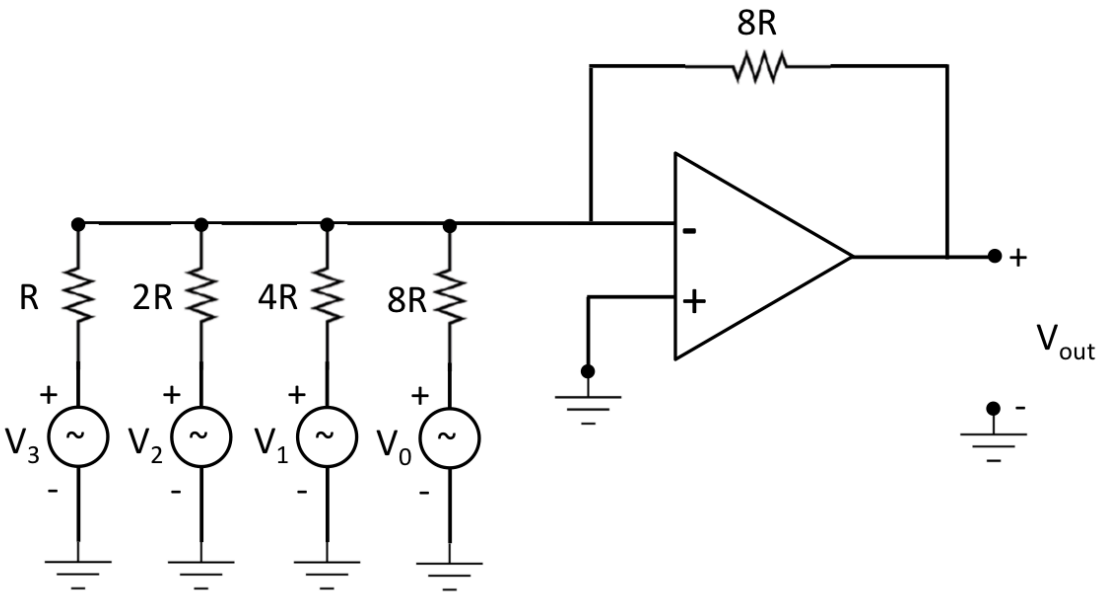
Consider the Op Amp circuit shown below.

a) **(6 points)** Find V_{out} as a function of V_3, V_2, V_1, and V_0 as well as all resistors.
(Hint: Nodal voltages approach is by far the easiest way to solve this circuit!)

b) **(2 points)** What is the output of this circuit for the combination of input voltages shown in the table below:

V_3	V_2	V_1	V_0	V_{out}
0V	0V	0V	0V	
0V	0V	0V	**1V**	
0V	**1V**	**1V**	**1V**	
1V	0V	0V	0V	
1V	**1V**	**1V**	**1V**	

c) **(2 points)** What does this circuit do? *(Hint: You've used another version of this circuit in recent lab ☺)*

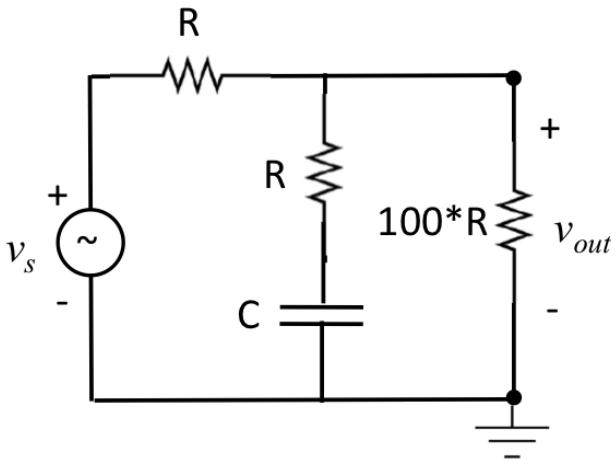


Question 6: Circuits with Capacitors (6 points)

For the circuit shown below, find v_{out} under the following two conditions:

a) **(3 points)** The voltage source v_s is a DC source (battery) with v_s=9 V
(Hint: what does the capacitor look like for a DC signal?)

b) **(3 points)** The voltage source v_s is an AC source of the form $v_s = 9V \cdot \sin(2 \cdot \pi \cdot f \cdot t)$ where *f* is a very high frequency. *(Hint: what does the capacitor look like for a very high frequency signal?)*

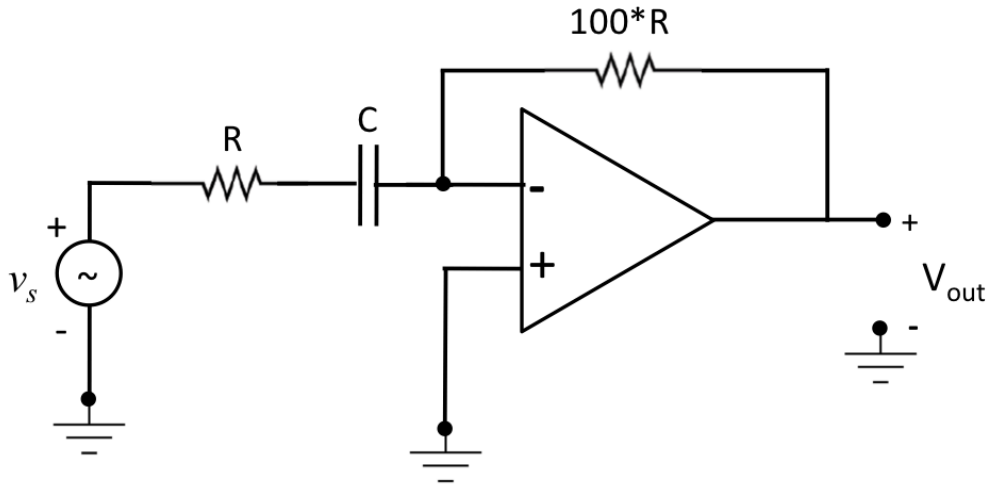


BONUS 1 (EASY): An Op Amp and a Capacitor (6 points)

Find gain G=V_{out}/v_{si}

a) **(3 points**) For a signal having low frequency (DC signal)

b) **(3 points)** For a signal having very high frequency (AC signal with infinitely large frequency)



BONUS 2 - SUPER BONUS: SYNTHESIS QUESTION (15 points)

You were tasked to synthesize (design) a light-show system that operates under following conditions:

- Your input is stereo music which consists of two channels (left and right). You can think of it as two separate voltage sources;
- The left channel signal goes through a **low-pass filter** before it gets amplified by a factor of 10. Such an amplified signal is then ***compared*** to a 5V reference. If the signal is **LARGER** than the reference, a red light emitting diode (hooked up to the output of the comparator) turns on;
- The right channel signal goes through a **high-pass filter** before it gets amplified by a factor of 10. Such an amplified signal is then ***compared*** to a 5V reference. If the signal is **SMALLER** than the reference, a green light emitting diode (hooked up to the output of comparator) turns on;

a) **(10 points)** Draw a schematic of the circuit that performs all tasks mentioned above. You can use Op Amps, resistors, capacitors, batteries, voltage and current sources, and anything else that you may desire. If you use Op Amps, please make sure that you Indicate their biases as well.

b) **(2 points)** If the input signal has an amplitude of 1V, how large are the bias voltages for Op Amps?

c) **(3 points)** You can assume that, when on, each LED has 1V drop across its terminals, and 10mA current flowing through it. Make sure that your circuit takes care of this, so that the LEDs don't burn out (i.e. draw too much current)!