ENGR-4300

Electronic Instrumentation

Quiz 2

Spring 2012

Name ________________________

Section ___

Question I (18 points) ___________

Question II (16 points) ___________

Question III (15 points) ___________

Question IV (18 points) ___________

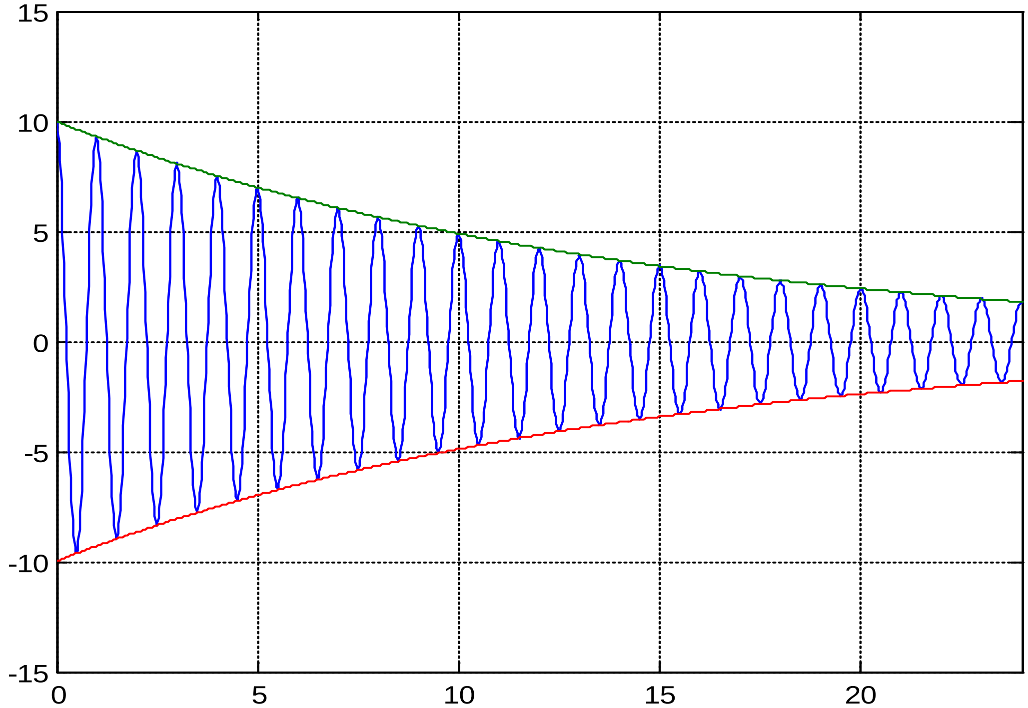
Question V (16 points) ___________

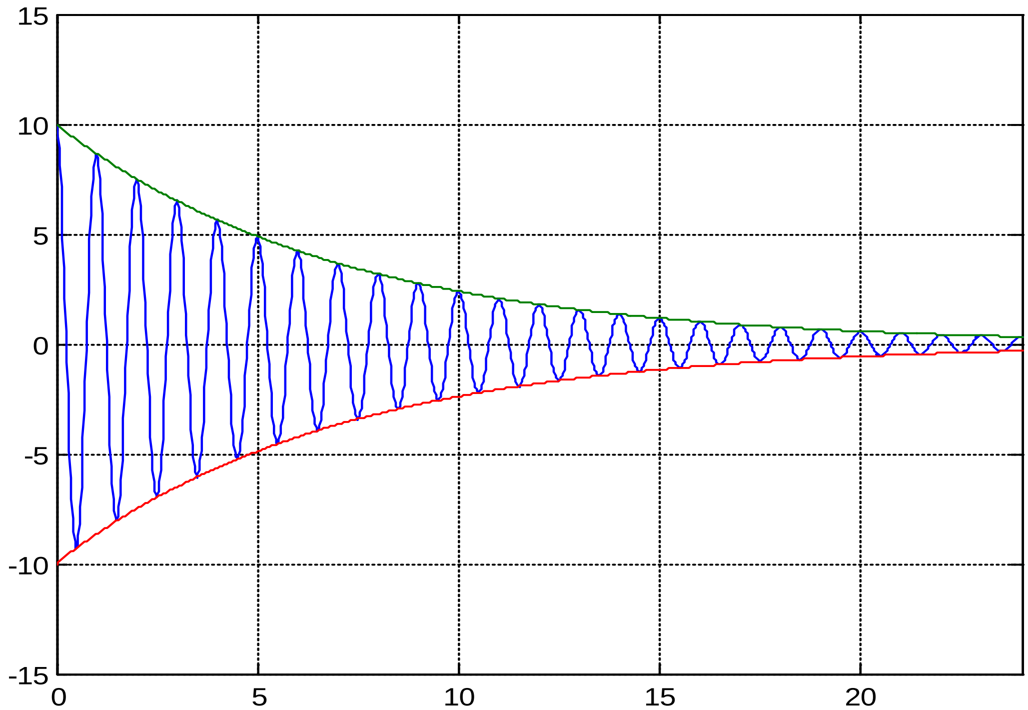
Question VI (17 points) ___________

Total (100 points) ______________

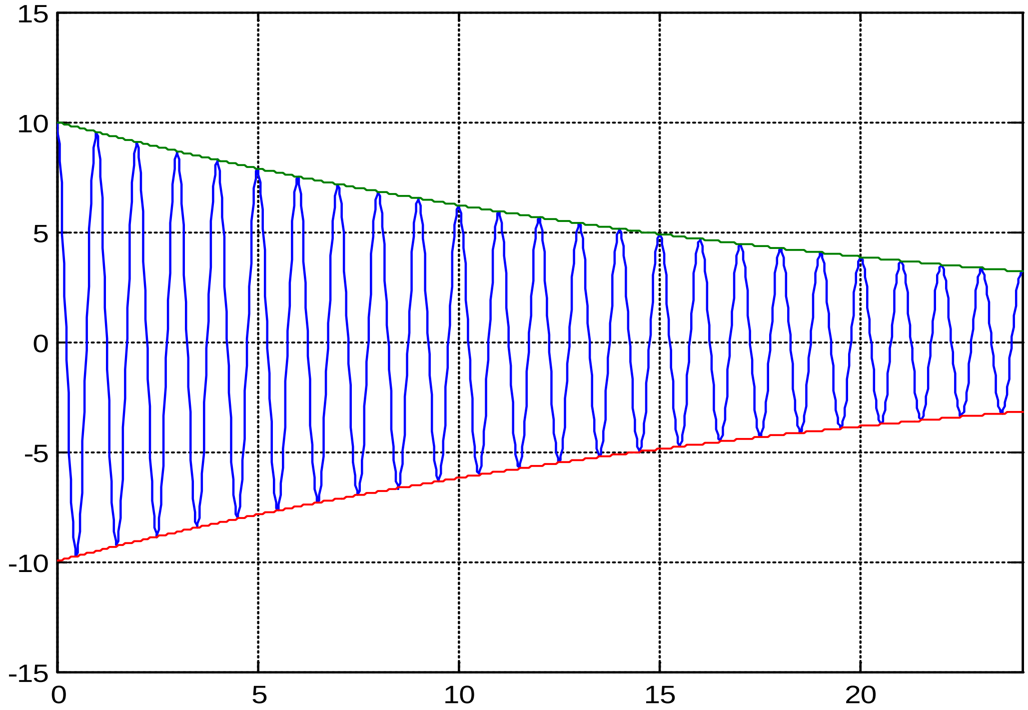
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification.

Question I – Damped Sinusoids (18 points) We have a very large damped oscillator that moves very slowly. Depending on the damping that is applied to the system, its oscillation decays in one of the three ways shown below. The horizontal units are hours. The vertical units are arbitrary.





Question I – Damped Sinusoids (continued)



1) (2pt) What is the frequency of the oscillation in these plots (it is the same in all three)? Give your answer in both cycles per day and Hertz. (Use at least 2 significant figures)

24 cycles per day or 24 cycles in (60*60*24)sec or $2.78\text{x}10^{-4}$Hz

$\omega = 2\pi f = 0.00175$

2) (6pt) Determine the damping constant for each plot. (Use at least 3 significant figures)

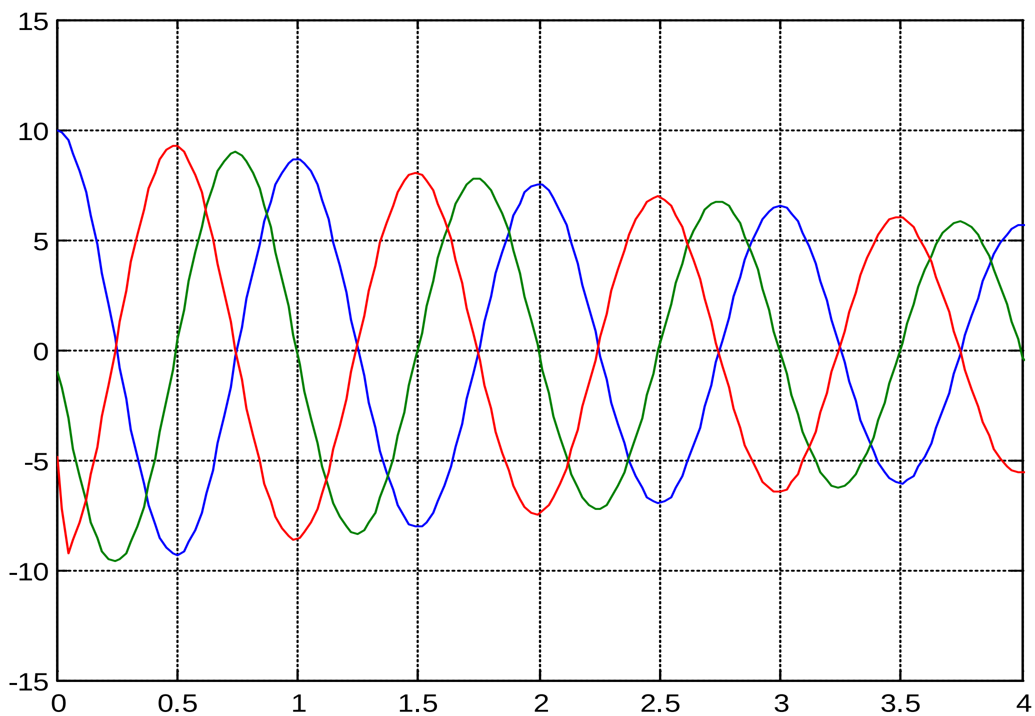
$$V = V_o e^{-t/\tau} = V_o e^{-\alpha t} \qquad \ln\frac{V}{V_o} = -\alpha t \qquad \frac{1}{t}\ln\frac{V_o}{V} = \alpha$$

5 Hr	18000 sec	$3.85\text{x}10^{-5}$ s^{-1}	.138 hr^{-1}	τ = 7 hr
10 Hr	36000 sec	$1.93\text{x}10^{-5}$ s^{-1}	.069 hr^{-1}	τ = 14 hr
15 Hr	54000 sec	$1.28\text{x}10^{-5}$ s^{-1}	.046 hr^{-1}	τ = 21 hr

3) (4pt) Write the mathematical expression for the function plotted in any one of the figures.

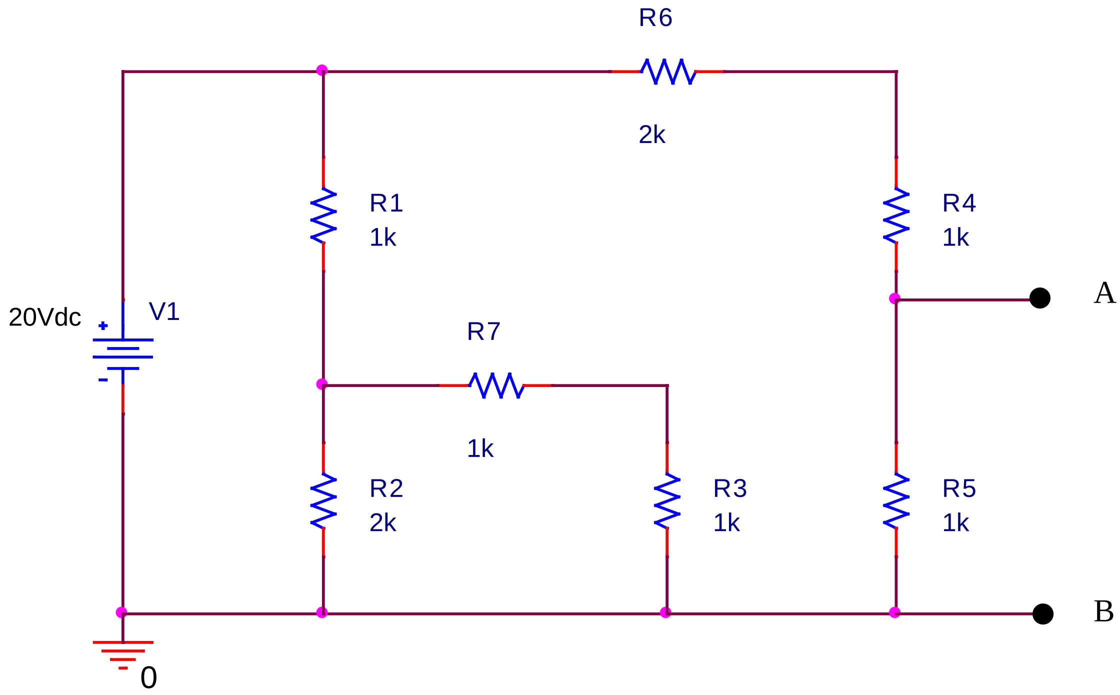
$V(t) = 10e^{-\alpha t}\cos(\omega t)$ for all three. Use the alphas and taus from above.

4) (6pt) Shown below is the function from one of the figures above plotted only for the first 4 hours rather than all day. Also shown are the first and second derivatives of this function. The derivatives have been scaled so that all three functions can be seen on the same plot. That is, the first and second derivatives have been divided by one of the characteristic parameters of the function. Identify which function is the first derivative and which function is the second derivative. Also, what number has been divided into the derivatives so the three functions scale the same? Blue, green, red are function, 1st derivative, 2nd derivative



This could also have been used to find more info on the plots above. The frequency is especially clear here. The derivative function changes cosine to –sine to –cosine. This moves the plots to the left as shown. Since each derivative multiplies the function by ω, we have to divide by this for the first derivative and by its square for the second, to scale the same way.

Question II – Thevenin Equivalents (16 points)



1) (5pt) Find the Thevenin equivalent voltage with respect to A and B for the circuit shown above)

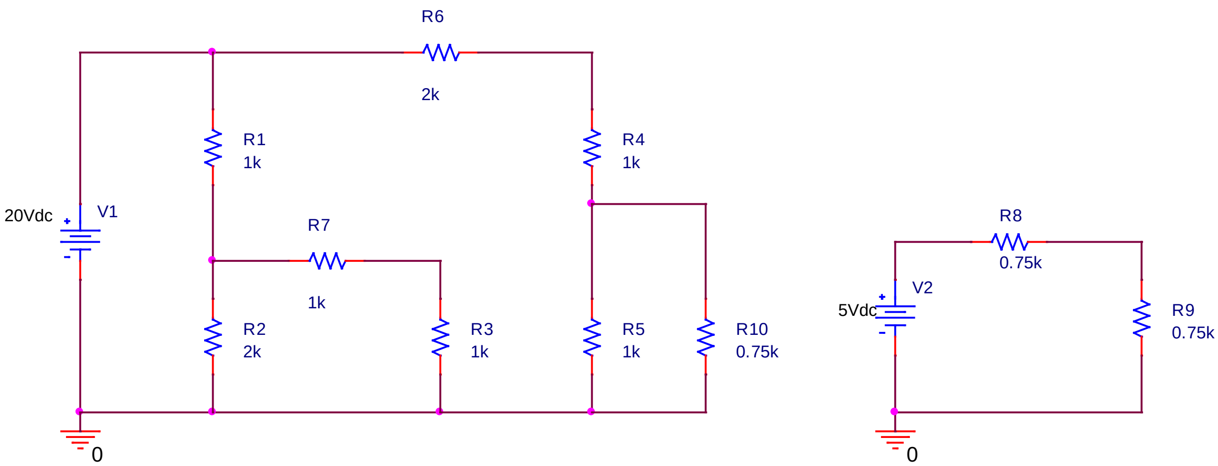
Only R6, R4 and R5 matter because they connect to the source. The voltage across AB is ¼ of the source or 5V.

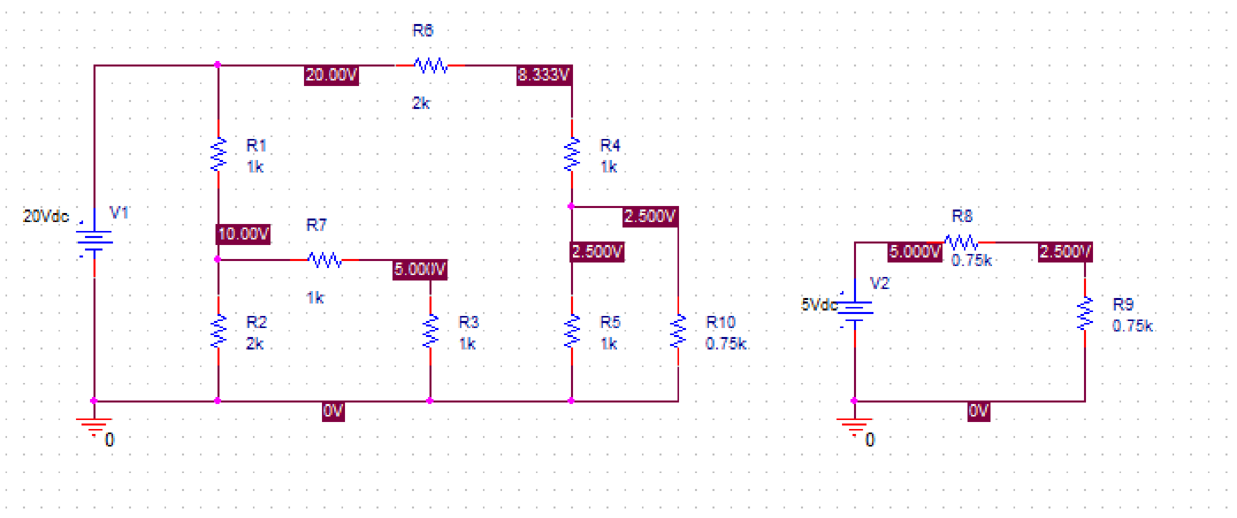
2) (5pt) Find the Thevenin equivalent resistance with respect to A and B for the circuit shown above.

The resistance is also pretty easy to calculate. Shorting the voltage source shorts out the same components that had no affect on the voltage. Thus, the resistance is 3k in parallel with 1k or 0.75kΩ.

Question II – Thevenin Equivalents (continued)

3) (4pt) Draw the Thevenin equivalent circuit with a load resistor RL of 750Ω between points A and B

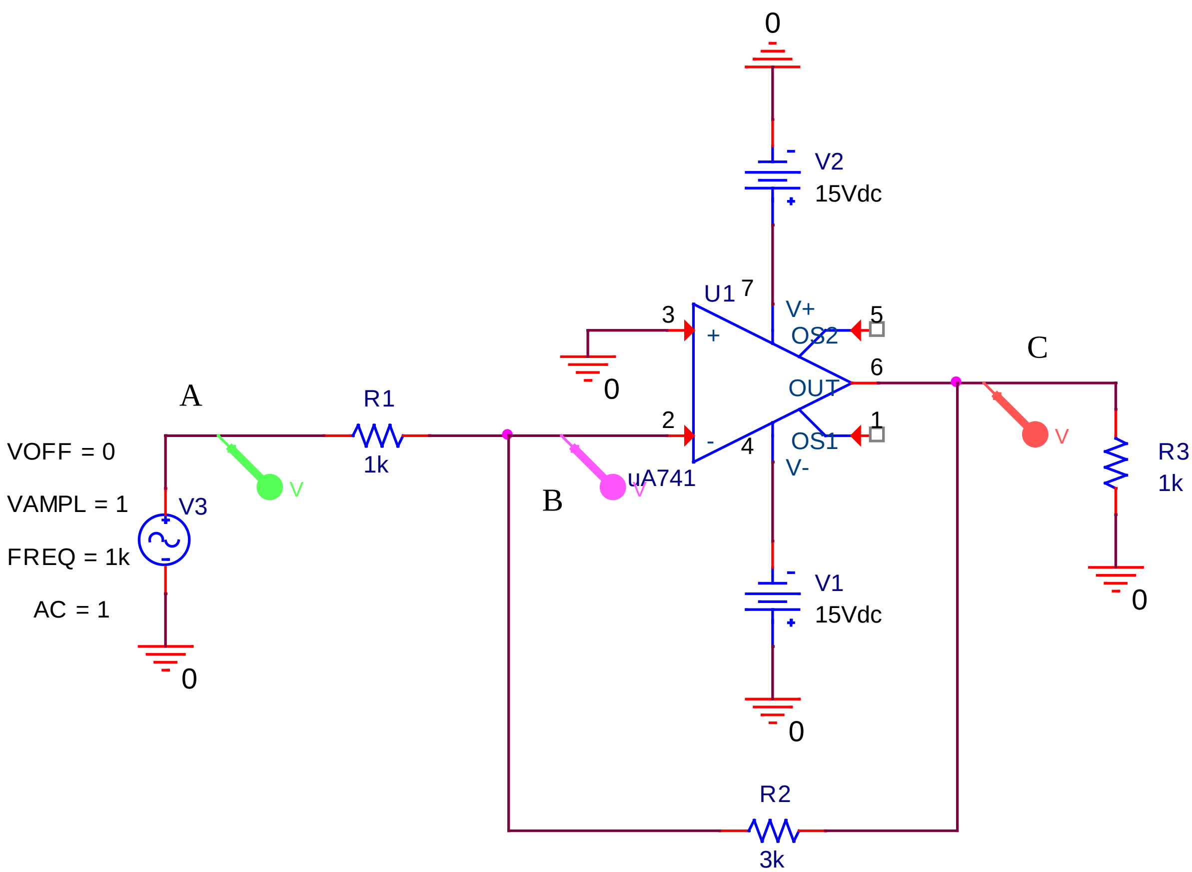




4) (2pt) What is the voltage across R_L?

It will be half of 5V or 2.5V, as is also seen in the PSpice simulation.

Question III – Op-Amps (15 points)



Assume the following components in the above circuit:

V3: V_{off}=0, V_{ampl}=1V, f=1kHz; R1=R3=1kΩ, R2=2kΩ

1) (1pt) The circuit above is an amplifier you've seen. What type of amplifier is it?

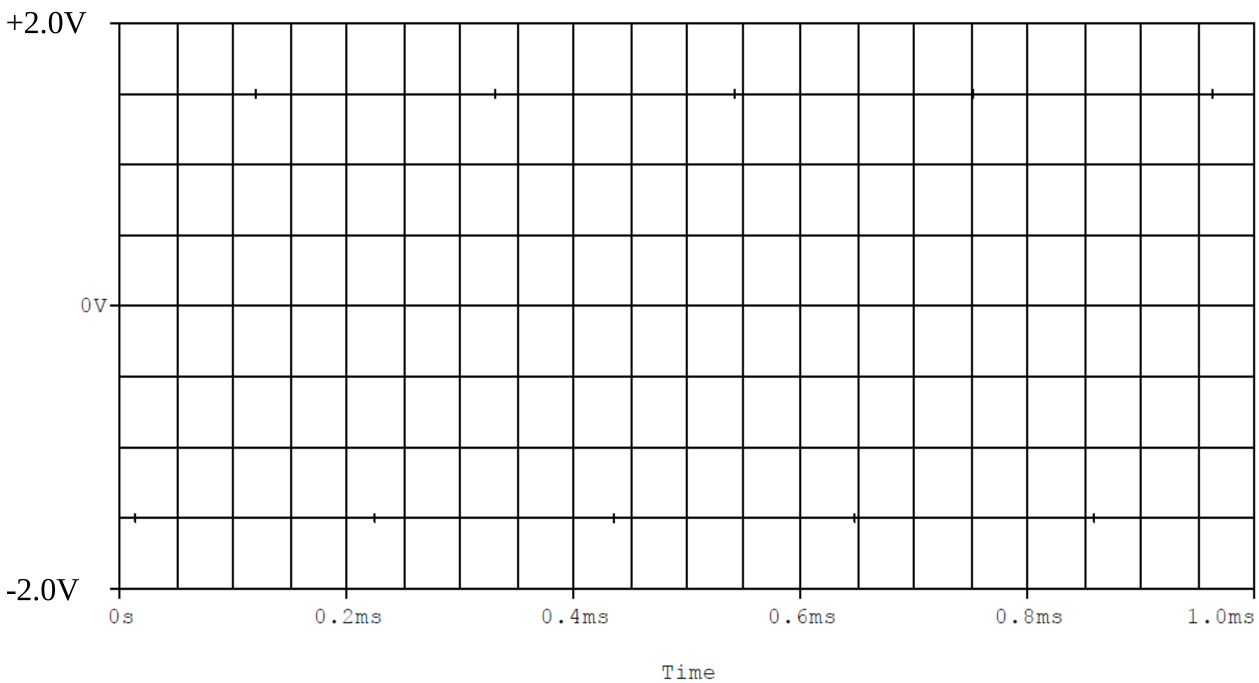
Inverting op-amp

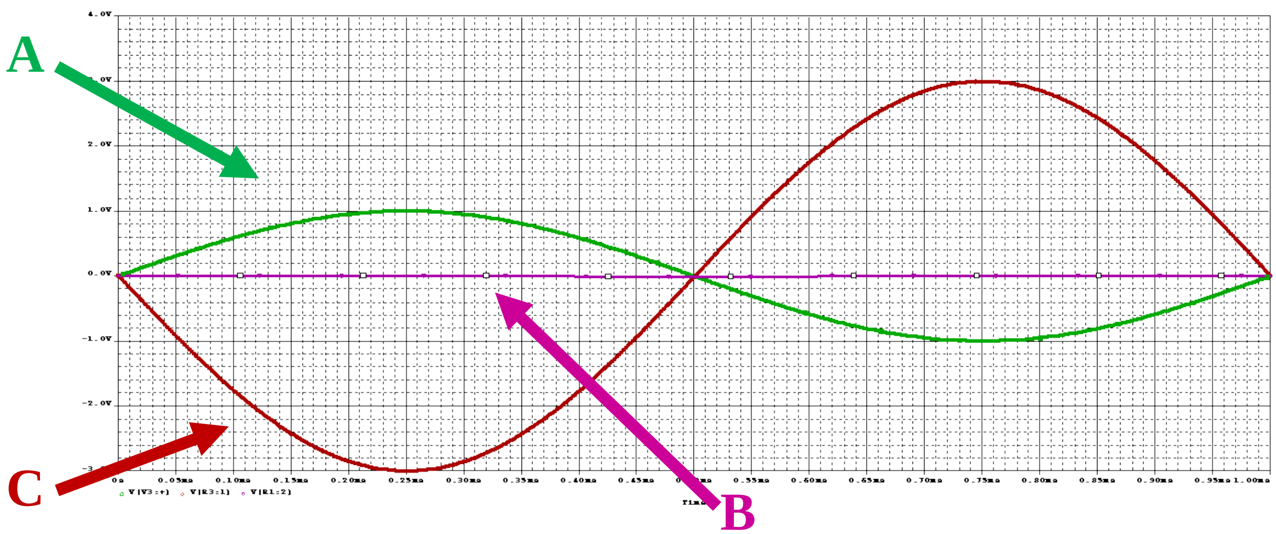
2) (3pt) Write the general equation for the output C (Vc) in terms of the input voltage V3. (Do not enter specific voltage values but use the values of the resistors)

$$\frac{V_C}{V_A} = \frac{-R_2}{R_1} = -3$$

Question III – Op-Amps (continued)

3) (9pt) Carefully, sketch and label one cycle of the input voltage V3 (point A), the output voltage at C (Vc), and the voltage at point B (V_B) on the plot below. Explain your answers (show your work). Gain is -3, the neg input of the op-amp (B) is grounded because the voltage from the + to the – input is zero.

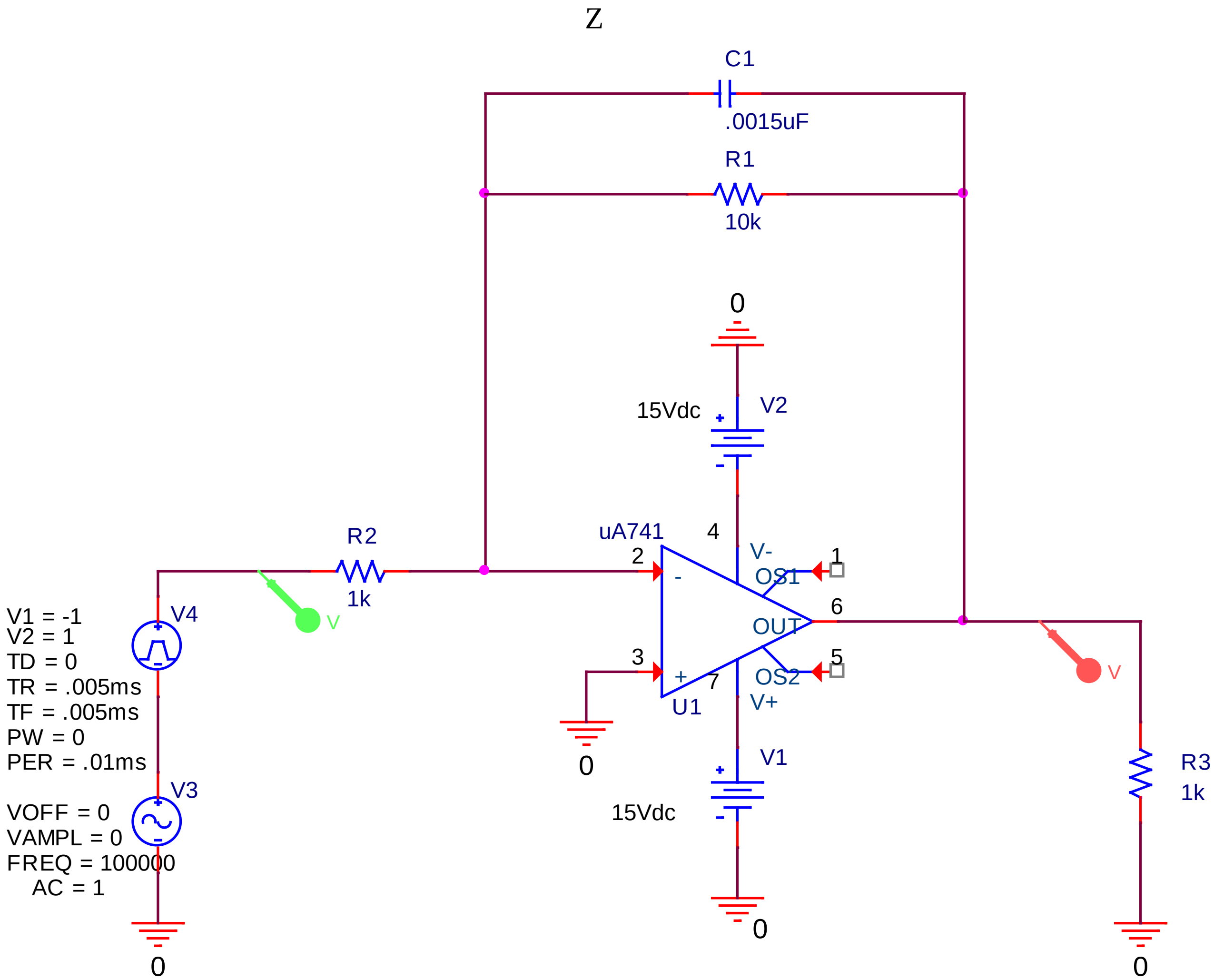




4) (2pt) Approximately, how large can the input voltage at A be if the amplifier is to work correctly? Explain your answer.

About 5V because the gain of 3 puts the output at 15 which is the limit of the op-amp swing with 15V supplies. It will actually be a bit less, around 13.5V, but the concept is what is important here.

Question IV – Op-Amp Applications (18 points) In the circuit shown below, there are two sources in series. This was done for convenience. Only one is used at a time. The case shown, for example, only uses the top source (V4).



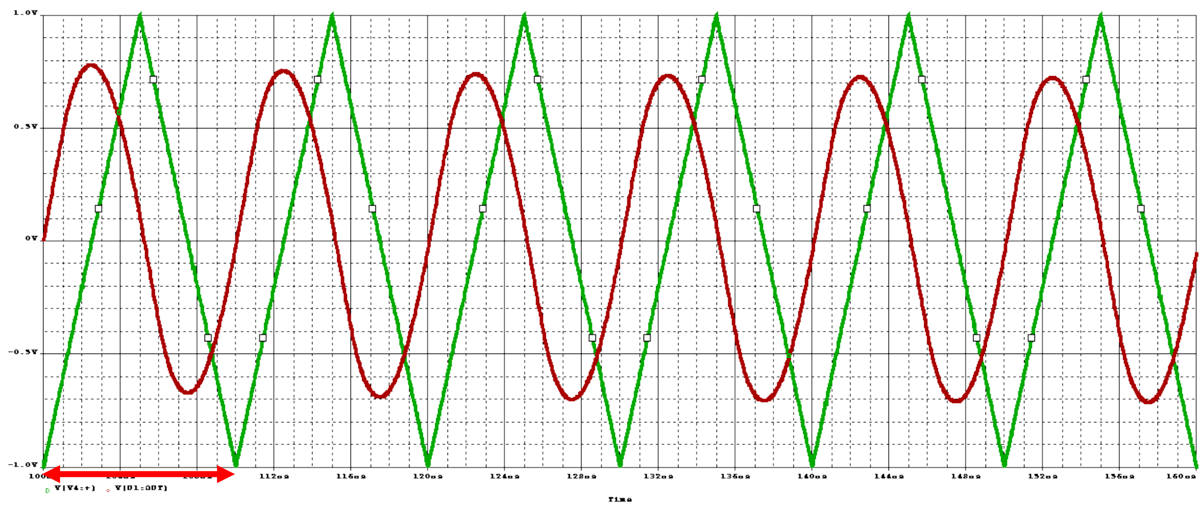
1) (2pt) What function is this circuit designed to perform at low frequencies?

Inverting op-amp with gain -10 (the specific gain is not required for this answer)

2) (2pt) What function is this circuit designed to perform at high frequencies?

Integrator with scaling factor $1/RC=1/(1000*0.0015*10^{-6})$ (the scaling factor is not required for this answer.)

3) (4pt) For the source conditions shown above, the input and output voltages produced are shown below. Identify which is the input and which is the output voltage. Also, label the scales on the plot. The lettering is likely too small to read, but there is enough information given about the voltage source so that you can label the plot.



From the source, the period is 0.01ms, which is shown by the arrow above. The positive amplitude is 1V and the negative is -1V so the vertical scale goes from -1V to +1V. The triangular wave produces the parabolic shapes, so that can also be used to identify the input and output. The area under the triangular wave (linearly increasing or decreasing with time) is

$$\frac{\left(\dfrac{t^2}{.0025ms}\right)}{2RC} = \frac{(2.5x10^{-6})}{2(1000)(0.0015)(10^{-6})} = \frac{2.5}{3} = .833$$

which is approximately the quadratic increase over the rise time from 0 to 2.5μs so the plot looks consistent. Because the impedance of the capacitor is about 10% of the resistor, there will be a slight decrease in the overall output level.

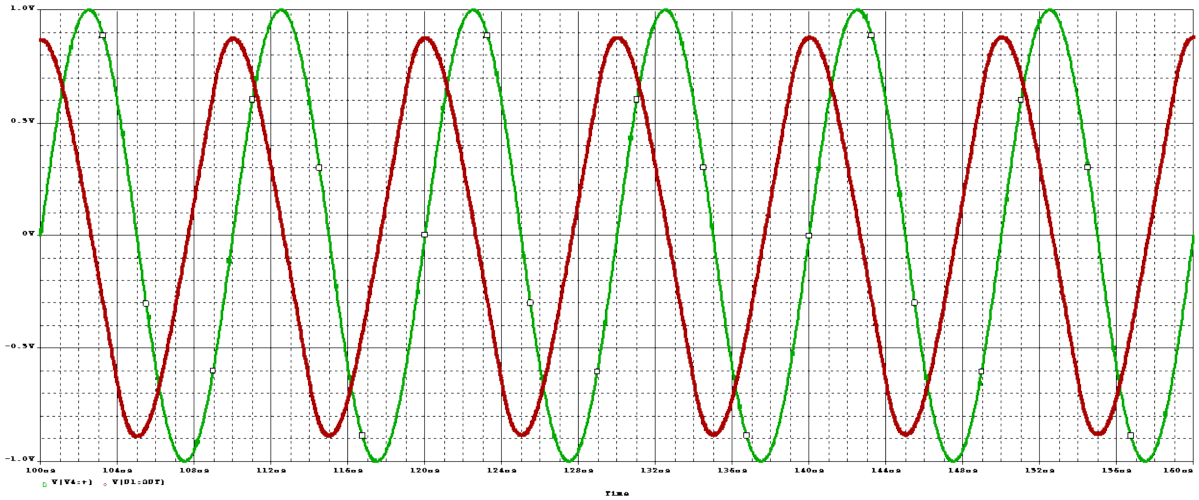
4) (4pt) Determine whether the circuit is operating at a high frequency or a low frequency. This can be done more than one way. Any reasonable answer will be accepted, but you need to explain your answers. Some kind of calculation is best.

The calculation above showing that the circuit is integrating is a good explanation for high frequency operation. Also, one can argue that the impedance of the capacitor is small enough to dominate the operation of the circuit, which requires high frequency. To see this, compare

$$\frac{1}{\omega C} = \frac{1}{2\pi 10^5(0.0015x10^{-6})} \approx 100$$

which is a lot smaller than 10000, the resistor value, which also supports the designation of high frequency. Note that this calc is for the feedback impedances, not the impedances of the integrator.

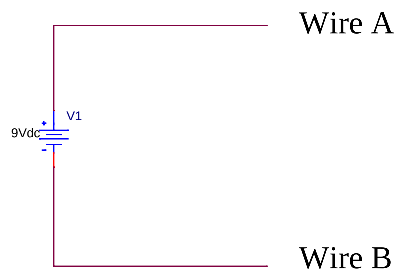
5) (6pt) The top source was turned off and the bottom source turned on. The measured input and output voltages are shown below. The scales are the same as for the first plot. Again, identify which plot is the input and which is the output. Also indicated what the amplitude of the input voltage is since it is not specified on the circuit diagram.



The amplitude of the input is 1V because the green curve reaches the top of the plot. The output should also be about equal to the input in magnitude but behind by 90 degrees in phase because we get the negative of the cosine from the sine. We did not ask for a very deep explanation here, so any reasonable explanation will be accepted.

Question V – Troubleshooting, Debugging, Data Understanding (16 points)

1. Power Supplies (3pts) Circle all correct answers.

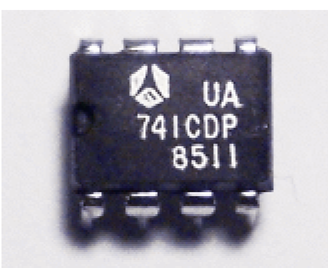


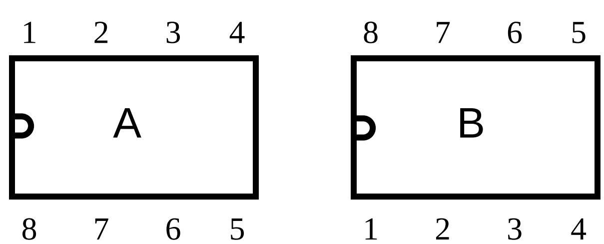
For a 9V battery connector (shown above) and the PSpice circuit diagram (above right)

- Wire A represents the red wire and Wire B represents the black wire
- Wire B represents the red wire and Wire A represents the black wire
- Wire A is connected to the circuit ground to provide +9V at some other point in a circuit
- Wire B is connected to the circuit ground to provide +9V at some other point in a circuit
- Wire A is connected to the circuit ground to provide -9V at some other point in a circuit
- Wire B is connected to the circuit ground to provide -9V at some other point in a circuit

2. 741 Op-Amp (4pts) Circle all correct answers.

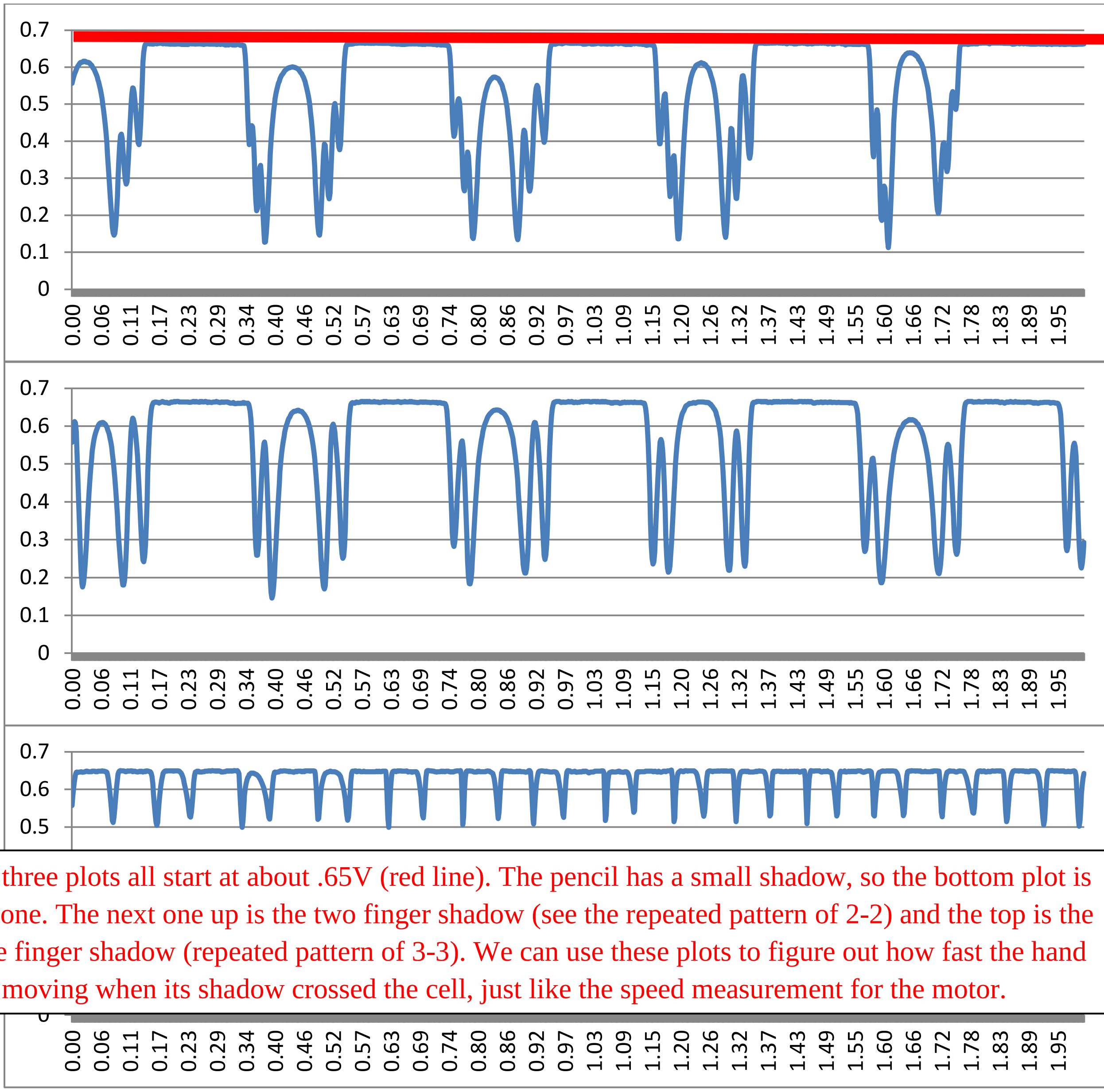
Shown below is a photo of a 741 op-amp. The small dimple is at the left.





- The pins on the op-amp are numbered as shown in the figure labeled A
- The pins on the op-amp are numbered as shown in the figure labeled B
- The 741 requires a positive DC voltage (e.g. +9V) on pin 4 and a negative DC voltage (e.g. -9V) on pin 7 to operate
- The 741 requires a negative DC voltage (e.g. -9V) on pin 4 and a positive DC voltage (e.g. +9V) on pin 7 to operate
- The output signal is found on pin 6
- The output signal is found on pin 2
- The output signal is found on pin 3
- The input signal is connected to either pin 2 or pin 3

3. (9pts) Data Understanding. The three figures below show a voltage signal produced by a small solar cell. Without any obstacles blocking the light on the cell, it produces a reasonably constant voltage of about 0.65V for the light conditions in the room. As an obstacle is caused to move past the cell, it will be partially shadowed, which results in a lower measured voltage. *Note – this question is inspired by the Beakman's motor project.*

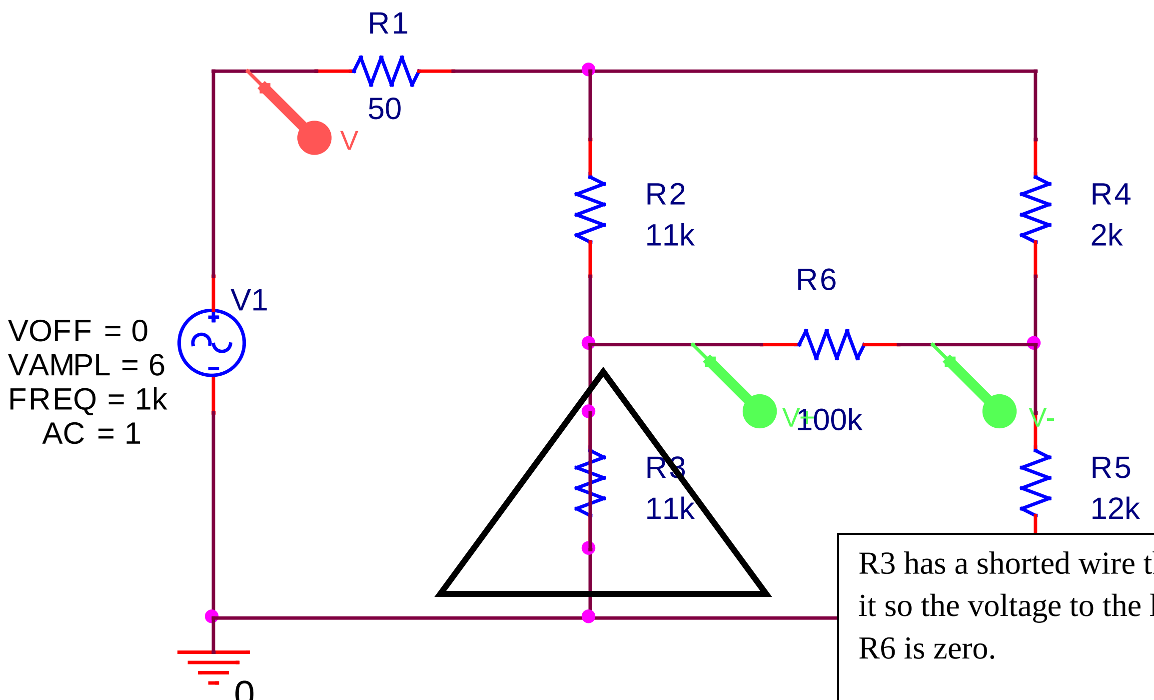


The three plots all start at about .65V (red line). The pencil has a small shadow, so the bottom plot is that one. The next one up is the two finger shadow (see the repeated pattern of 2-2) and the top is the three finger shadow (repeated pattern of 3-3). We can use these plots to figure out how fast the hand was moving when its shadow crossed the cell, just like the speed measurement for the motor.

The data shown are from three experiments. In one, a pencil is caused to move back and forth across the cell. In the second, a hand with two fingers extended moves back and forth. In the third, the hand has three fingers extended. In the latter two cases, only the fingers produce shadows. Identify which figure is for each experiment. Explain your answer and also explain why you think the motor project was the inspiration for this question.

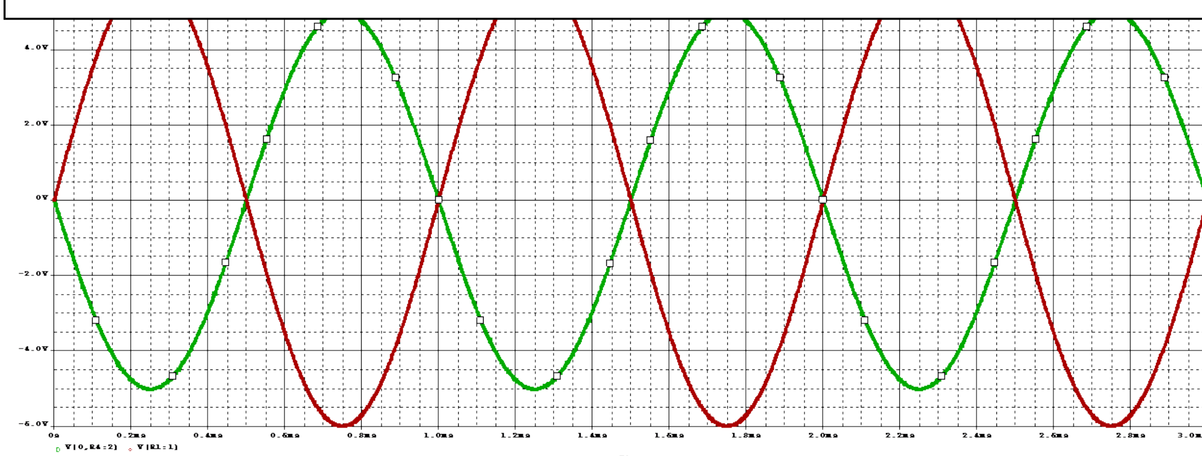
Question VI – Misc (17 points)

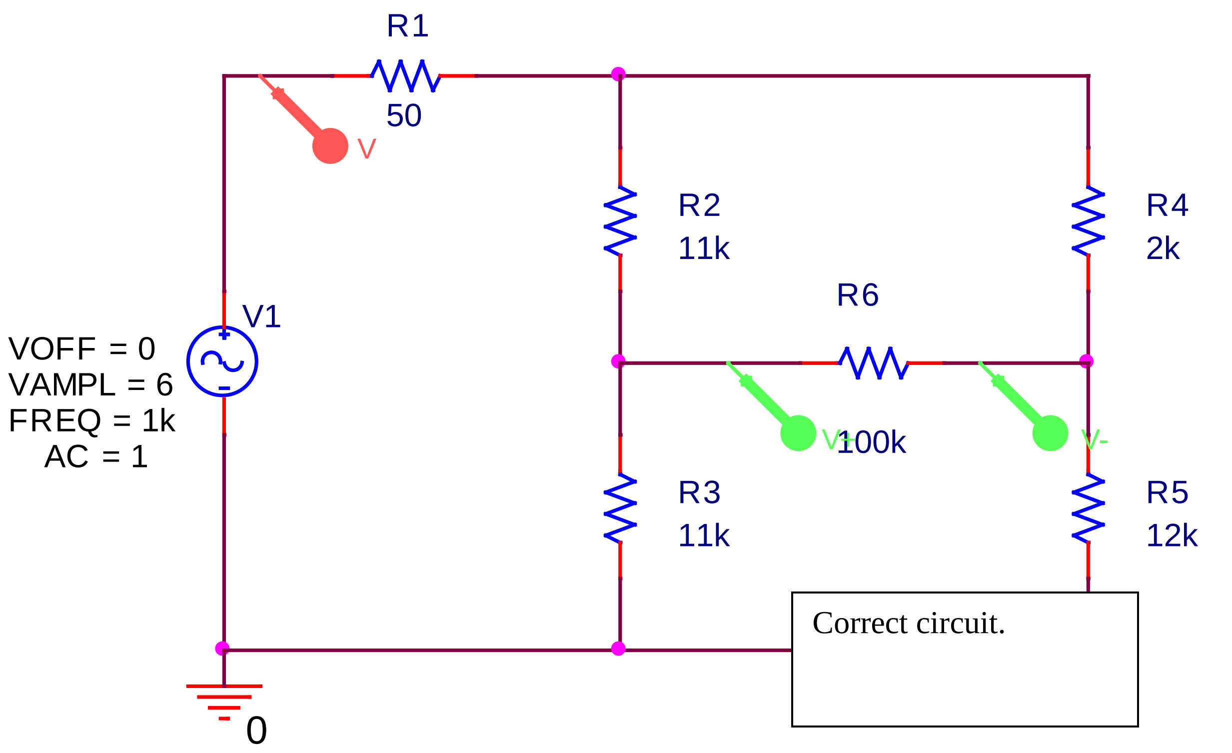
1. (12pts) The operation of a bridge circuit was simulated using PSpice. The first time the circuit was set up it had an error. The second time it was done correctly. Both circuits and results from both circuits are shown below (in no special order). Identify which is the correct circuit, identify the error in the incorrect circuit, identify which result goes with each of the two circuits (calculate the output for the given input for both cases to justify your answer). Note that each data plot shows the input voltage and the differential voltage measured across R6 (the load resistor in this case).

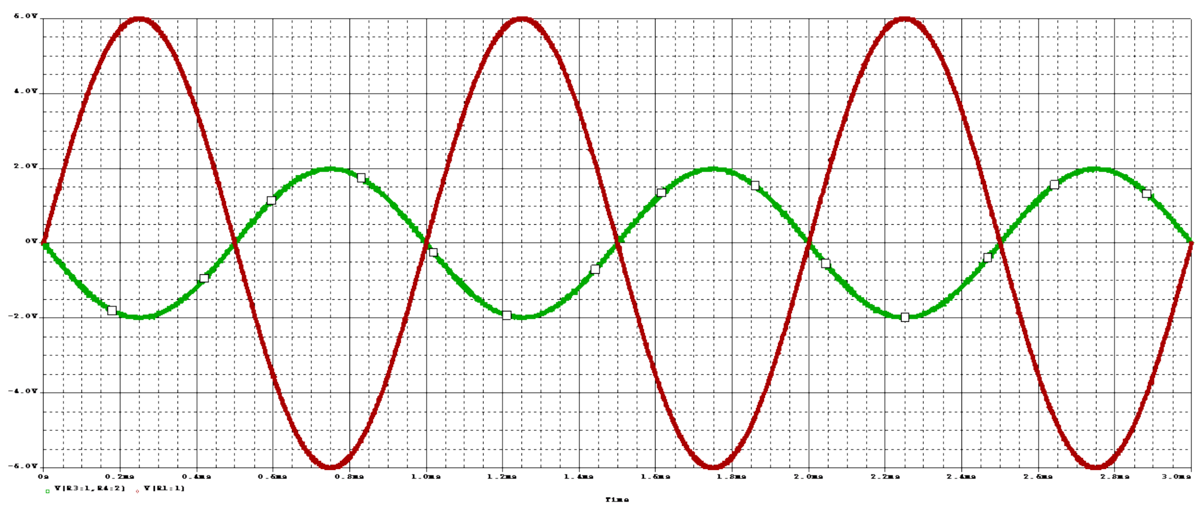


R3 has a shorted wire through it so the voltage to the left of R6 is zero.

$Vleft = 0V \quad Vleft = 5.1V$ (see calc below). The voltage across the load should be 5.1V which it is (green curve). The red curve is the source voltage (6V amplitude).







$Vleft = 3V$, $Vright = \left(\frac{12}{14}\right)6 = 5.1V$ so the difference is 2.1V, which is the amplitude of the green curve. In this calculation, we have made the assumption that the voltage across the 50 Ohm resistor is negligible, which is definitely close enough to give us the estimate we need to identify the curves. The red curve has an amplitude of 6Vso it is the source voltage.

2. (5pts) Besides the cantilever beam we have been studying extensively for the last couple of weeks, give 5 examples of physical systems that can be characterized as damped harmonic oscillators. *Hint – we have worked with at least one other system in this course. The rest of your answers should come from everyday life or other courses.*
   a. Example: RLC circuit (the other system we have considered)
   b. Example: Other cantilever beams like diving boards, arrows once they hit their target, stair railings ….
   c. Example: Pendulum
   d. Example: Spring mass system
   e. Example: Tall structures like the CN tower in Toronto, any tall building. (These are also cantilever beams)

Musical instruments: Strings on stringed instruments, drum heads, xylophones,