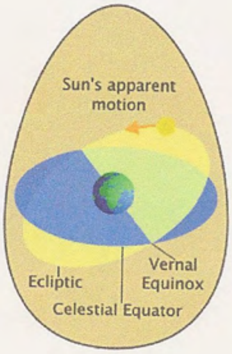


ENGR-2300

Electronic Instrumentation

Quiz 2

Spring 2013

Name Solution

Section ___

Question I (25 points) __________

Question II (25 points) __________

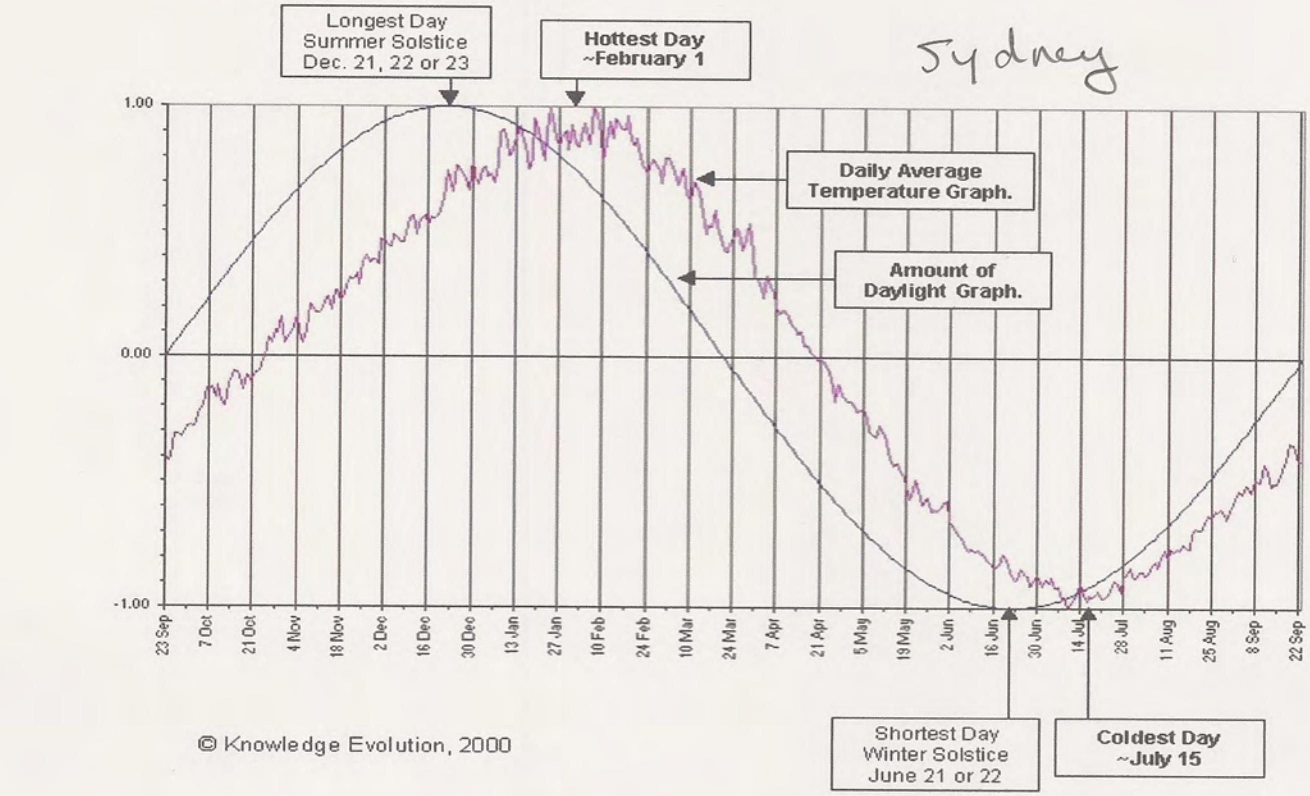
Question III (25 points) __________

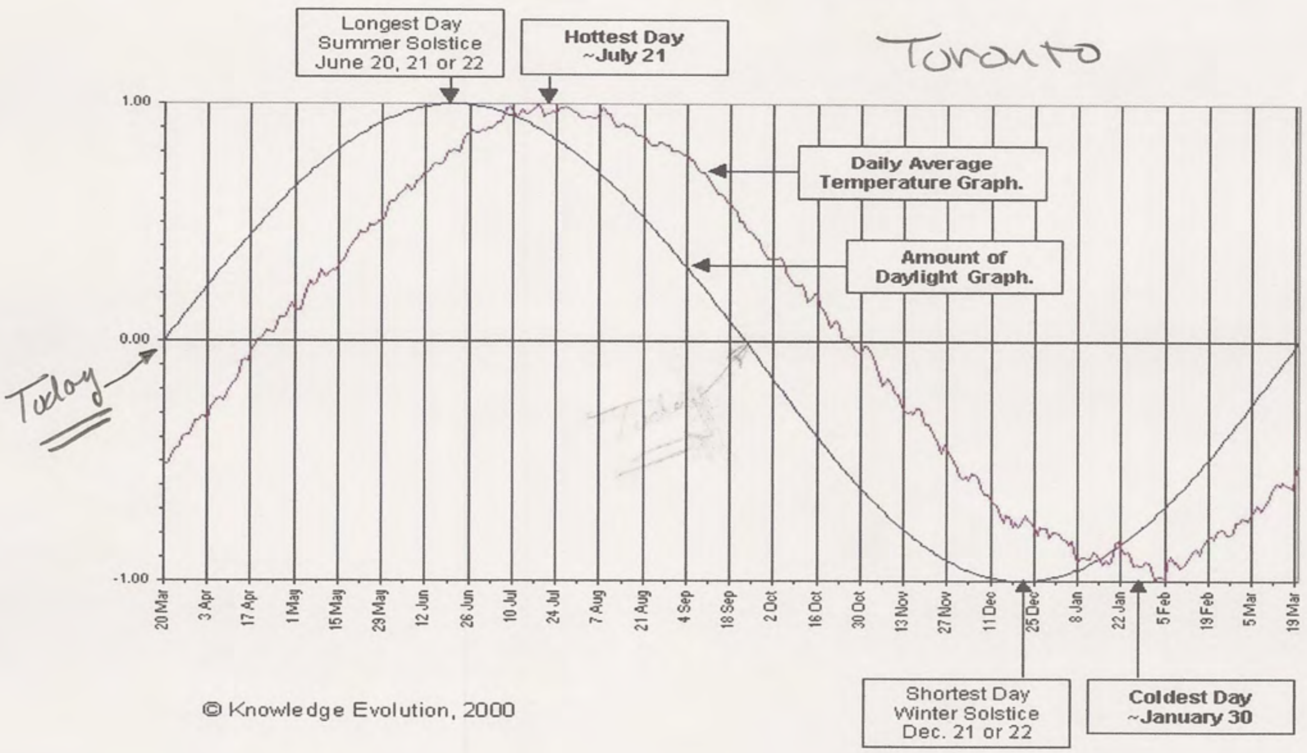
Question IV (25 points) __________

Total (100 points) __________

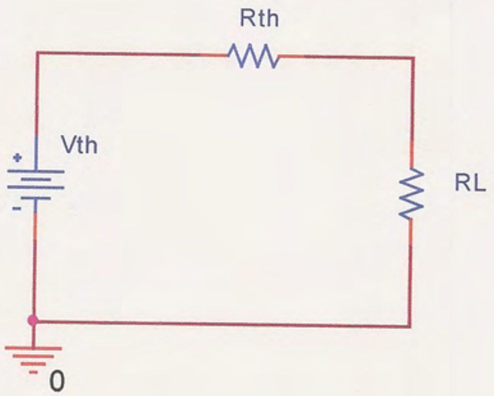
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES <u>AND UNITS</u>. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

20 March – Vernal Equinox





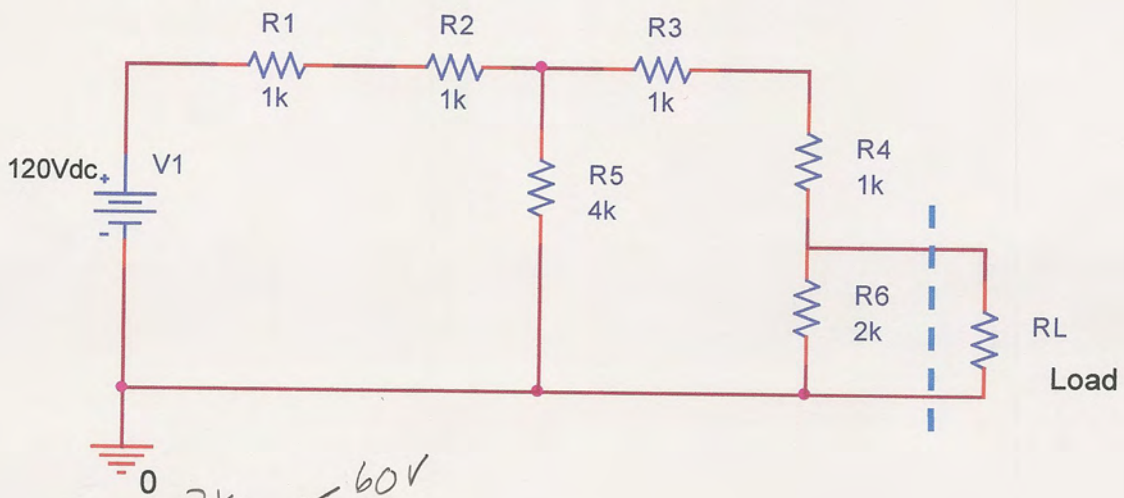
I. Thevenin Equivalent Voltage Source

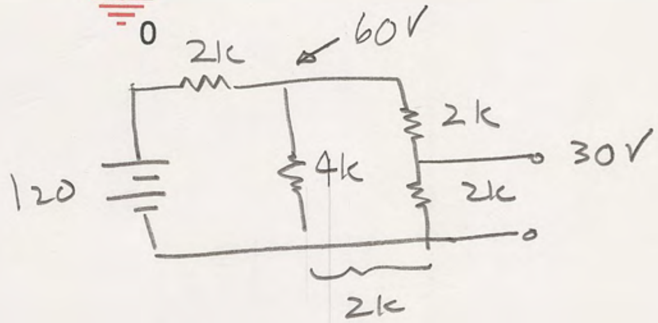


The Thevenin equivalent circuit consists of a voltage source in series with a resistor, which provides a very simple replacement for much more complex circuits. If we have this simple source, analyzing changing loads becomes quite easy.

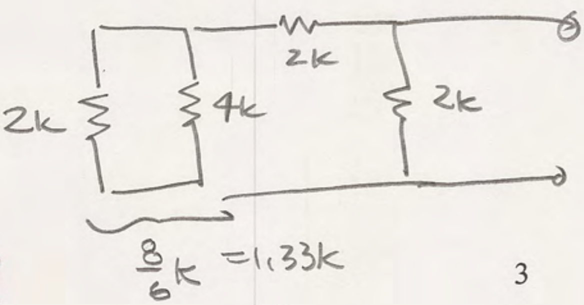
In this problem, you are to find the Thevenin voltage and resistance for three circuits. The load is to the right of the dashed line in the first two circuits.

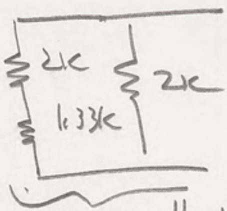
Circuit 1: (This is the simplest of the three problems.) {10 pts}





$\Rightarrow V_{TH} = 30V$



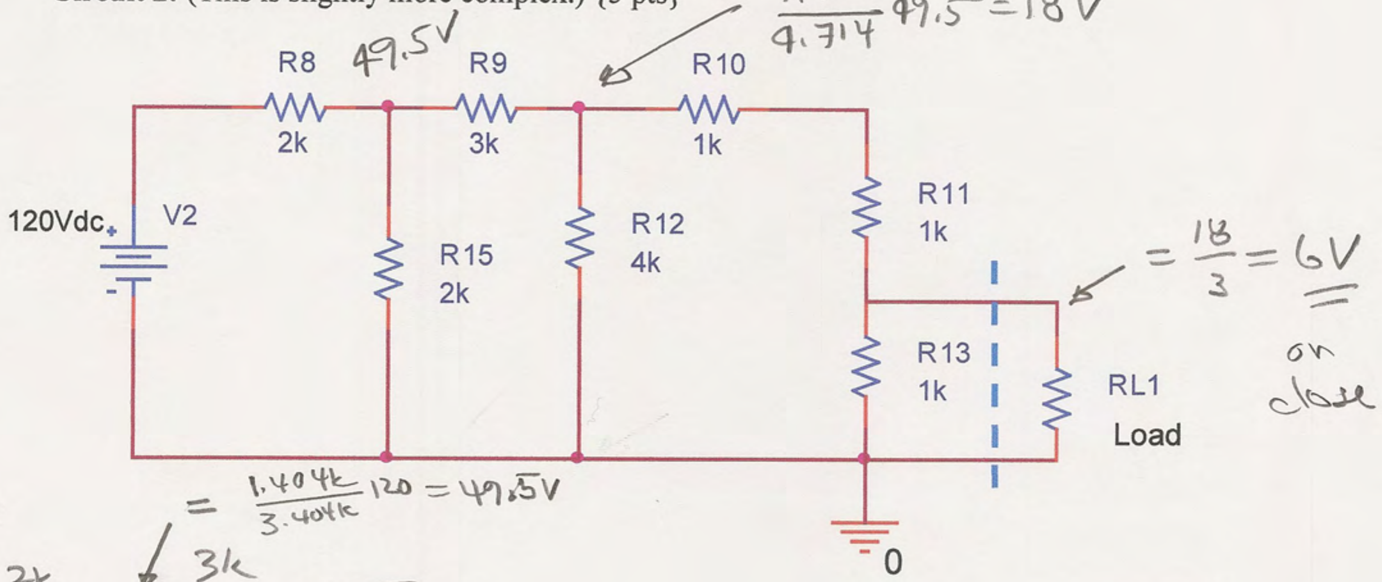


$3.33k \| 2k = \frac{6.66k}{5.33} = 1.25k$

$R_{TH} = 1.25k$

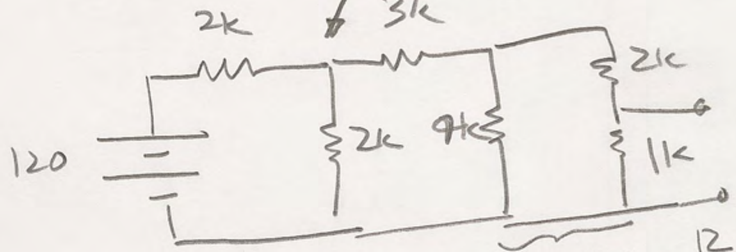
Circuit 2: (This is slightly more complex.) {5 pts}

$\frac{1.714}{4.714} 49.5 = 18\,V$



V_{TH}

$= \frac{1.404k}{3.404k} 120 = 49.5V$

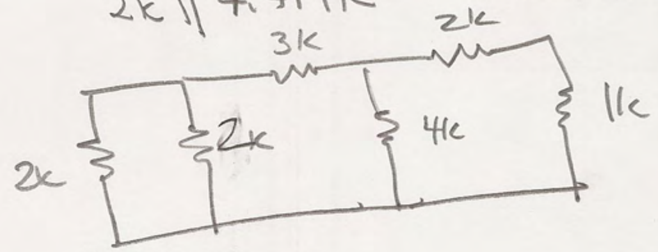


$4k \| 3k = \frac{12}{7}k = 1.714k$

$2k \| 4.714k = 1.404k$

$V_{TH} = 6V$

R_{TH}



$R_{TH} = 800$

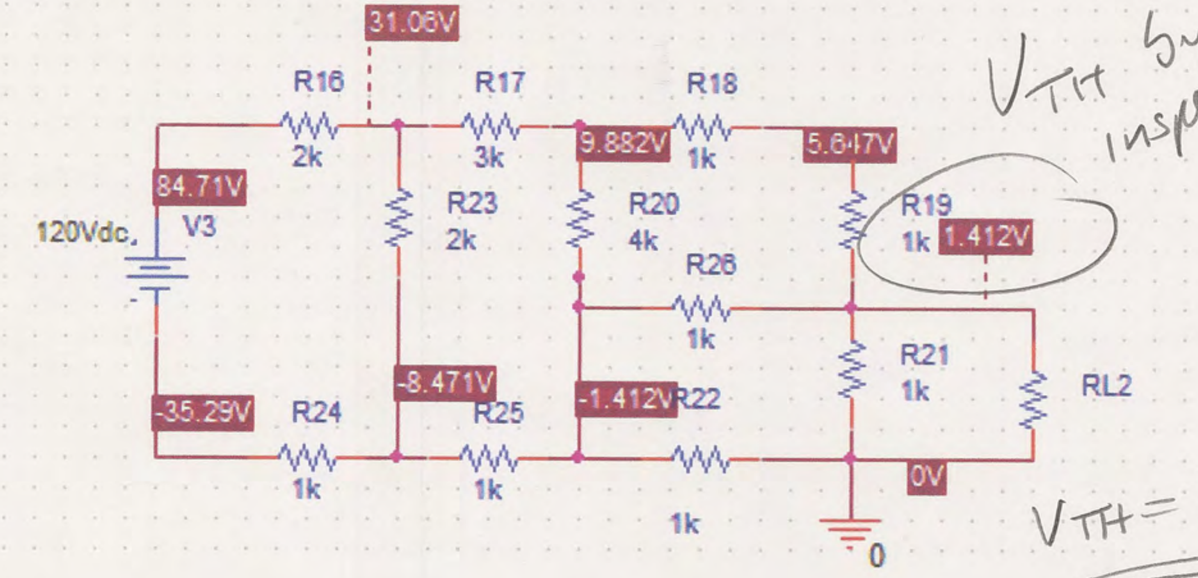
$4k \| 4k = 2k$

$4k \| 1k = \frac{4}{5}k = 800\Omega$

Circuit 3:

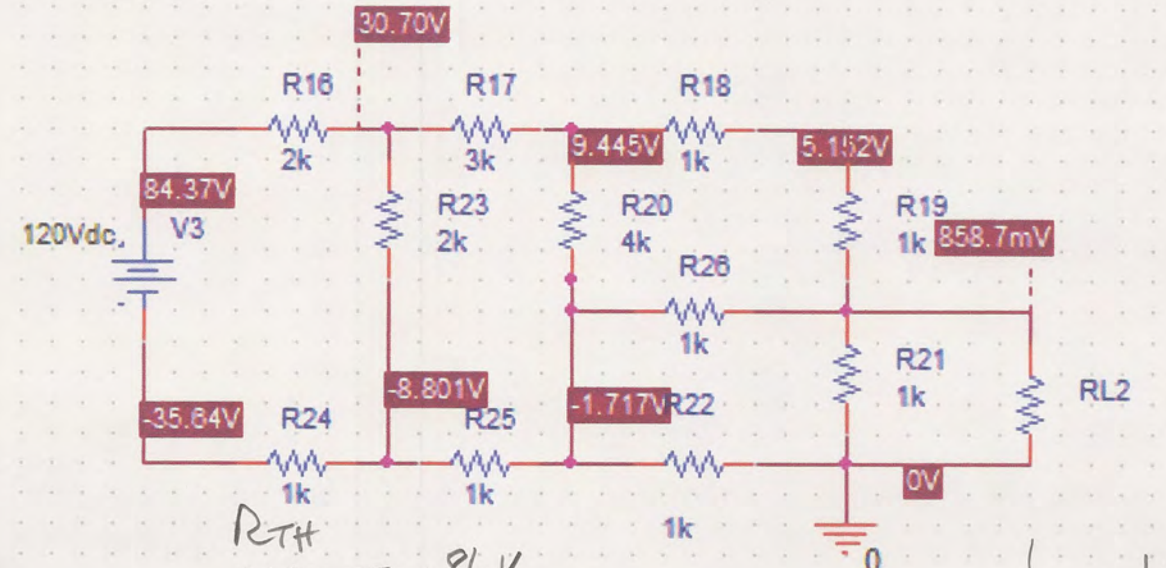
The 3rd circuit is significantly more complicated than the other two. Rather than analyze it from first principles, we will use the results from a PSpice simulation. In the first plot, the load resistor is very large (10MOhms) while in the second the load resistor is much smaller (1kOhm). Using the given voltages at each of the nodes for an open circuit load (RL1 is the load) and for a 1kΩ load, determine Vth and Rth. {10 pts}

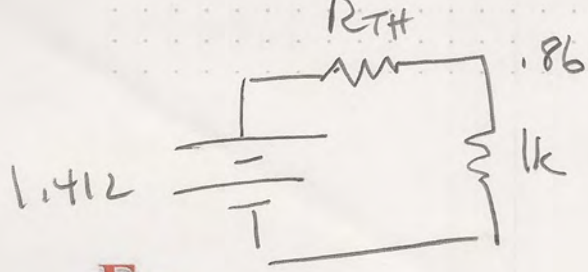
RL2



V_{TH} by inspection

$V_{TH} = 1.412V$



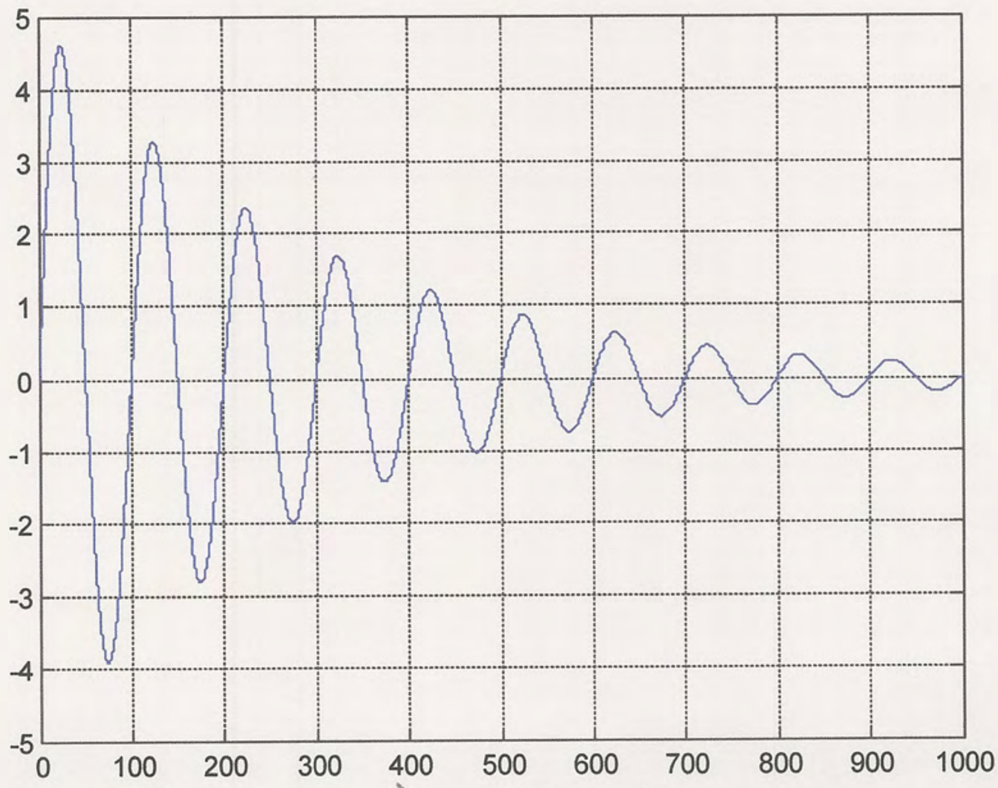


$V_{out} = .86 = \frac{1}{1+R_{TH}} 1.412$

$R_{TH} = \left(\frac{1.41}{.86} - 1\right)k = 640\Omega$

II. Harmonic Oscillators

The velocity measured for an oscillating cantilever beam is shown in graphical form as:



where the horizontal scale is time (100 sec per division) and the vertical scale is velocity (1 m/s per division).

a. Find the decay constant α and the angular frequency ω for this function. {6 pts}

$\omega = 2\pi f = \frac{2\pi}{100} = \frac{\pi}{50} = 0.063$ Very Small

$5e^{-\alpha t} = 1$ for $t \simeq 470$

$-\alpha 470 = \ln .2 \Rightarrow \alpha = .0033 = \frac{1}{300}$

b. Write the mathematical expression for the velocity in the form $v(t) = Ae^{-\alpha t}\sin\omega t$. Use real values for the constants and provide units where appropriate. {4 pts}

$$V = 5e^{-t/300}\sin\left(\frac{\pi}{50}t\right)$$

c. Find the acceleration *a(t)* of the beam from your answer to part b. Again, use real values for the constants and provide units where appropriate. {6 pts}

$$a = 5\left(-\frac{1}{300}\right)e^{-t/300}\sin\left(\frac{\pi}{50}t\right) + 5e^{-t/300}\left(\frac{\pi}{50}\right)\cos\left(\frac{\pi}{50}t\right)$$

d. Assume that you would like to build an LC oscillator circuit that operates at the same frequency and the beam above. You have a 100μF capacitor and need to make an inductor. What value of inductance is necessary to achieve this frequency? {4 pts}

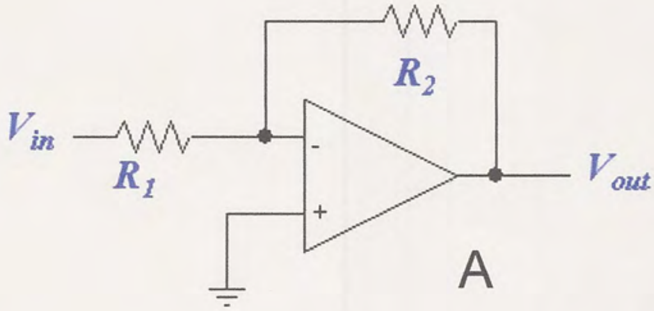
$$\omega = \frac{\pi}{50} = \frac{1}{\sqrt{LC}} \qquad L = \left(\frac{50}{\pi}\right)^2\frac{1}{C} = \left(\frac{50}{\pi}\right)^2\frac{1}{10^{-4}} \cong 25\,MH$$

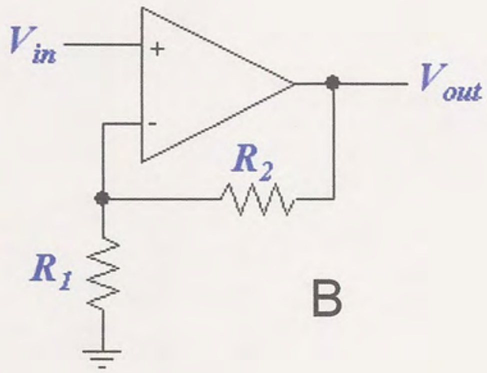
Very Unrealistic

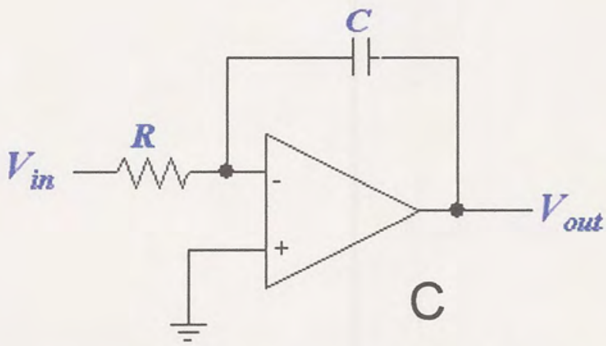
e. What is the primary color of the Mobile Studio board? {5 pts … really!}

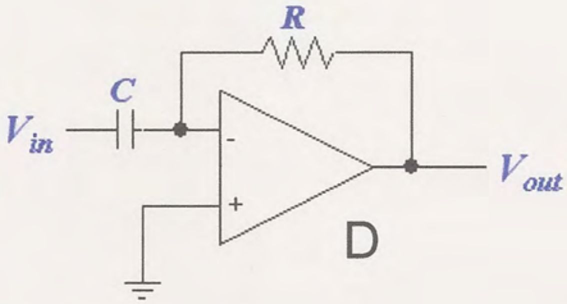
Red – But any answer is OK for 5pts
(I am curious to know your answer)

III. Operational Amplifiers





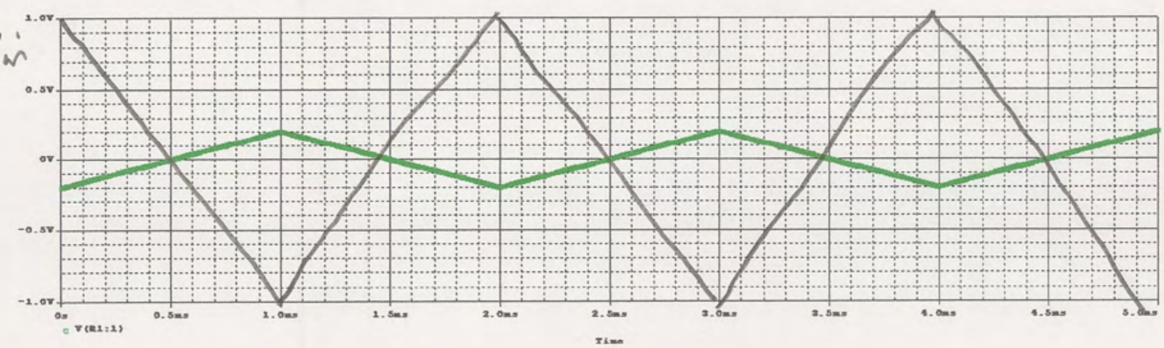




a. {4 pts} What type of amplifier is each circuit?
   a. A
   b. B
   c. C
   d. D

b. {4 pts} The input voltage is shown below. Solve for and sketch the output voltage for circuit A with R_1=1kΩ and R_2=5kΩ.

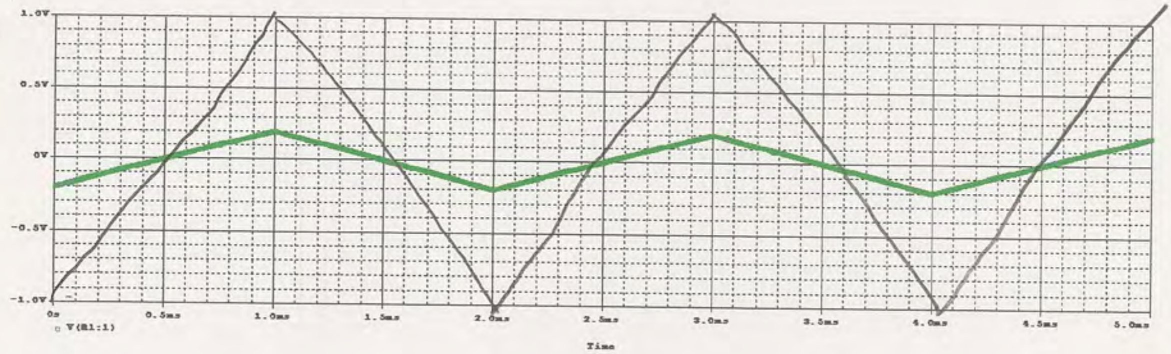
$V_{out} = -5V_{in}$



The vertical scale is -1V to +1V and the horizontal scale is from 0 to 5ms.

c. {4 pts} The input voltage is shown below. Solve for and sketch the output voltage for circuit B with R_1=1kΩ and R_2=4kΩ.

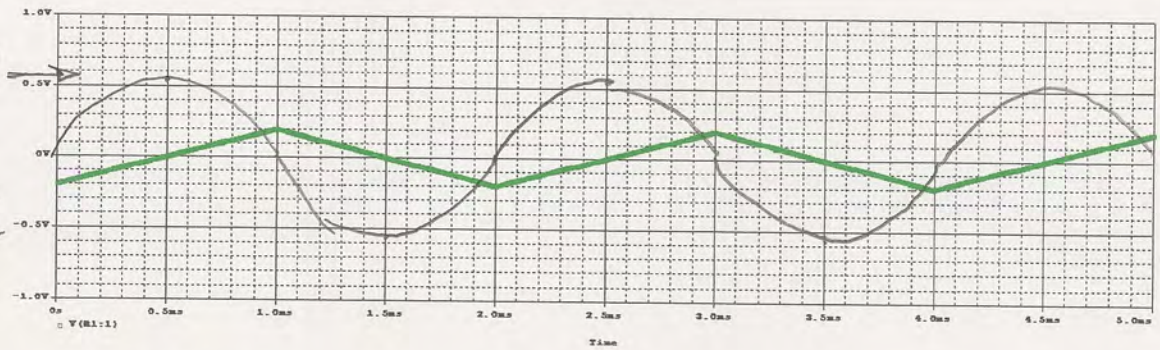
Vout = 5Vin



d. {4 pts} The input voltage is shown below. Solve for and sketch the output voltage for circuit C with R=2kΩ and C=0.047μF. *(Extra Credit)*

.53

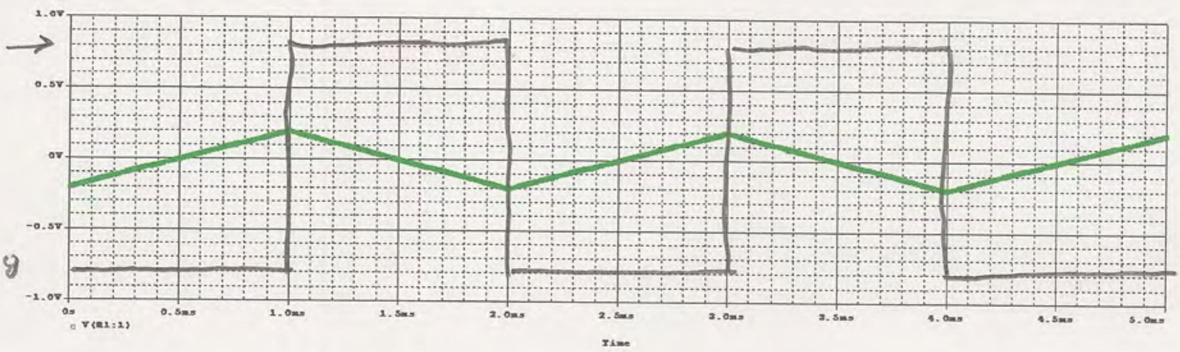
Vout = ∓4.25x10^6 t^2/2



e. {4 pts} The input voltage is shown below. Solve for and sketch the output voltage for circuit D with C=.33μF and R=6kΩ.

.8 →

-.8



Vout = ∓.8 fr—

Space for the analysis of the circuits above:

A $V_{out} = -\frac{5k}{1k} V_{in} = -5V_{in}$

B $V_{out} = \left(1 + \frac{4k}{1k}\right) V_{in} = 5V_{in}$

C $V_{out} = -\frac{1}{RC} \int V_{in}\, dt$

$= -\frac{1}{(2k)(.047\mu)} \int V_{in}\, dt$ $\quad V_{in} = \pm at$ (a = slope)

$= \mp (10640)(400) \int t\, dt$ $\quad$ slope $\frac{.4V}{1mS} = 400$

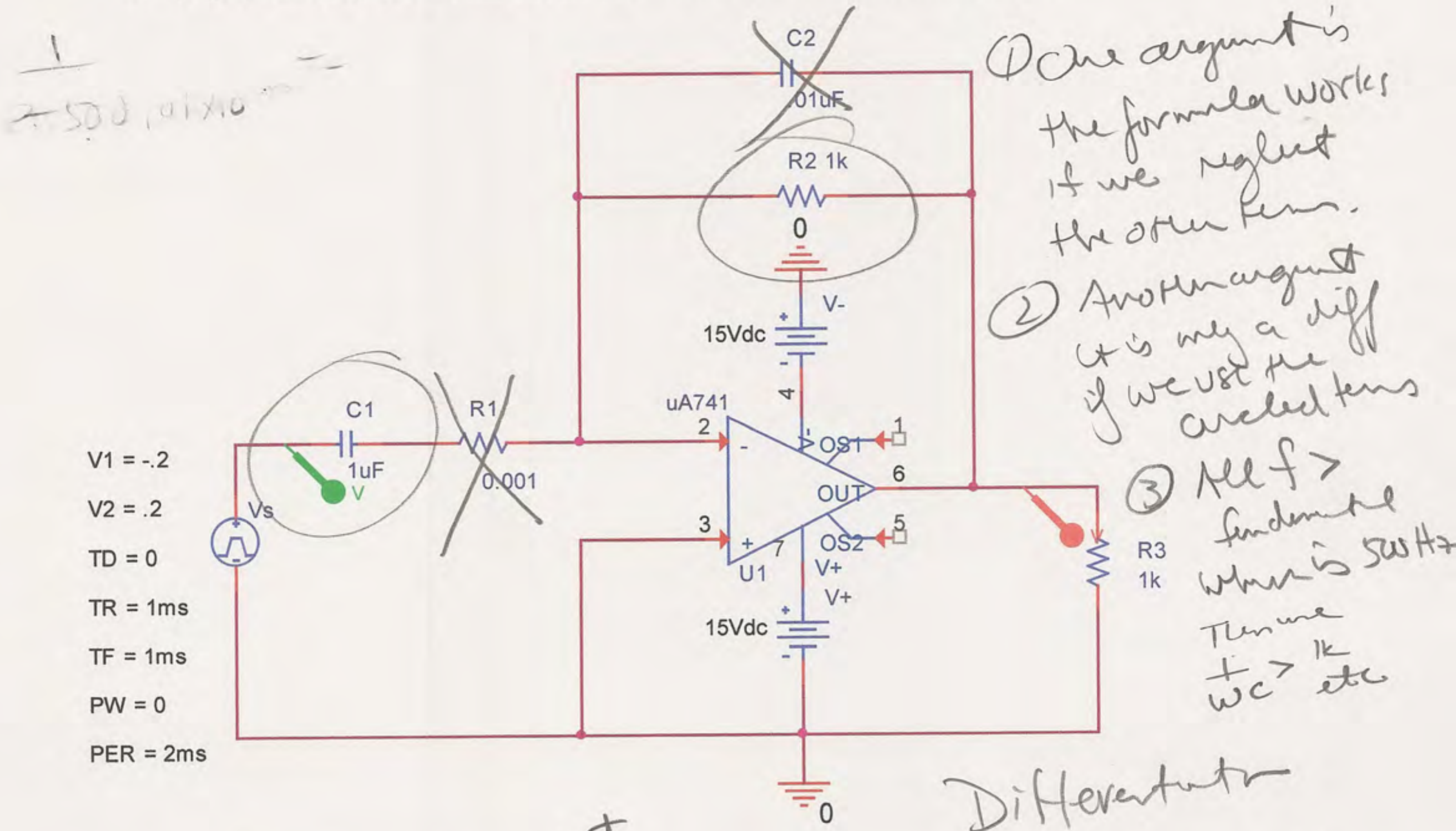
$= \mp 4.25 \times 10^6 \frac{t^2}{2}$

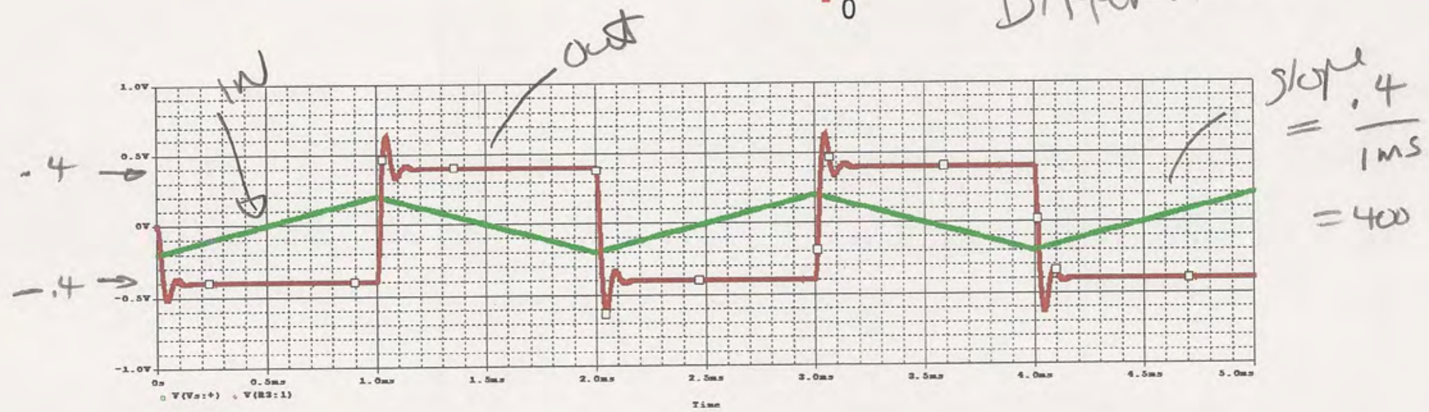
for $t = .5ms$ Vout changes by 530mv

D $V_{out} = -RC \frac{dV_{in}}{dt} = (.33\mu F)(6k) \frac{d}{dt}(\pm 400t)$

$\approx \mp .8$

f. {9 pts} The response of the circuit below has been simulated using PSpice.





Label the input voltage and the output voltage on the plot showing the signals. {2 pts} The circuit configuration does not look exactly like any of the ideal op-amp circuits. However, it largely provides the functionality of one of the ideal circuits. From the input and output voltages, identify what kind of circuit this is {3 pts}, indicate the circuit components that you can neglect in your analysis and why, and verify mathematically that it is working at least approximately the way it should. {4 pts}

$V_{out} = -RC\frac{dV_{in}}{dt} = -(1000)(10^{-6})(\pm 400) = \mp .4$

IV. Concepts, Troubleshooting and Data Analysis

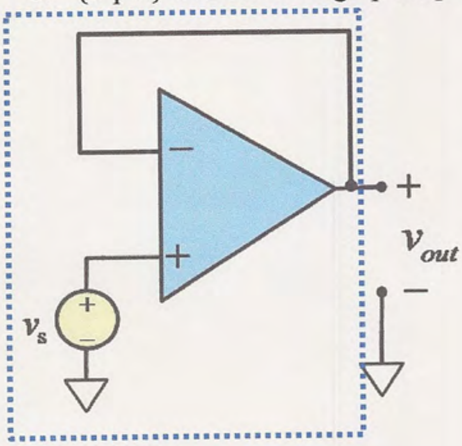
a. {5 pts} Today's date is 3-20-2013. Because the date consists of three numbers, how would you represent each number with the resistor color code, if indeed it can be done? If it can be, give the color code. If it cannot be, cross out the number.

a. 3   3 orange   0 3 0 $= 3\times10^0$ ⇒ Black Orange Black

b. 20   2 is red $200 = 20\times10^0$ ⇒ Red Black Blue

c. ~~2013~~   Too many digits

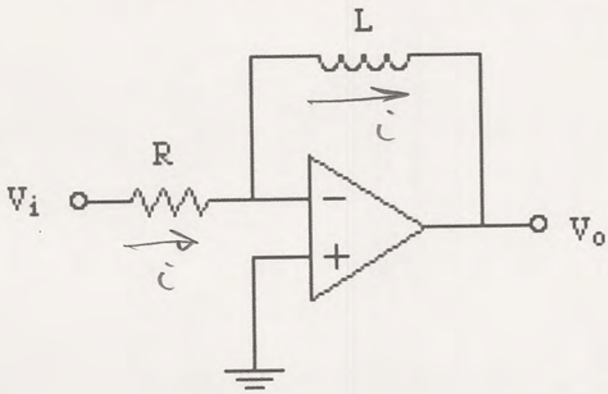
b. {5 pts} The following op-amp circuit is built. What kind of an amplifier circuit is it? Determine the Thevenin equivalent voltage V_{TH} and the Thevenin equivalent resistance R_{TH} for this circuit including the source v_s (that is, everything inside the dashed box).



$V_{oc} = V_{out} = V_s$

$R_{TH} = 0$ Because V_{out} does not depend on the load.

c. {5 pts} An ideal op-amp circuit is configured with an inductor in the feedback loop and an input resistor, as shown below. What mathematic operation will this circuit perform? Derive the expression for V_o in terms of V_i.



$i = \frac{V_i}{R}$ $V_{out} = -L\frac{di}{dt}$

$\Rightarrow V_{out} = -L\frac{d}{dt}\left(\frac{V_i}{R}\right)$

$= -\frac{L}{R}\frac{d}{dt}V_{in}$

Differentiator

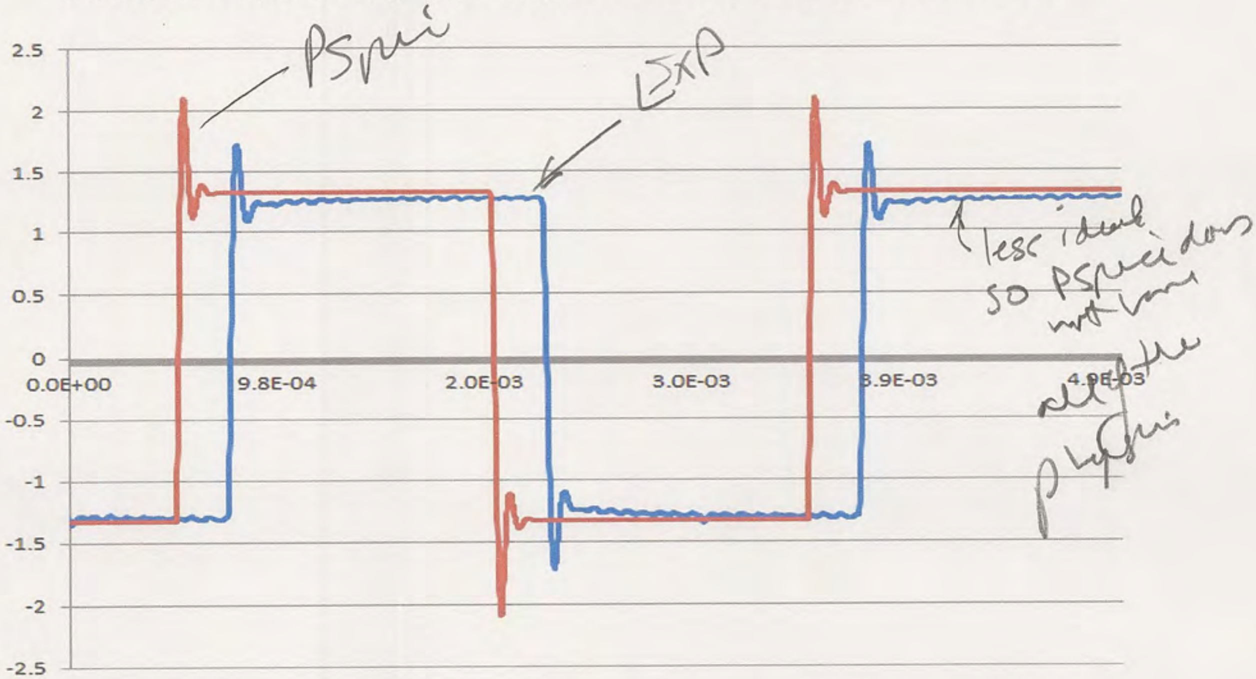
d. {5 pts} On the second page of this quiz, you will find two figures. One shows the total amount of daylight each day and the average daily temperature each day for a city in the southern hemisphere (Sydney) and the other shows the same information for a city in the northern hemisphere (Toronto). Identify which is for Sydney and which is for Toronto. The vertical scale goes from -1 to +1 and the horizontal scale is labeled with the days of the year. Find today's date and label it. Based on this plot, what do you think is the general mathematical form of the daylight as a function of time? You should write the expression in terms of functions and constants. You do not need to evaluate the constants.

Daylight = A + B sin ωt

↑ freq = 1 per year

↑ average Illumination (time is always light)

e. {5 pts}Shown below is the output voltage for a configuration like the one in part f of problem 3. One signal is from PSpice and one signal from an experiment with the voltages measured by Mobile Studio. Identify which one is which and explain your answer. Note that the two plots are displaced in time to make them easier to see.



These plots were generated in Excel. It is possible to copy PSpice data into Excel, just like experimental data from Mobile Studio.