

## ENGR-2300

## Electronic Instrumentation

## Quiz 4

Spring 2014

 **Answers**

Question I (25 points) \_\_\_\_\_

Question II (25 points) \_\_\_\_\_

Question III (25 points) \_\_\_\_\_

Question IV (25 points) \_\_\_\_\_

Total (100 points) \_\_\_\_\_

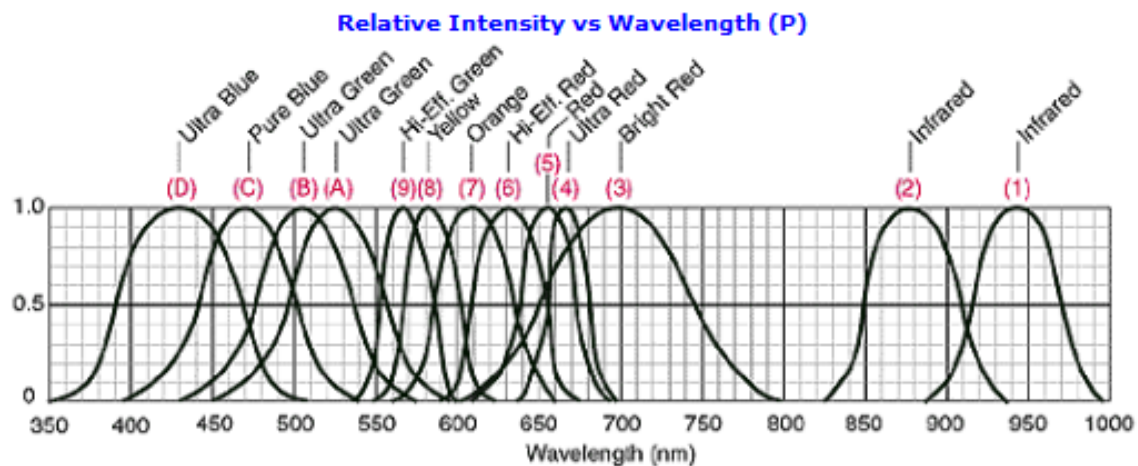
On all questions: **SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS.** No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

### Some Additional Background

Some Typical LED Operating Info:

	Wavelength (nm)	Color Name	Fwd Voltage (Vf @ 20ma)	Intensity 5mm LEDs	Viewing Angle	LED Dye Material
	940	Infrared	1.5	16mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	880	Infrared	1.7	18mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	850	Infrared	1.7	26mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
	660	Ultra Red	1.8	2000mcd @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
	635	High Eff. Red	2.0	200mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
★	633	Super Red	2.2	3500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	620	Super Orange	2.2	4500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	612	Super Orange	2.2	6500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	605	Orange	2.1	160mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
★	595	Super Yellow	2.2	5500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	592	Super Pure Yellow	2.1	7000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	585	Yellow	2.1	100mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	4500K	"Incan-descent" White	3.6	2000mcd @20mA	20°	SiC/GaN -- Silicon Carbide/Gallium Nitride

	6500K	Pale White	3.6	4000mcd @20mA	20°	SiC/GaN -- Silicon Carbide/Gallium Nitride
★	8000K	Cool White	3.6	6000mcd @20mA	20°	SiC/GaN - Silicon Carbide / Gallium Nitride
	574	Super Lime Yellow	2.4	1000mcd @20mA	15°	InGaAlP - Indium Gallium Aluminum Phosphide
★	570	Super Lime Green	2.0	1000mcd @20mA	15°	InGaAlP - Indium Gallium Aluminum Phosphide
	565	High Efficiency Green	2.1	200mcd @20mA	15°	GaP/GaP - Gallium Phosphide/Gallium Phosphide
	560	Super Pure Green	2.1	350mcd @20mA	15°	InGaAlP - Indium Gallium Aluminum Phosphide
	555	Pure Green	2.1	80mcd @20mA	15°	GaP/GaP - Gallium Phosphide/ Gallium Phosphide
	525	Aqua Green	3.5	10,000mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride
	505	Blue Green	3.5	2000mcd @20mA	45°	SiC/GaN - Silicon Carbide / Gallium Nitride
★	470	Super Blue	3.6	3000mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride
	430	Ultra Blue	3.8	100mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride




From Wikipedia: A **Zener diode** is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage, "zener knee voltage", "zener voltage", "avalanche point", or "peak inverse voltage".

The device was named after Clarence Zener, who discovered this electrical property. Many diodes described as "zener" diodes rely instead on avalanche breakdown as the mechanism. Both types are used. Common applications include providing a reference voltage for voltage regulators, or to protect other semiconductor devices from momentary voltage pulses.

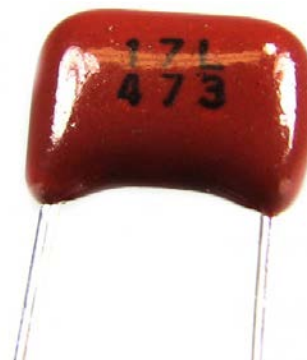
Type Number	Nominal Zener Voltage $V_Z @ I_{ZT}^{(2)}$ (Volts)	Test Current $I_{ZT}$ (mA)	Maximum Zener Impedance $Z_{ZT} @ I_{ZT}^{(1)}$ ( $\Omega$ )	Maximum Regulator Current $I_{ZM}^{(2)}$ (mA)	Maximum Reverse Leakage Current	
					$T_A = 25^\circ\text{C}$ $I_R @ V_R = 1\text{V}$ ( $\mu\text{A}$ )	$T_A = 150^\circ\text{C}$ $I_R @ V_R = 1\text{V}$ ( $\mu\text{A}$ )
1N746A	3.3	20	28	110	10	30
1N747A	3.6	20	24	100	10	30
1N748A	3.9	20	23	95	10	30
1N749A	4.3	20	22	85	2	30
1N750A	4.7	20	19	75	2	30
1N751A	5.1	20	17	70	1	20
1N752A	5.6	20	11	65	1	20
1N753A	6.2	20	7	60	0.1	20
1N754A	6.8	20	5	55	0.1	20
1N755A	7.5	20	6	50	0.1	20
1N756A	8.2	20	8	45	0.1	20
1N757A	9.1	20	10	40	0.1	20
1N758A	10	20	17	35	0.1	20
1N759A	12	20	30	30	0.1	20

## Capacitor Codes

Physically larger capacitors, like electrolytics, usually have the capacitance value written simply on them. For smaller capacitors, like ceramics, there are three numbers written to indicate the value. The first two digits of the code represent part of the value; the third digit corresponds to the number of zeros to be added to the first two digits. This is the value in pF.

For Example: CODE: 4 7 3   
 VALUE: 47000 or .047 $\mu\text{F}$

There is also often a letter after the three numbers. This indicates the tolerance of the value.



## Mothers' Day (11 May 2014)

Since Mothers' Day occurs this Sunday just before final exams begin, I thought I would remind everyone since it is easy to be distracted with our many other obligations and tasks this time of year. This also gives me an excuse to tell you a little about my mother and grandmothers.



**Gertrude Kessenich Connor** – My paternal grandparents were among the 50 million who died in the influenza pandemic after WWI. The photo at the left is from her funeral mass card. My father was orphaned when he was less than 2 weeks old. In spite of how difficult winter travel was, he and his older brother and sister were picked up by relatives from Waunakee, WI to be raised by his maternal grandparents. The good news for me was that this brought my dad to about 5 miles from my maternal grandparents' farm in the Town of Vienna. The Kessenichs are a large extended family that came to Wisconsin from Germany in the middle of the 19<sup>th</sup> Century. Reunions often had 100s of attendees when I was growing up.

**Alice Anderson Bowers** – The only grandmother I have known was born 2 years later than Gertrude and lived to be nearly 100. She had two sisters who made it to 102. She is shown at left with my mother, my great grandfather Ole Anderson and my brother Jim in 1943. Grandpa Ole was 89. Like Gertrude, she came from a large farming family (Norwegian Lutherans instead of German Catholics). She was the eldest child and, when Ole drank his second wife into an early grave, she had to leave secretarial school and became the de facto mother. She remained the family matriarch, holding all family

holiday events (Christmas, Easter ...) at her house. She was an exceptionally strong-willed woman who, with my Grandpa Gene, helped many members of both families survive the Great Depression. She had a very sharp tongue but generally saved her dark side for at home and was the sweetest, kindest person everywhere else, especially to her many grandchildren.

**Marie Bowers Connor** – My mother, shown in our kitchen during the 1950s, was 91 when she died in 2011. She was an RN and loved to fish and go to hockey games with my dad, but, like her mother, was exceptionally nice to her children and many grandchildren. When she came to visit us in NY, she always left our freezer full of pies. Unlike her mother, she was kind everywhere, but maybe used her gentle ways to get what she wanted. I miss her every day.



**Question I Multiple Choice & Short Answer Questions (25 points)**

For these multiple choice questions, circle the correct answer or, for the first question, fill in the blanks. All questions are 3pts, except h, which is worth 4pts. Be sure to explain your answer.

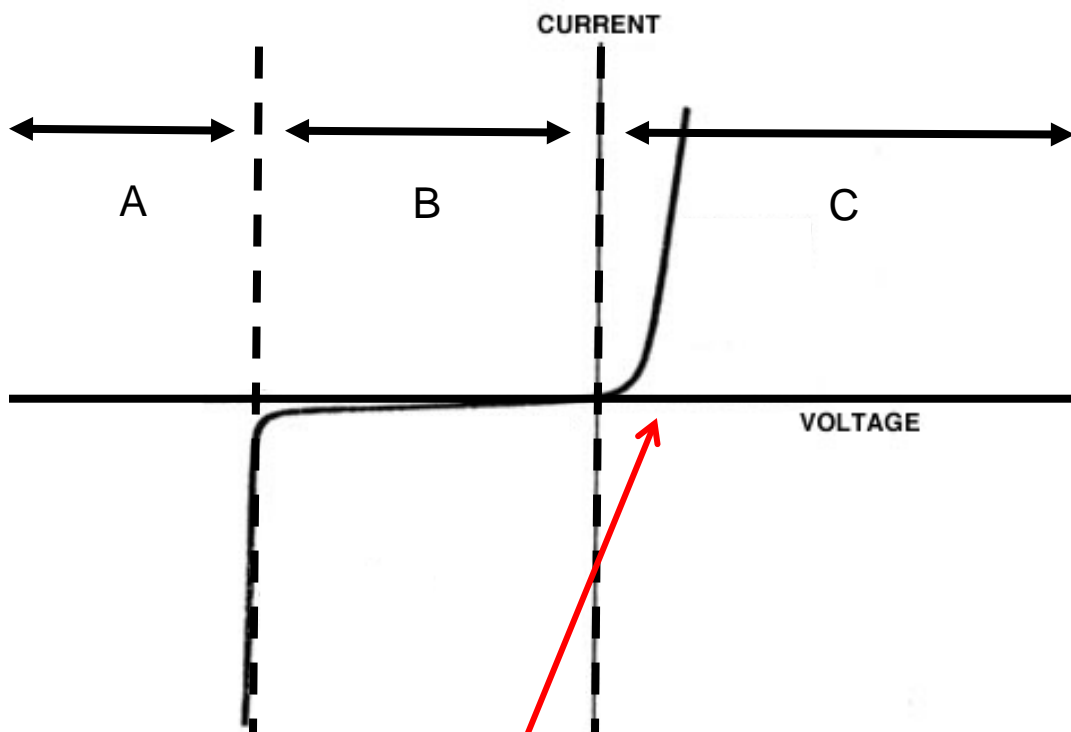
**Hint: if there is no figure with the question, it is a good idea to draw one.**

- a. There are three voltage ranges shown in the diode I-V curve below. Write the letter from the figure in the blank next to the name for the range.

**a. Breakdown Region A**

**b. Forward Bias Region C**

**c. Reverse Bias Region B**



- b. The voltage across each forward-biased diode in a typical full wave bridge rectifier is

a. Near the source voltage

b. Near twice the source voltage

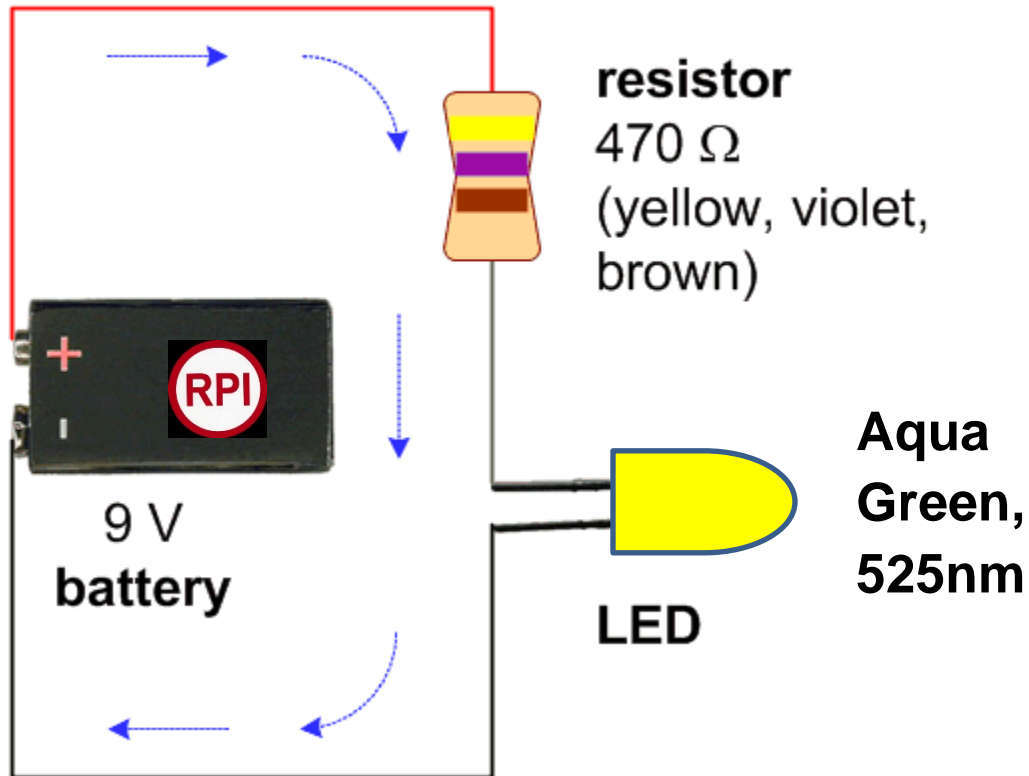
c. Near half the source voltage

**d. Near 0.6 to 0.7 volts**

e. Near zero volts

**Question I Multiple Choice & Short Answer Questions (continued)**

- c. What is the current through the LED, if we use the specified green LED? (Choose the closest answer.)



- a. 5 mA  
b. 9 mA  
**c. 12 mA**  
d. 14 mA  
e. 19 mA

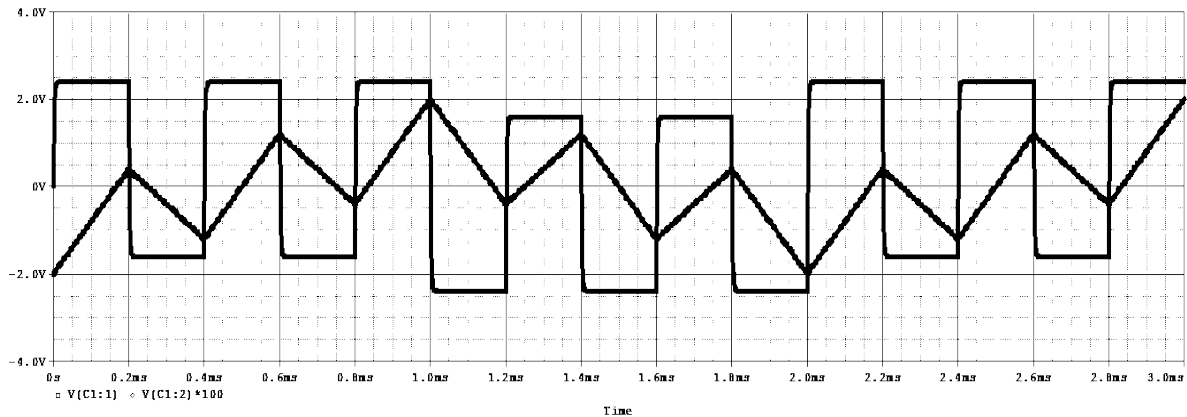
$$I = (9 - 3.5) / 470 = 11.7 \text{ mA}$$

- d. A full-wave bridge rectifier is built using four IR LEDs rather than conventional diodes (like the 1N4148). For a given AC input voltage, will the rectified current through the load resistor be
- a. Smaller -- More voltage drops across each diode, leaving less to drive the load current**  
b. Larger  
c. The same  
d. None of the above

than it was with four 1N4148 diodes?

### Question I Multiple Choice & Short Answer Questions (continued)

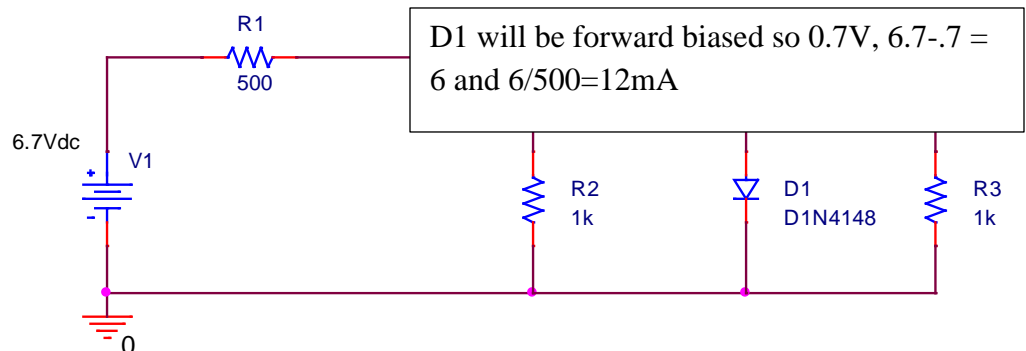
- e. If a second smoothing capacitor for a filtered half-wave rectifier voltage is **added in series** to an existing smoothing capacitor (for the same load resistance and frequency values) will the ripple:
- Become smaller.
  - Become larger – Capacitors in series are smaller, so more ripple.**
  - Stay the same.
  - None of the above.
- f. The input voltage to a passive differentiator circuit is the combination of a 500Hz triangular wave and a 2.5kHz triangular wave. The figure below shows both the input and the voltage measured at the output of the differentiator. The output voltage has been multiplied by 10 to make it easier to see. If the frequency of the second wave is raised



to 25kHz, which of the following will be true about the amplitude of the output voltage?

- It will remain about the same as it was for  $f = 2.5\text{kHz}$
  - It will increase noticeably from its value at  $f = 2.5\text{kHz}$  -- the slope increases**
  - It will decrease noticeably from its value at  $f = 2.5\text{kHz}$
  - There is not enough information provided to select any of the given answers.
- g. What is the approximate current magnitude through the resistor R1 in the circuit below?

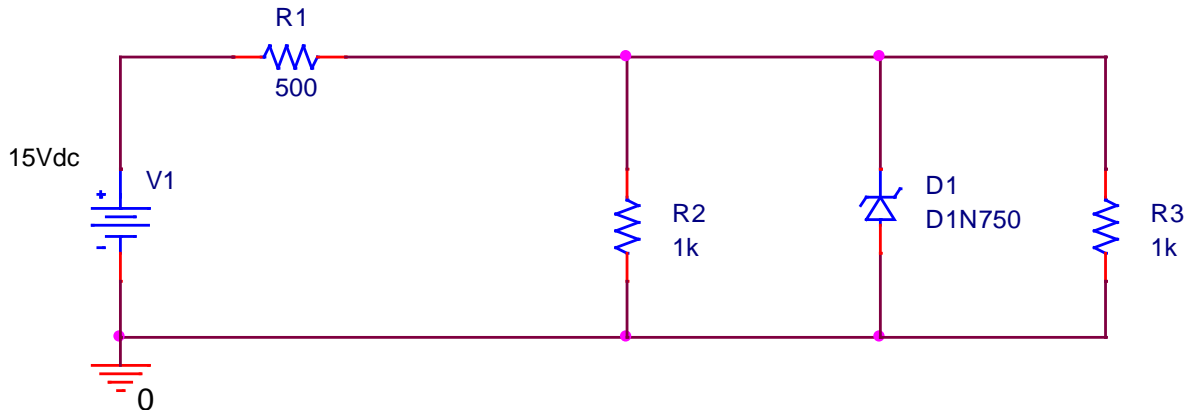
- 0 mA
- 1 mA
- 2 mA
- 5 mA
- 10 mA
- 12 mA**
- 15 mA





**Question I Multiple Choice & Short Answer Questions (continued)**

- h. What is the approximate power dissipated by the Zener diode? (4pts)
- 0 mW
  - 20 mW
  - 35 mW
  - 50 mW**
  - 75 mW
  - 100 mW



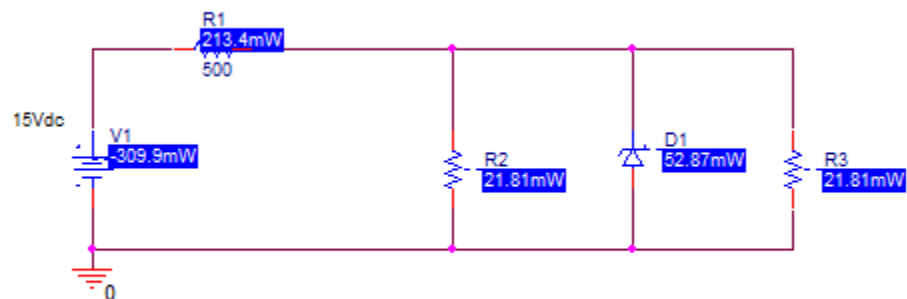
*The current through R1 is  $(15-4.7)/500 = 20.6\text{mA}$*

*The current through R2 and R3 each equal 4.7mA*

*The current through D1 is  $(20.6-9.4)=10.2\text{mA}$*

*$IV=4.7(10.2)=48\text{mW}$*

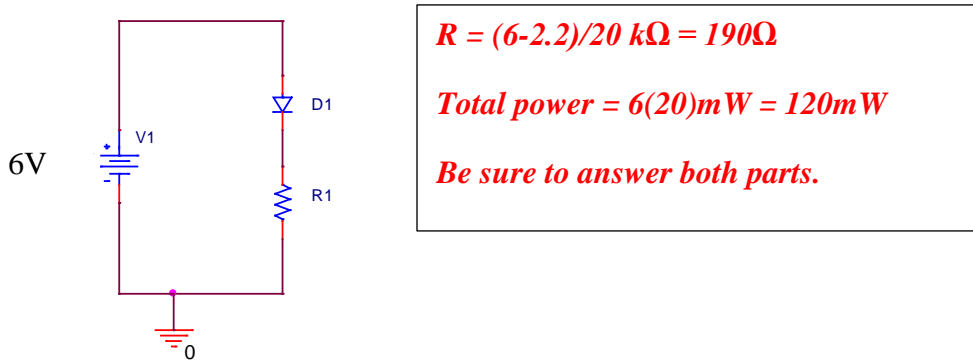
*From PSpice, the answer is a little different because the diode model is more realistic*



**Question II - LEDs (25 points)**

A 633nm Super Red LED is driven by a standard DC source. The source we have is four 1.5V AA batteries in series for a total of 6V. From the chart provided at the beginning of the quiz, we need a forward bias voltage of 2.2V and a current of 20 mA.

- a) Using this voltage source, **determine the resistance R1** necessary to achieve the desired operating conditions for the diode. Also determine the total power dissipated in the circuit. (8pts)



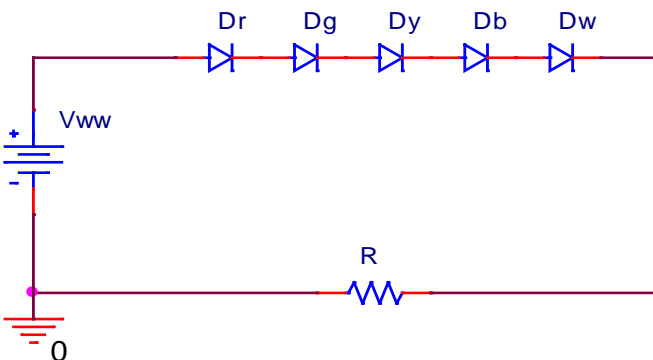
We now want to use multiple LEDs like a short string of holiday lights. For this purpose, we will use five different color LEDs: Red, Green, Yellow, Blue and White. We will use the five LEDs marked with a ★ in the table above. For the power supply, we will use one of two universal AC adapters available online that can output one of the following voltages (switch selectable):

Universal AC Adapter 15V 16V 18V 18.5V 19V 19.5V 20V 22V 24V 70W

Universal AC Adapter 3V 4.5V 6V 7.5V 9V 12V 10W

For the next question, select the minimum voltage from one of the power supplies.

- b) **Determine the voltage V<sub>ww</sub> and resistance R** to achieve the desired operating conditions for the series combination of 5 LEDs shown below. Assume that the current is 20mA, since we have to be limited to the smallest maximum current for any of our five LEDs. Use the typical forward bias voltages from the table. The power supply voltage should be the minimum value that will turn on all of the LEDs. (8pts)



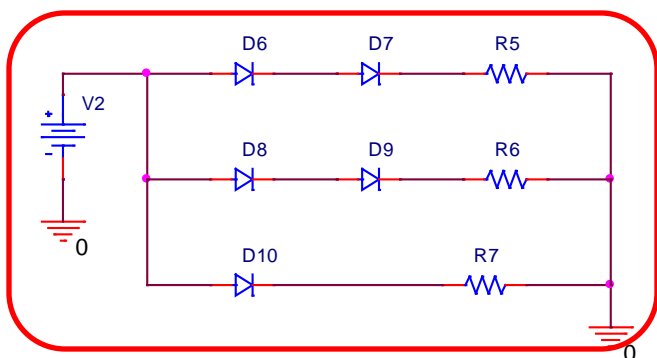
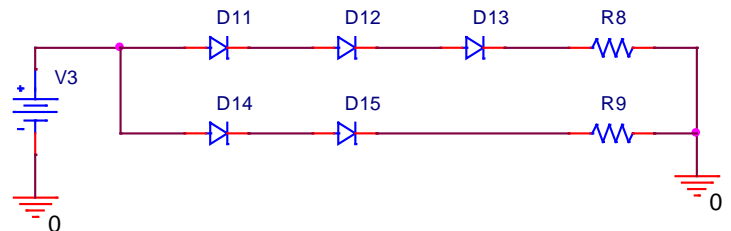
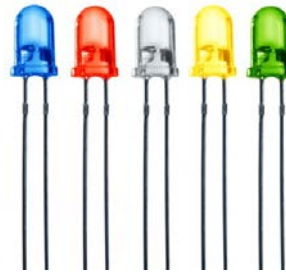
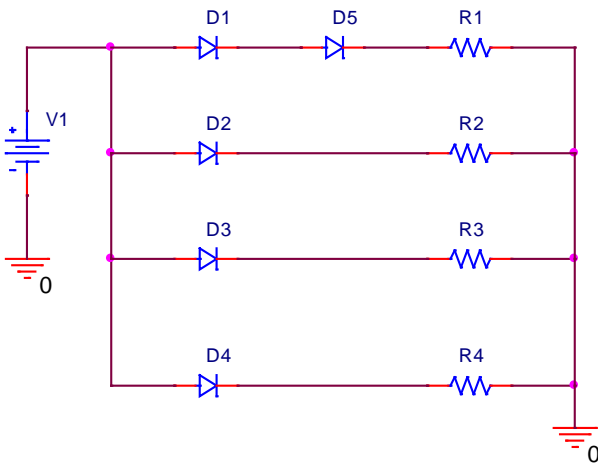
**Question II - LEDs Circuits (Cont)**

*The voltages are 2.2, 2.2, 3.6, 2, 3.6 which add up to 13.6V*

*The next larger voltage is 15V*

$$R = (15-13.6)/20 \text{ k}\Omega = 70\Omega$$

- c) **Determine the configuration and resistances** to achieve the desired operating conditions for the series/parallel combination of 5 LEDs if we are limited to only a 6V source and you are to use the minimum number of components required to light up all five LEDs. Assume that the current in each of the LEDs is 20mA, since we have to be limited to the smallest maximum current for any of our LEDs. Use the typical forward bias voltages from the table. Note, two options have been eliminated (all in series and each diode in its own parallel leg), so you only have to consider 3 possibilities. (9pts)



*Cannot use the simplest because any 3 LEDs add up to more than 6V. The next one works, but there are several options. Choose (3.6+2), (3.6+2.2), 2.2. Then*  
 $R5 = (6-5.6)/20 \text{ k}\Omega = 20\Omega$   
 $R6 = (6-5.8)/20 \text{ k}\Omega = 10\Omega$   
 $R7 = (6-2.2)/20 \text{ k}\Omega = 190\Omega$

*All correct options were accepted.*

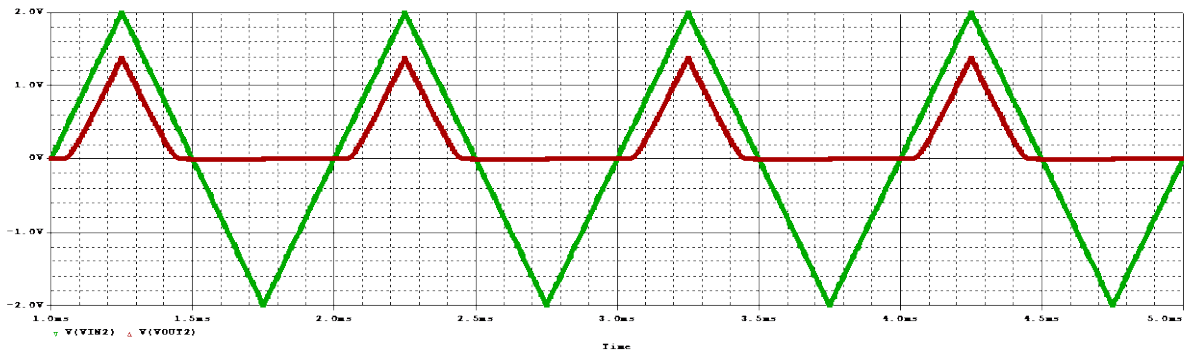
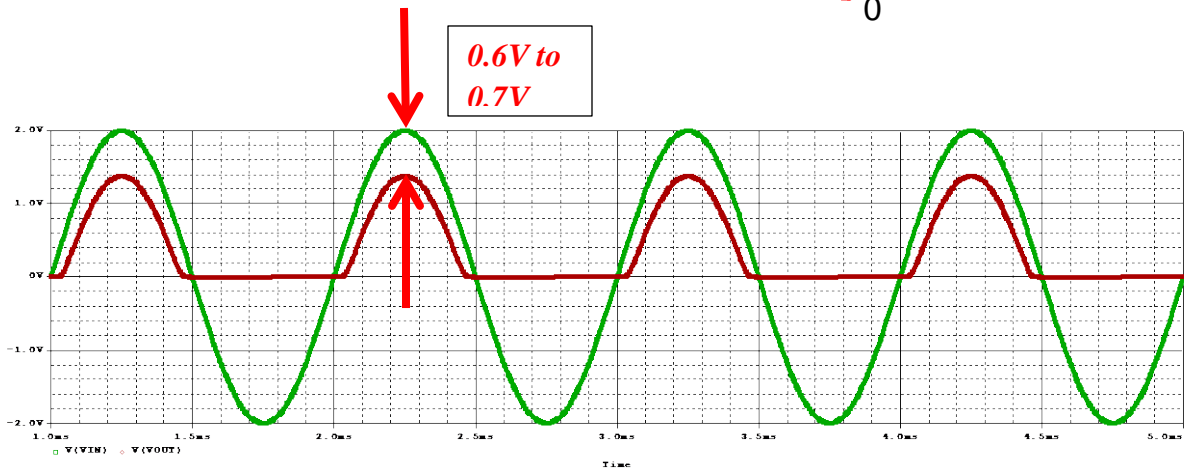
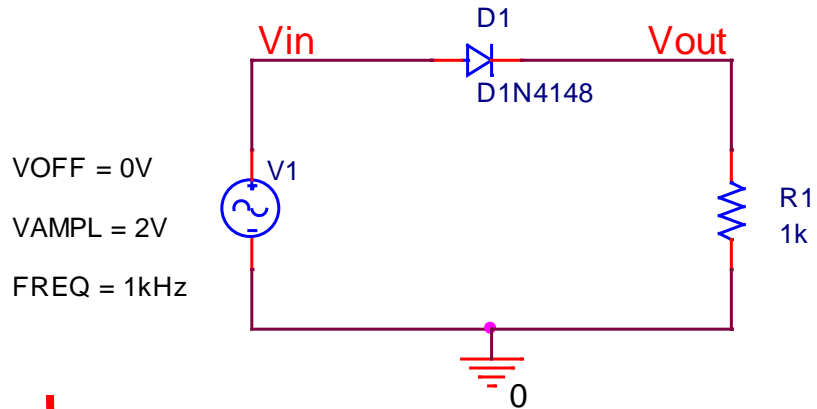
*Note, one could also select the top left config to avoid the small resistances.*

*Another option: Choose (3.6+2), (2.2+2.2), 3.6. Then*  
 $R5 = (6-5.6)/20 \text{ k}\Omega = 20\Omega$   
 $R6 = (6-4.4)/20 \text{ k}\Omega = 80\Omega$   
 $R7 = (6-3.6)/20 \text{ k}\Omega = 120\Omega$

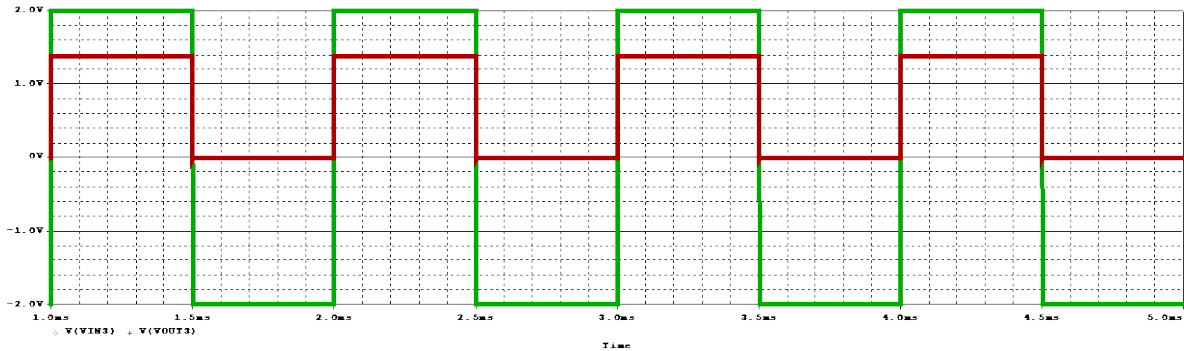
**Question III – Diode Circuits (25 Points)**

In this problem, we will look at variations of common diode circuits.

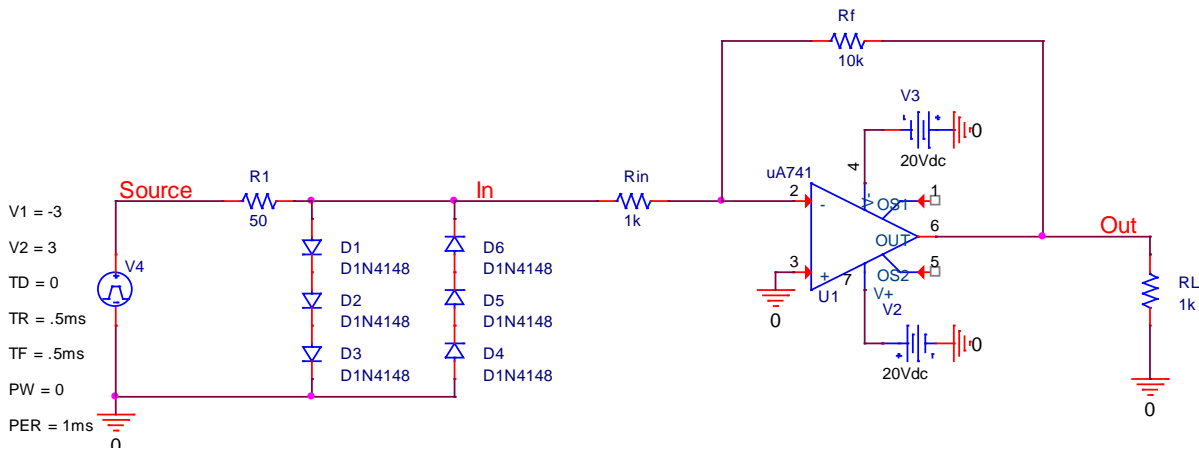
- a. Rectifier (9pts) – A 1N4148 diode is configured as shown to rectify the three input voltages shown below. The vertical scale in each case goes from -2V to +2V. Carefully sketch the output voltage across the resistor for each case.



**Question III – Diode Circuits (Cont)**



b. Limiter (11pts) – In the following circuit, six diodes are used in a limiter configuration with the goal of keeping the power delivered to the load below the rating for the resistor.



What is the gain of the op-amp configuration? Also identify the type of amplifier it is. (2pts)

*-10, inverting*

Determine the limit on the input voltage V(In) due to the diodes. (2pts)

*3 times 0.6 to 0.7 or 1.8V to 2.1V with the latter the number given on the formula sheet.*

What is the saturation limit on the output voltage V(Out) due to the DC sources that power the op-amp? (2pts)

*Ideally, 20V but usually a little less than that*

What is actually limiting the load voltage? Also, at this limit, what is the power delivered to the load resistor? (2pts)

*If you use 0.7V, it is the power supply saturation. If you use 0.6V, it is the diodes. Power is near 400mW (a little less is OK).*

**Question III – Diode Circuits (Cont)**

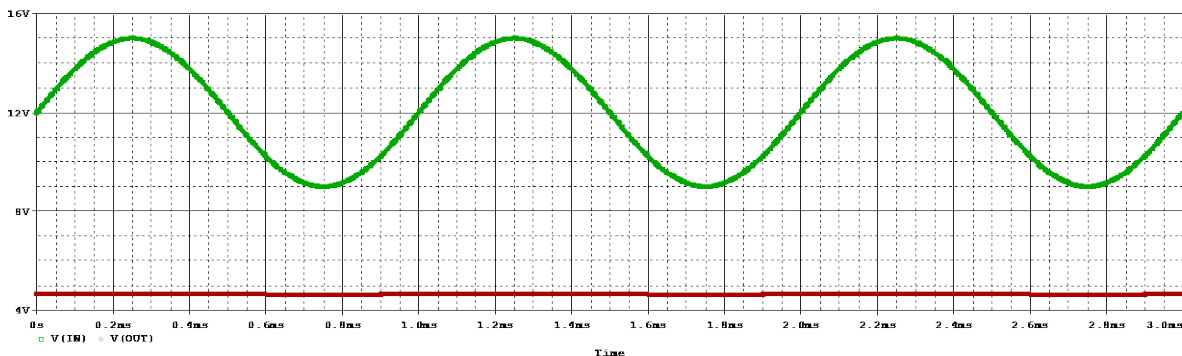
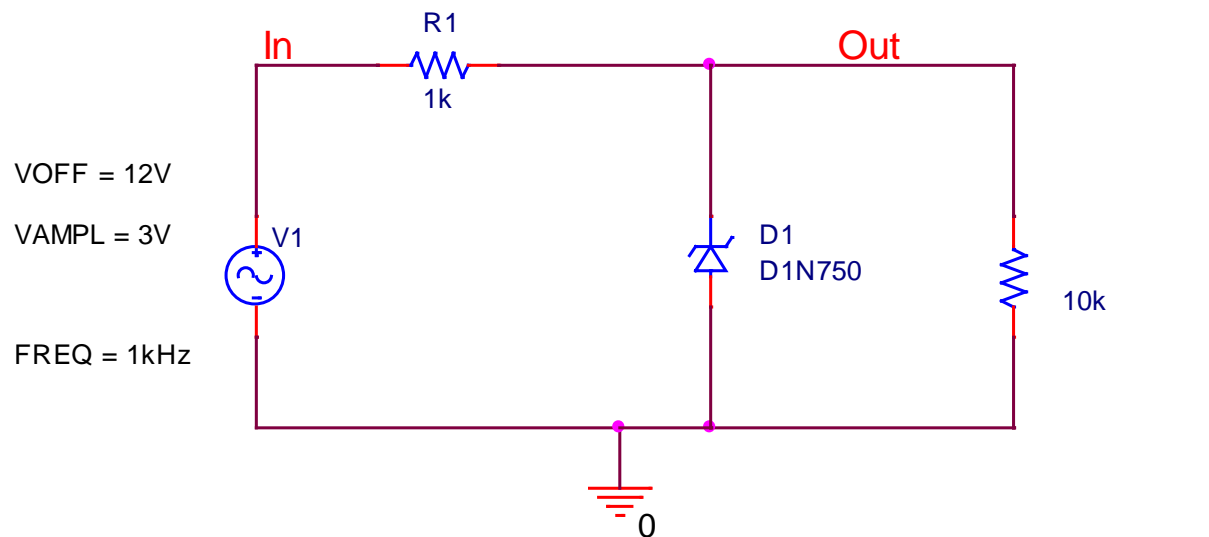
What is the power limit for the resistors we have used in class? (1pt)

*1/4 Watt*

How would you change the diode configuration above to avoid over-heating the load resistor?  
For your new configuration, determine the load resistor power. (2pts)

*Go to 2 diodes in each direction for the limiting. Then the output is limited to 14V and the power is (according to PSpice, a little less than 1/4 W. Calculating,  $(14^2)mW = \text{About } 200mW$ . The more realistic PSpice model allows the voltage to get a little larger.*

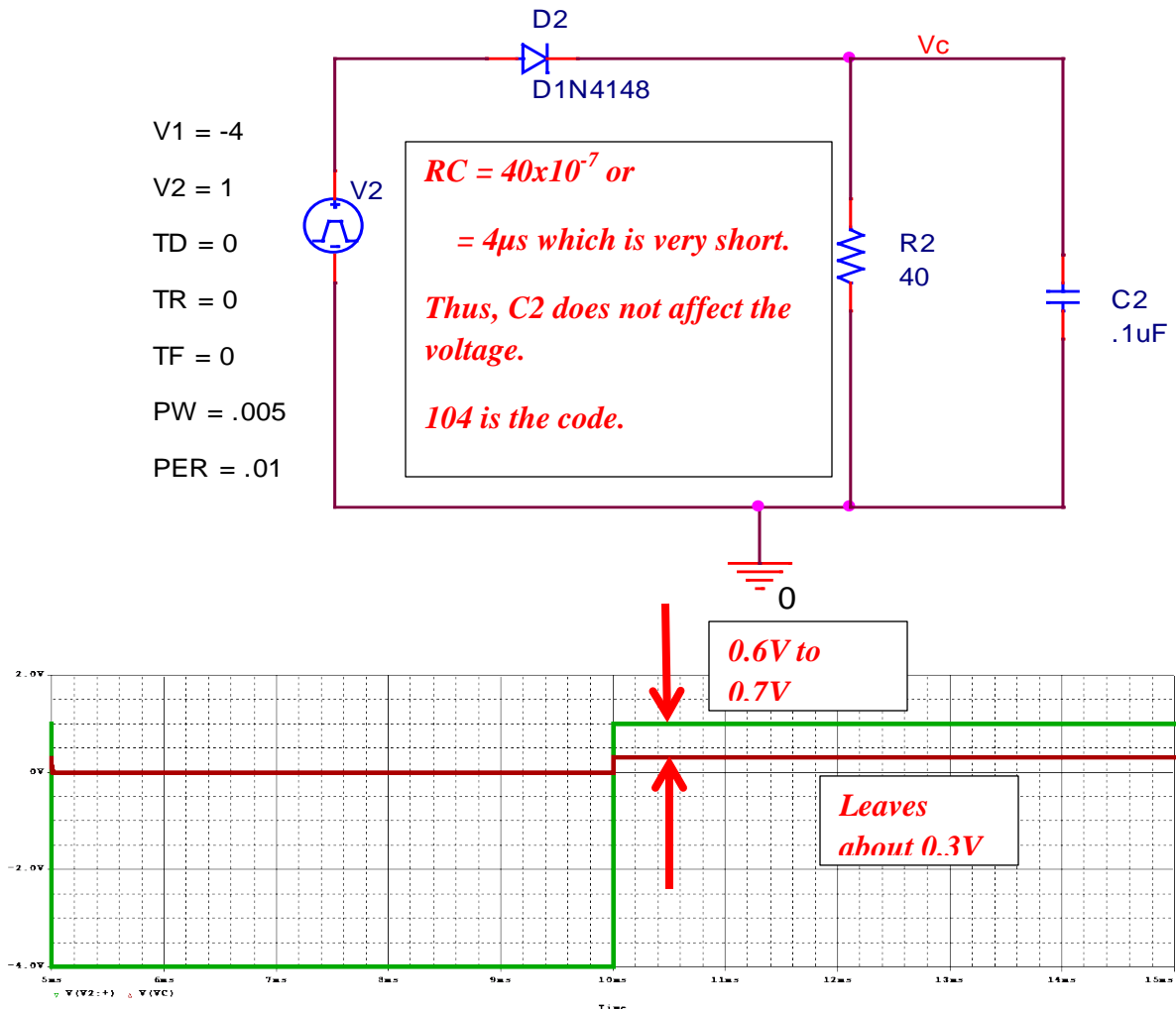
- c. Zener (5pts) – A 1N750 Zener diode is used with the goal of producing a nearly constant DC signal from an AC input. Plot the output voltage V(Out) on the figure below. (2pts)  
To regulate the voltage, the Zener current must exceed the minimum knee current (~1mA). Determine the minimum Zener diode current. (3pts)



*The voltage is about 4.6 to 4.7V. Minimum current  $\approx (9-4.7)mA = 4.3mA$ . PSpice  $\approx 4mA$ .*

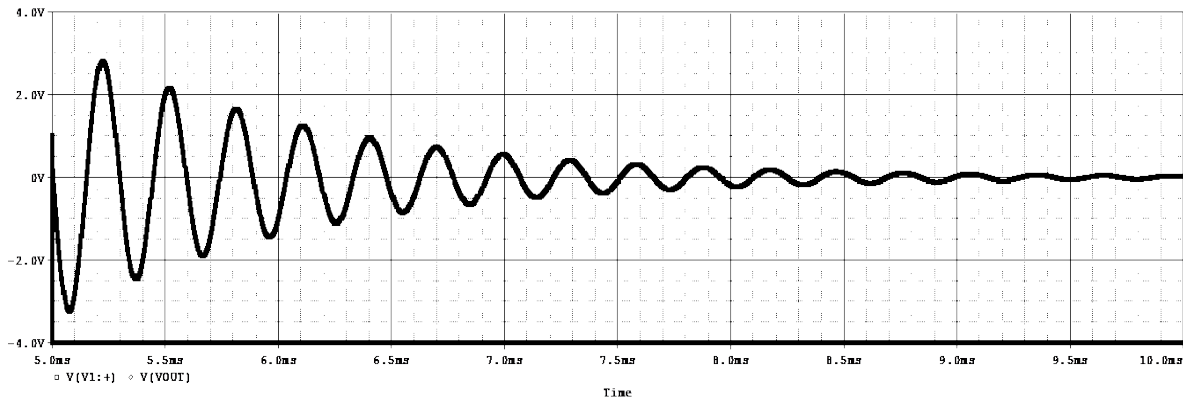
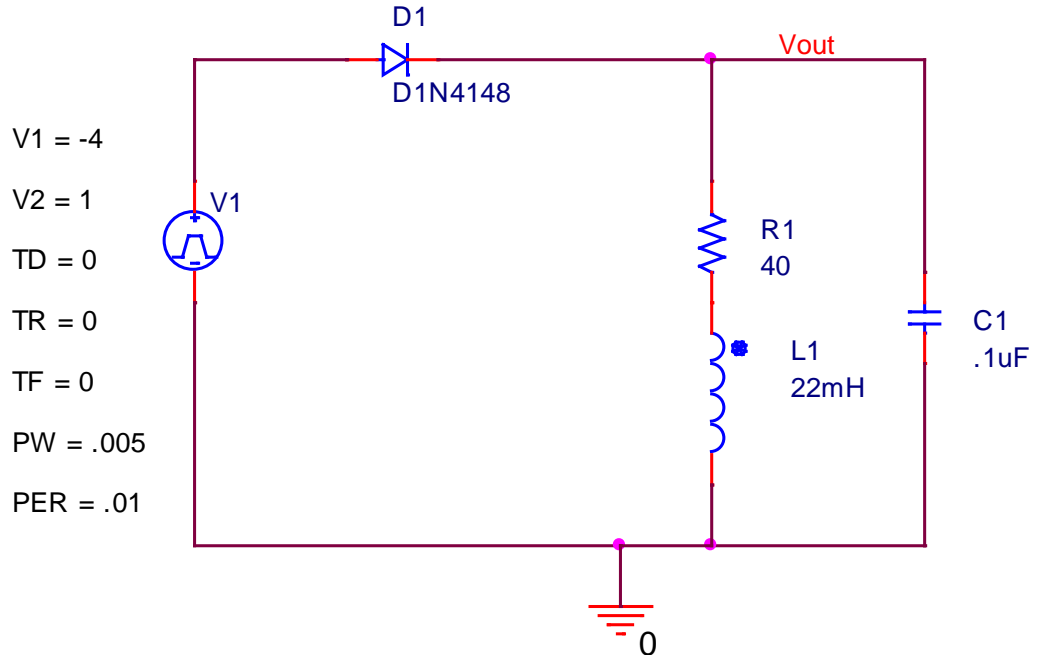
**Question IV – Complex Circuits (25 Points)**

- a. In this problem we return to an experiment done in Physics II that combines the use of diodes with a variety of passive components to produce a signal like in the cantilever beam experiment and project. Before addressing the actual experiment, consider the following circuit. The input voltage is a square wave that switches between 1V and -4V with a frequency of 100Hz. While it looks like the capacitor in this circuit may provide some smoothing, it is actually too small to have any effect. To show this, determine the RC time constant and show that it is much smaller than the period of the input signal. Then determine and sketch the capacitor voltage  $V_c$  on the figure below. The time scale in the figure goes from 5ms to 15ms (one period). Also, what 3 number code would you find on this capacitor? (6pts)



- b. The resistance in the circuit above was chosen to represent the resistance of a standard inductor ( $R1$  in the circuit below), which we will now consider. In the data figure, the input voltage and the output voltage  $V_{out}$  are shown for the first half of the square wave

period. For simplicity, assume that the output voltage during the second half of the cycle is the same as your answer for part a. It actually takes about 1ms to settle into this value, but, as you should see below, we will primarily be concerned with the first half of the period when we finally get to the actual Physics experiment.



The output voltage clearly shows the behavior we expect from a resonant circuit. Determine the resonant frequency from the plot and from the values of the circuit components. (4pts)

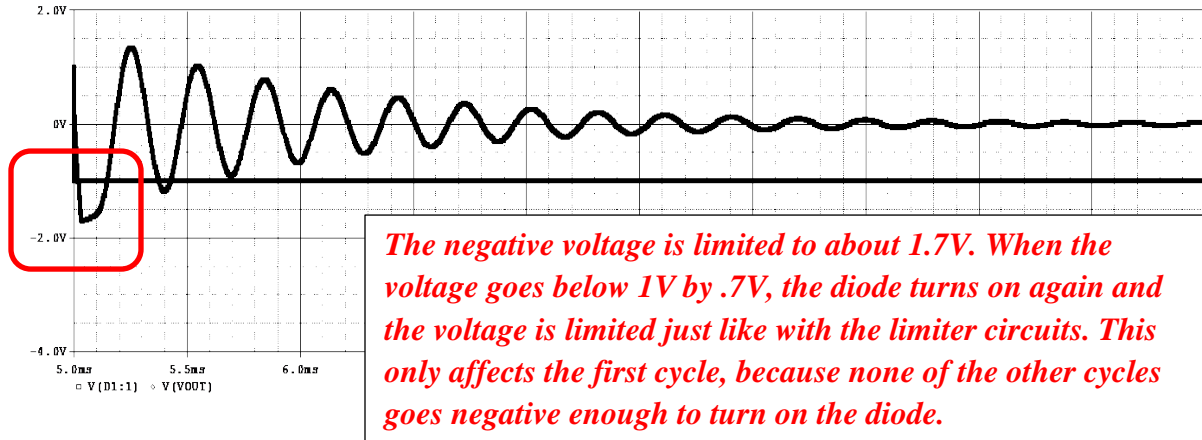
*From the plot,  $4T \approx 1.18\text{ms}$  or  $f = 3.4\text{kHz}$*

*From  $f = 1/(2\pi(LC)^{.5}) = 3.4\text{kHz}$*

*Answer can also be in terms of  $\omega$  which is  $2\pi$  larger or about 21,300 Radians*



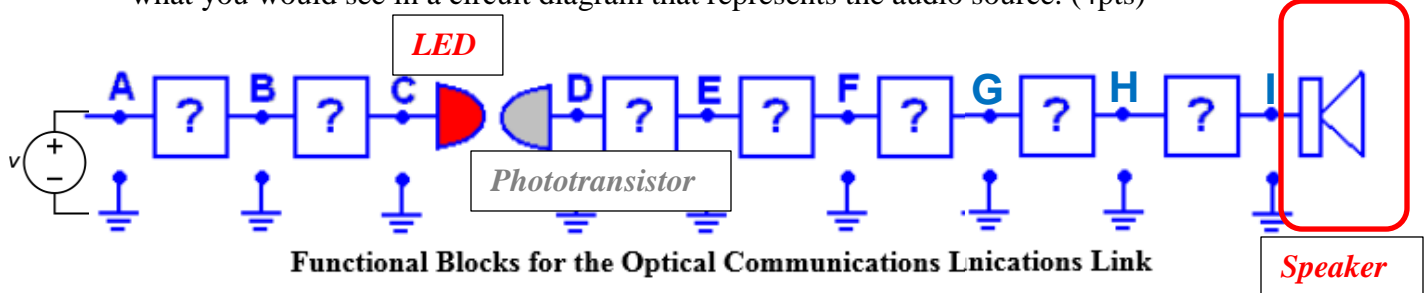
- c. In the Physics experiment, the input square wave oscillated between +1V and -1V, which significantly changes the output voltage. Again, both the input and output voltages are shown. Identify the big change in this signal and, from your knowledge of diode behavior, explain why it occurs. (5pts)



- d. **Extra Credit** Using the capacitor voltage you obtained in part a for the second half of the period, find the energy stored in the capacitor and in the inductor. (5pts)

*Answer:  $W_c = \frac{1}{2}CV^2$   $W_c = \frac{1}{2}LI^2$  The voltage is 0.3V, The current is determined by the resistance, the L impedance becomes zero in steady state.  $I = 0.3/40$ .*

- e. Optical Transmitter-Receiver Project – Shown below is the general diagram of the functional blocks for Project 4. Label the speaker, the LED and the phototransistor. Then add in the audio source using the appropriate circuit element or elements. That is, draw in what you would see in a circuit diagram that represents the audio source. (4pts)



- f. Next, identify each block below by indicating the node letters on either side. Then, explain the function of the block. For clarity, one of the elements has already been identified and its function described. (6pts)

- |                                    |  |
|------------------------------------|--|
| 1) Audio Amplifier <b>GH</b>       | 7) Bias Resistor & DC Blocking Capacitor <b>D – E Provides the DC bias voltage and current for the phototransistor and allows only the AC voltage to reach the pre-amplifier</b> |
| 2) DC Blocking Capacitor <b>AB</b> |  |
| 3) Pre-amplifier <b>EF</b>         |  |
| 4) Astable Multivibrator <b>BC</b> |  |
| 5) Matching Network <b>HI</b>      |  |
| 6) Volume Control <b>FG</b>        |  |