ENGR-4300

Electronic Instrumentation

Quiz 4

Spring 2012

Name ___________________________

Section ___

Question I (20 points) ____________

Question II (20 points) ____________

Question III (20 points) ____________

Question IV (20 points) ____________

Question V (20 points) ____________

Total (100 points) _______________

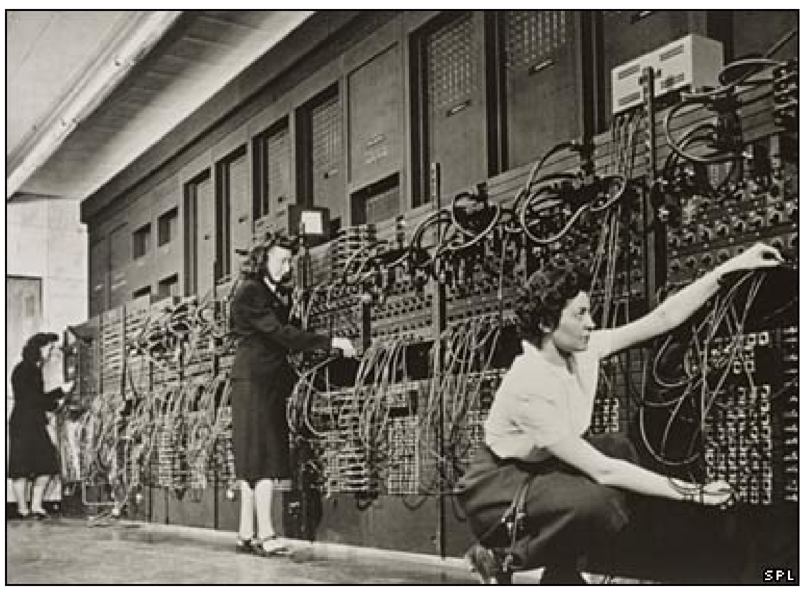
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES <u>AND UNITS</u>. No credit will be given for numbers that appear without justification.

GPS: On May 2, 2000 "Selective Availability" was discontinued as a result of President Clinton’s 1996 executive order, allowing users to receive a non-degraded signal globally. Initially, the highest quality signal was reserved for military use, and the signal available for civilian use was intentionally degraded.

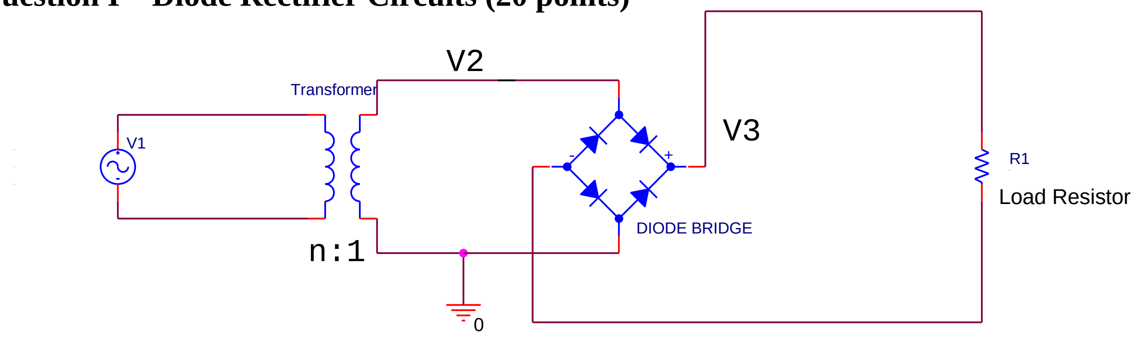
GARMIN™

Gary Burrell RPI MS EE ’63 co-founded Garmin International, a world-class manufacturer of GPS navigation systems.

ENIAC: On May 2, 1946 ENIAC, the first US computer was finished. (**Electronic Numerical Integrator And Computer)** The ENIAC was a modular computer, composed of individual panels to perform different functions. Twenty of these modules were accumulators, which could not only add and subtract but hold a ten-digit decimal number in memory. Besides its speed, the most remarkable thing about ENIAC was its size and complexity. ENIAC contained 17,468 vacuum tubes, 7,200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors and around 5 million hand-soldered joints. It weighed more than 30 short tons, was roughly 8 by 3 by 100 feet, took up 1800 square feet, and consumed 150 kW of power (leading to the rumor that whenever the computer was switched on, lights in Philadelphia dimmed). The task of taking a problem and mapping it onto the machine was complex, and usually took weeks. After the program was figured out on paper, the process of getting the program "into" the ENIAC by manipulating its switches and cables took additional days. This was followed by a period of verification and debugging, aided by the ability to "single step" the machine. The six women who did most of the programming of ENIAC were inducted in 1997 into the Women in Technology International Hall of Fame. Jennifer S. Light's essay, "When Computers Were Women", documents and describes the role of the women of ENIAC as well as outlines the historical omission or downplay of women's roles in computer science history. The role of the ENIAC programmers was also treated in a 2010 documentary film by LeAnn Erickson.



Question I – Diode Rectifier Circuits (20 points)



The diagram above shows the application of a diode bridge for performing rectification of the voltage from the output of the transformer. The sinusoidal source voltage V1 = $120V_{RMS}$ and R1 = 4.7kΩ.

1. (5pt) Knowing that the voltage amplitude is $\sqrt{2}$ larger than the RMS voltage, what transformer turns ratio n:1 will give as close as possible to a 9V amplitude at V2? (n should be rounded to an integer.)

$$120 * 1.414 = 169.68$$

$$169.68 / 9 = 18.85 \approx 19\ turns = n$$

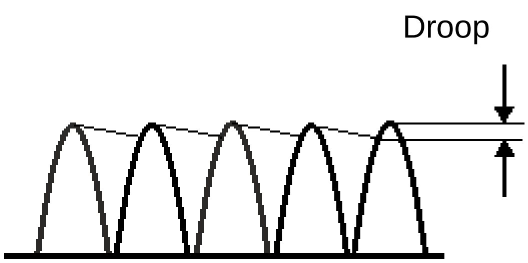
2. (5pt) What will the actual peak voltage be on the output of the full wave bridge (across R1). Let the idealized diodes have V_{on} = 0.7V and V2 is the voltage from the turns ratio in question 1?

$$V_{peak} = 9 - .7 - /7 = 7.6V$$

Question I – Diode Rectifier Circuits (continued)

3. (5pt) Given R1 above, what is the peak current that will flow through any of the 4 diodes?

The peak current is then the peak voltage divided by 4700 or about 1.6mA



4. (4pt) For a 50Hz input voltage V1 a capacitor is added in parallel with R1 to reduce the ripple in the voltage across the load resistance so that the droop from the peak value is less than 0.3V. Which of the following values is the minimum capacitance necessary to achieve this?

a) 1μF b) 4.7μF c)10μF d) 47μF e) 100μF f) 470μF

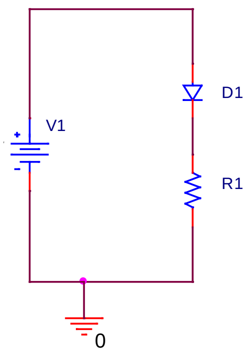
The time constant is τ=RC. The droop is 0.3V in half of the period of the 50Hz source. The peak voltage is about 7.6V so that the percentage droop is about 4% so that the time constant needs to be 0.1/.04=250ms and C=53uF. Thus the smallest value is 100uF.

Question II - LEDs and Phototransistor Circuits (20 points)

A white LED is driven by a standard DC source. The source we have is a combination of four 1.5 Volt batteries. We need a forward bias voltage of 3.3V and a current of 30 mA.

a) (*5pt*) Using the four 1.5 Volt batteries in series, **determine the resistance R1** necessary to achieve the desired operating conditions for the diode. Also determine the total power dissipated in the circuit.

6V



Current = 30mA = (6-3.3)/R or R=2.7/.03=90Ohms

Power = 6V(30mA)=.18W=180mW

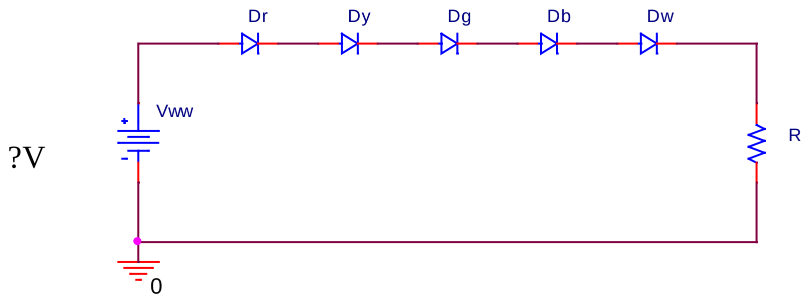
We now want multiple LEDs like a short string of Holiday lights. For this purpose, we will use five different color LEDs: Red, Yellow, Green, Blue and White. The five LEDs we have are found in the table below. Our Red LED is labeled Super Red in the table and all five LEDs are indicated in bold letters.

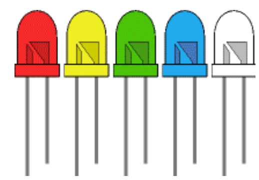
Color	Material	Wavelength (nm)	V-forward
Super Red	GaAlAs	660	1.8
Green	GaP	565	2
Red	GaAsP	645	2
Red	AlInGaP	646	2
Orange	AlInGaP	610	2
Yellow	AlInGaP	590	2
Amber	GaAsP	605	2.1
Red	GaP	700	2.1
Green	GaP	555	2.1
Green	AlInGaP	574	2.2
White			3.3
Blue	SiC	430	3.5
Green	InGaN	505	3.5
Blue	InGaN	470	3.5
White	InGaN		3.5
Green	InGaN	525	3.7
Green	InGaN	525	4
Blue	SiC	430	4.5

Question II - LEDs and Phototransistor Circuits (continued)

For the power supply, we will use a universal AC adapter that can output one of the following voltages (switch selectable): 3V, 6V, 9V, 12V, 15V, 18V, 21V or 24V. Power is limited to 20W. For the next two questions, you must select the minimum voltage from the power supply.

b) ***(5 pt)*** **Determine the voltage Vww and resistance R** to achieve the desired operating conditions for the series combination of 5 LEDs shown below. Assume that the current is 30mA, 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.





The sum of the 5 on voltages is (1.8+2+3.3+3.5+4.5)=15.1V

The next larger voltage is 18V so we choose that voltage for Vww.

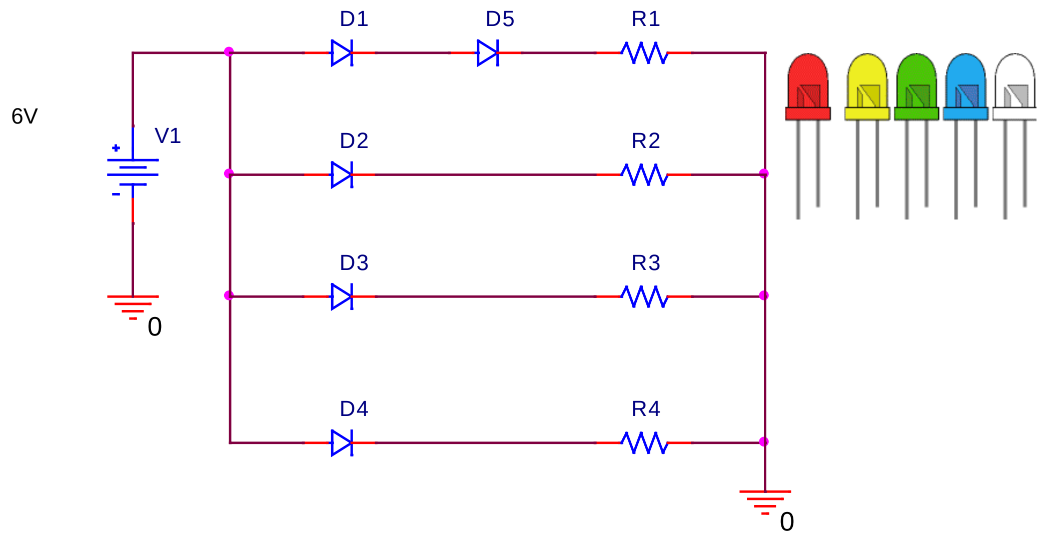
The resistance is determined by the current limit of 30mA=(18-15.1)/R or R=97Ohms

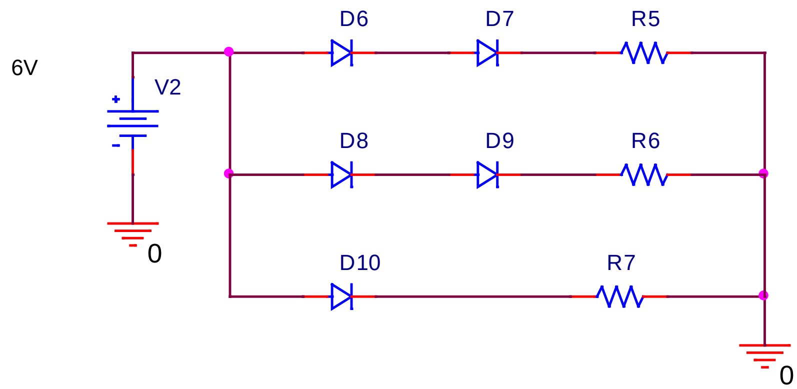
Checking I=(2.9/97)=0.030A so it does check.

Question II - LEDs and Phototransistor Circuits (continued)

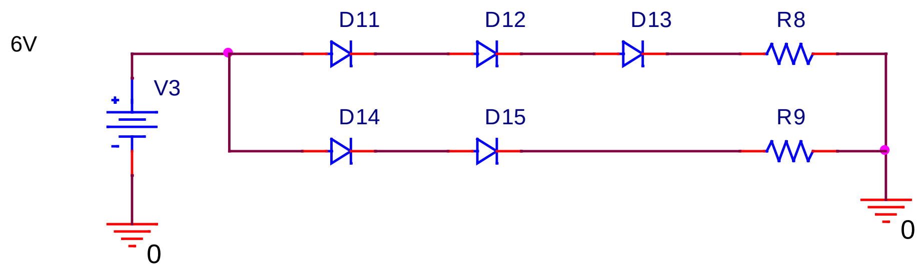
c) *(5 pt)* **Determine the configuration and resistances** to achieve the desired operating conditions for the series/parallel combination of 5 LEDs if we are limited to only the 6V source we can configure with the four 1.5V batteries and you are to use the minimum number of components required to light up all five LEDs. Assume that the current in each of the LEDs is 30mA, since we have to be limited to the smallest maximum current for any of our seven 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.

The 5 on voltages are 1.8 2 3.3 3.5 4.5. The simplest (least components) design is the last one, so let's see if we can make that one work. Then try the second one, etc. Shown is one solution. Are there others?





1.8 2 3.3 3.5 4.5. Let D10 be 4.5, then 1.8+3.5=5.3 and 2+3.3=5.3 so this one can work. The first leg resistance is (6-5.3)/.03=24Ohms, the second is (6-5.3)/.03=24Ohms, and the last is (6-4.5)/.03=50Ohms.



Starting from 1.8 2 3.3 3.5 4.5, the first three add to 7.1 so there is no combo that works.

d) (5pts) Determine the total power dissipated in the circuit that achieves the desired operating conditions.

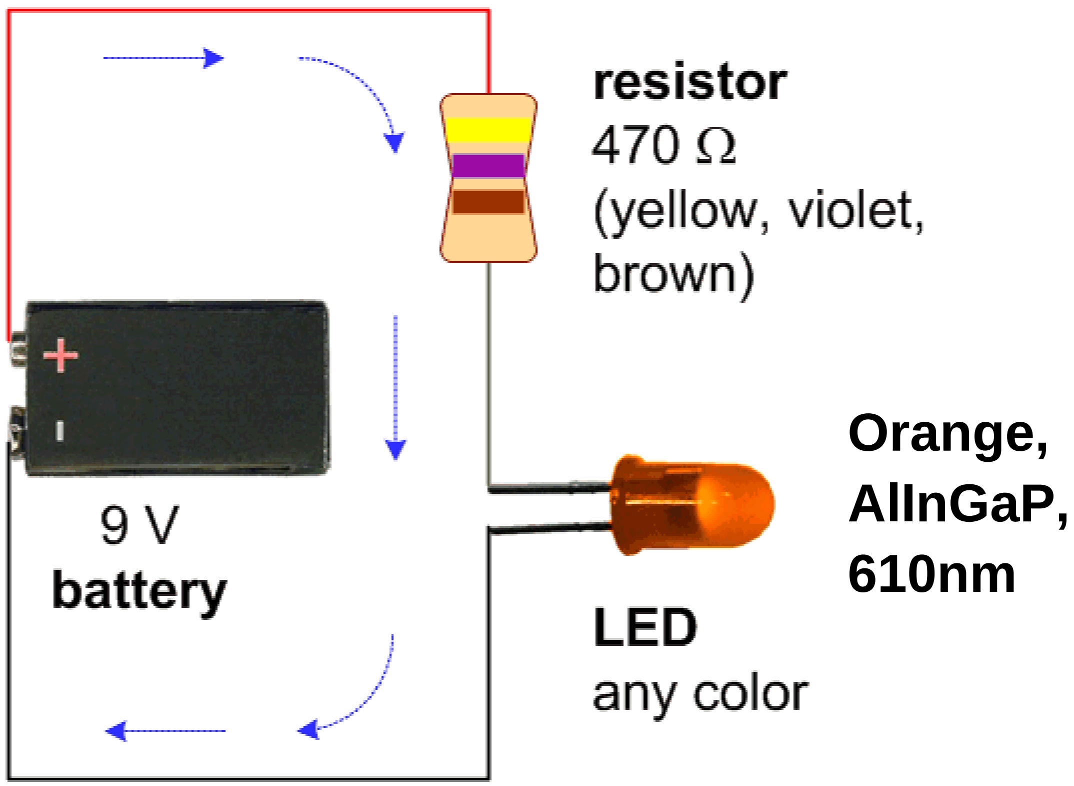
Again, the answer is pretty simple because there are 3 parallel legs, each of which consumes 30mA or the power is 6(90mA) = 540mW = .54W

Question III Multiple Choice & Short Answer Questions (20 points)

For multiple choice, circle the correct answer. All questions are 2pts.

a. The dc current through each forward-biased diode in a full wave bridge rectifier equals:
   a. The load current
   b. Near zero current
   c. Twice the dc load current
   d. Near infinite current

b. What is the current through the LED, if we use the specified orange LED?



An LED schematic with a 9V battery, 470 ohm resistor, and a single LED of any color.

   a. 0 mA
   b. 4.5 mA
   c. 12 mA
   d. 15 mA

I=(9-2)/470=15mA

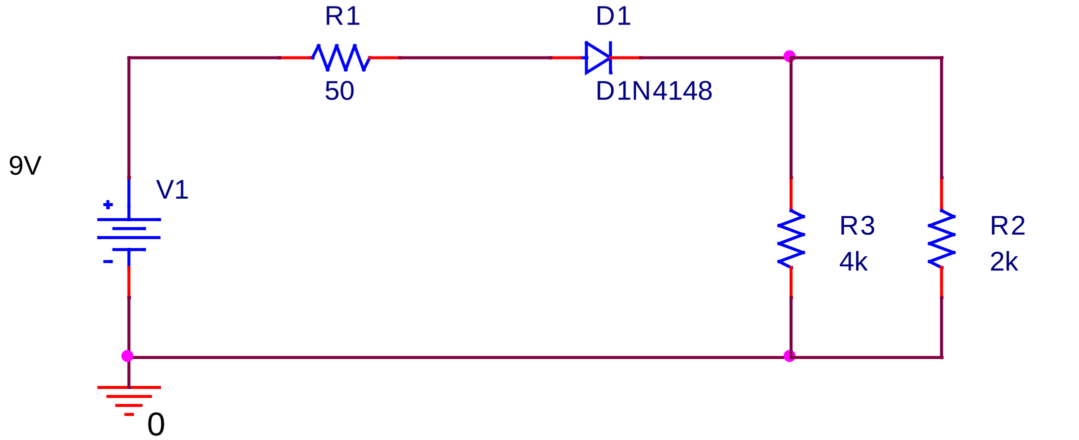
Question III Multiple Choice & Short Answer Questions (continued)

c. A filtered full-wave rectifier voltage has a smaller ripple than does a half-wave rectifier voltage for the same load resistance and capacitor values because:
   a. There is a shorter time between peaks
   b. There is a longer time between peaks
   c. The larger the ripple, the better the filtering action
   d. None of the above

d. Testing a good diode with an ohmmeter should indicate
   a. High resistance when forward or reverse biased
   b. Low resistance when forward or reverse biased
   c. High resistance when reverse biased and low resistance when forward biased
   d. High resistance when forward biased and low resistance when reverse biased

e. The peak forward voltage across a conducting diode in a full-wave bridge rectifier equals approximately:
   a. Twice the on voltage for the diode
   b. Twice the peak value of the secondary (output) voltage
   c. The peak value of the secondary (output) voltage
   d. The on voltage for the diode

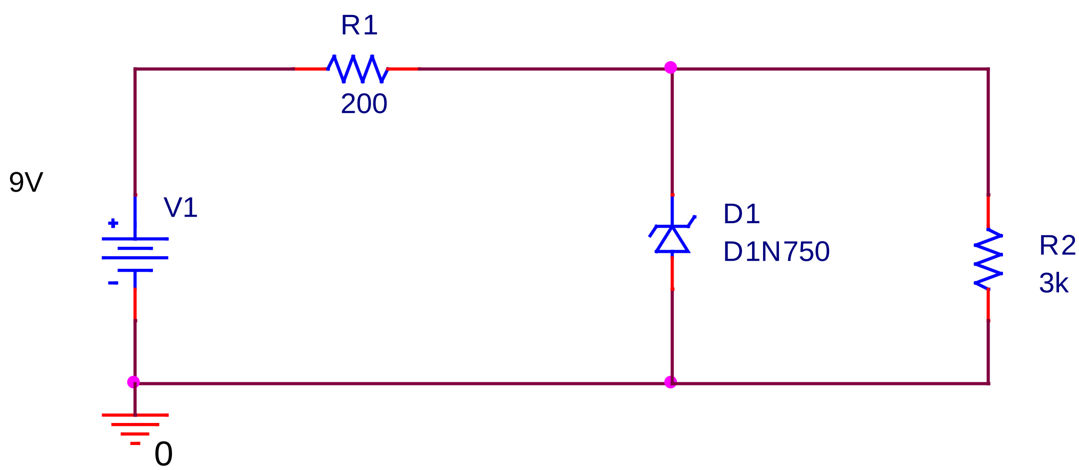
f. What is the current through the diode?



a. 4.5 mA
b. 3 mA
c. 6 mA
d. 2.5 mA

I=(9-.7)/1383=6mA (the total resistance is the parallel combo of 4k and 2k which is 1.3333K added to 50 or 1383)

g. What is the current through the zener diode? $V_Z = 4.7V$



a. 10 mA
b. 20 mA
c. 30 mA
d. 40 mA
e. 0 mA

I_{total}=(9-4.7)/200=21.5mA, $I_{resistor}$=4.7/3k=1.6mA, so I_{zener}=21.5-1.6=19.9mA

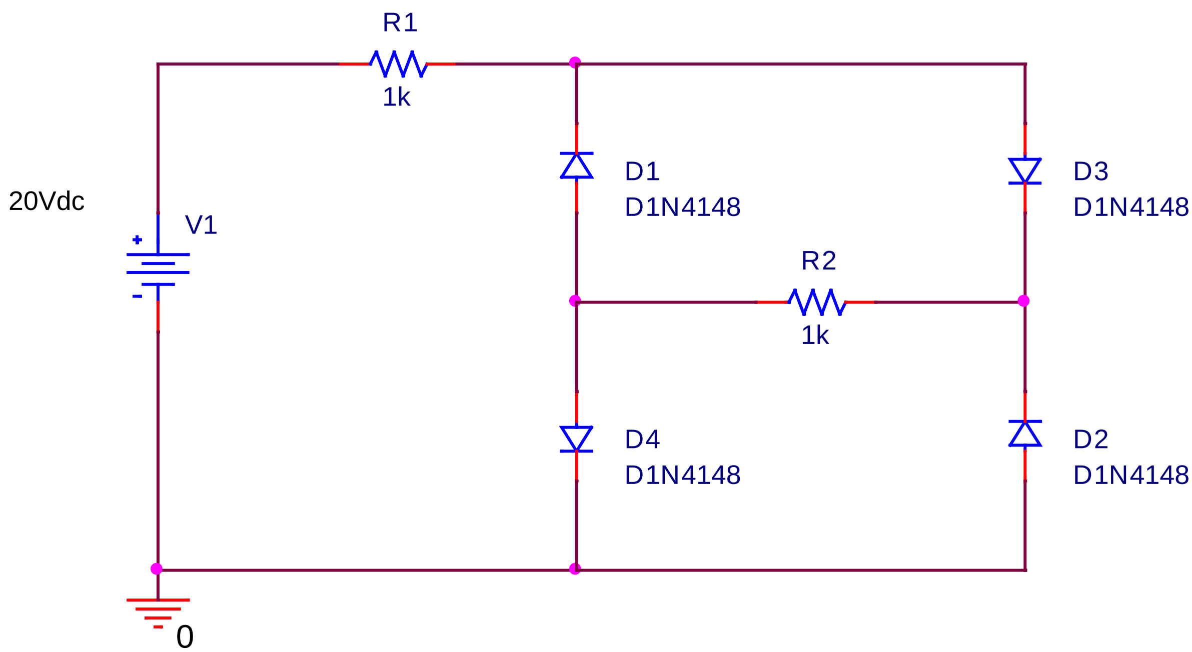
Question III Multiple Choice & Short Answer Questions (continued)

h. When a diode is reverse biased, the voltage across it
   a. Is directly proportional to the current
   b. Is inversely proportional to the current
   c. Is directly proportional to the source voltage
   d. Remains approximately the same no matter what the current is

i. When checking a diode, low resistance readings both ways indicate the diode is:
   a. Open
   b. Satisfactory
   c. Faulty
   d. Not the problem

j. What is the current through the load resistor R2?
   a. 0 mA
   b. 3 mA
   c. 6 mA
   d. 9 mA
   e. 12 mA

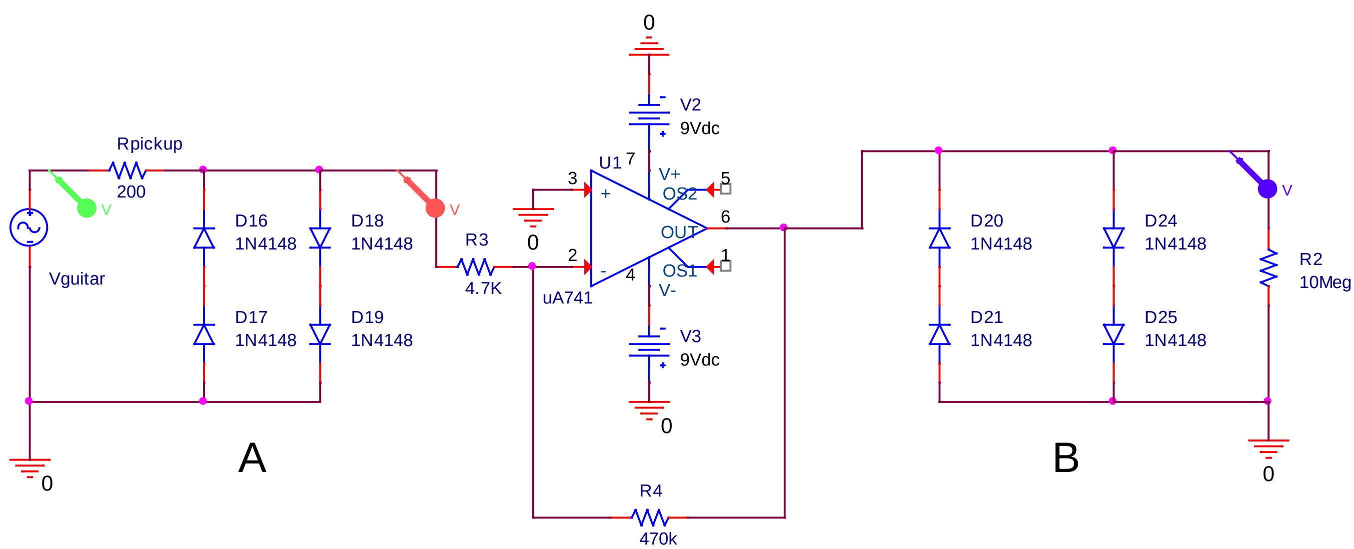
The current is the same through R1 and R2 and is given by (20-1.4)/2k=18.6/2k=9.3mA



Question IV - Diode Limiter vs. Op-Amp Saturation (20 points)

Hint: To answer the questions most efficiently in this problem, you should treat the diodes as ideal with a finite turn-on voltage.

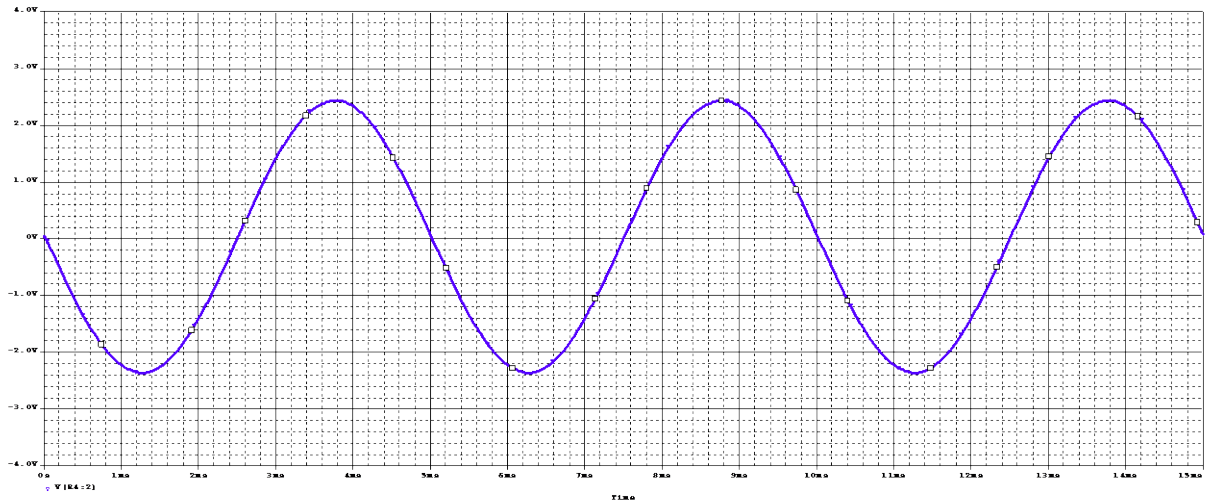
To show the general public the usefulness of the Mobile Studio, we use a one string 'electric guitar' with a homemade magnetic pickup. The voltage signal from the pickup is reasonably small so we use a simple inverting op-amp to increase the voltage level to something easily observed using either the oscilloscope or spectrum analyzer. The latter display is a lot of fun for musicians because it can clearly show the mix of harmonics generated by the string. Because children can get a little too exuberant as they pluck the string, we would like to limit the voltage output to the Mobile Studio so it stays on the display. For simplicity, assume that the peak-to-peak voltage is to be limited to about 5V. The circuit is shown below. In this circuit, all of the diodes are 1N4148 (0.7V forward voltage), the resistance of the pickup is 200Ω, the resistors in the op-amp are 4.7kΩ and 470kΩ, the op-amp is powered by two 9V batteries and the input impedance of the Mobile Studio is 10MΩ.



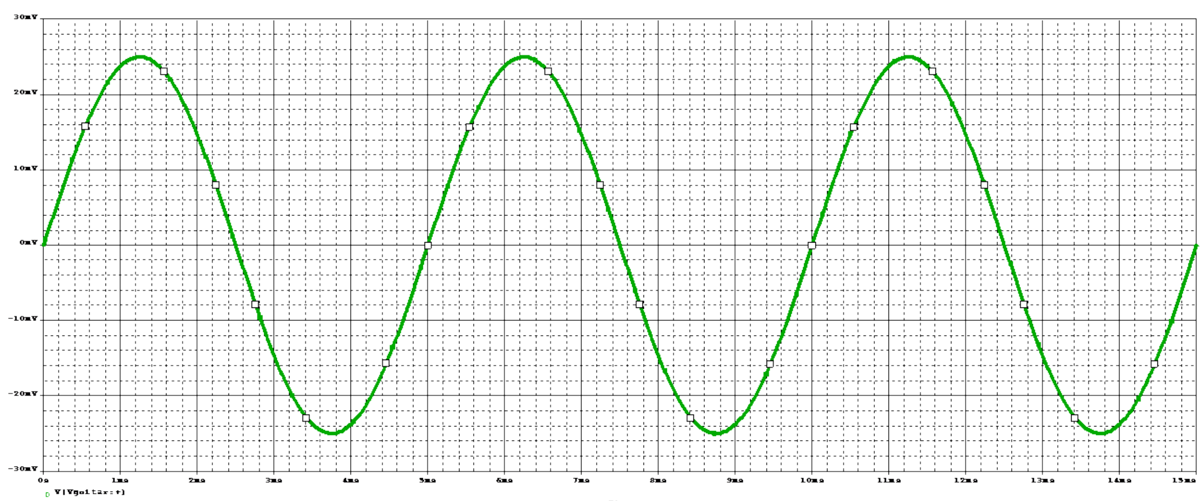
Two different circuit configurations are considered, each of which involves the use of diodes to limit the input to a simple non-inverting op-amp amplifier. All components used are the same as the ones used in class. The only difference between the circuits is where the diodes are placed in the circuit: either right after the pickup at point A or at the input to the Mobile Studio at point B. Note that in the figure the number of diodes shown is 4 for both cases. These are shown only as examples. You must decide how many diodes to use and where to put them in the circuit. You should use the minimum number of diodes that permits 5V peak-to-peak to be observed on the Mobile Studio. Thus, your design will permit a little more than 5V peak-to-peak but should not go over 8V peak-to-peak so that the 500mV/div scale can be used on the Mobile Studio.

Question IV - Diode Limiter vs. Op-Amp Saturation (continued)

Shown on the plot below is the output signal we wish to display on the Mobile Studio. The vertical scale goes from -4V to +4V and the horizontal scale from 0s to 15ms.



a. Before selecting the location and number of protection diodes, determine the approximate voltage produced by the guitar pickup that results in the measured voltage shown above and plot it on the figure below. Choose a vertical scale so that the voltage can be clearly read. (6 pts)

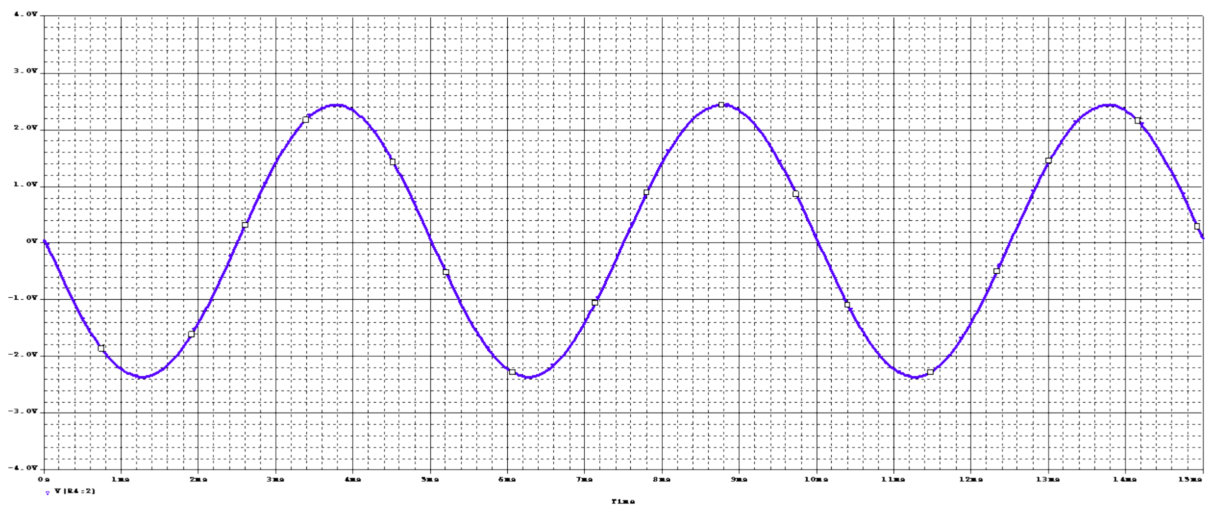


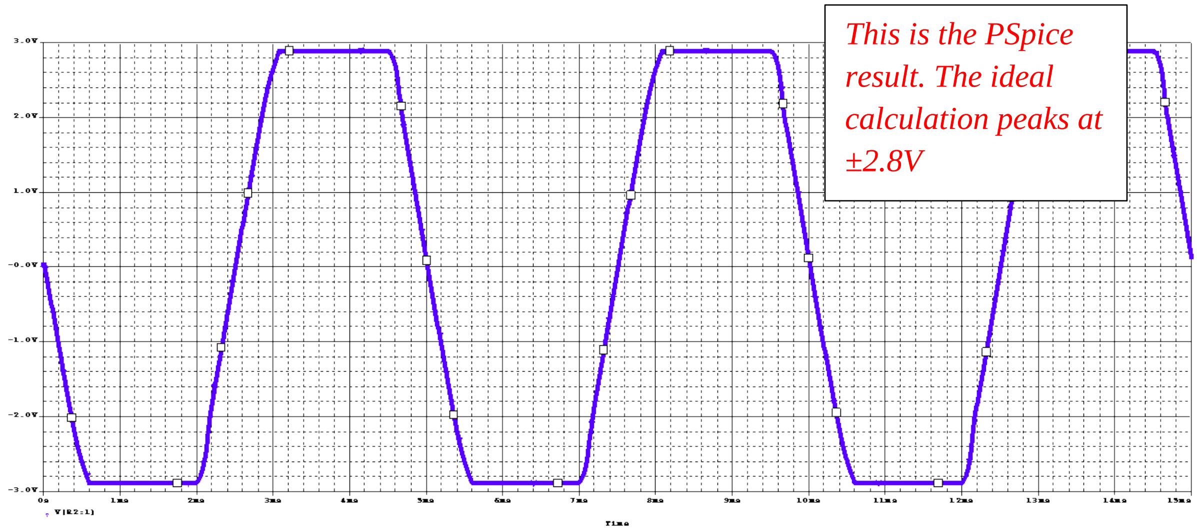
The peak-to-peak input voltage must be 5V(4.7k/470k = .05V or 50mV so the amplitude is 25mV. Note that the signal must also have the opposite sign.

b. Next, choose the location and number of diodes that allows the 5V peak-to-peak signal to be observed by the Mobile Studio oscilloscope but restricts voltages that are a little larger. Because we can only use the 1N4148 diodes, we have to allow signals that are a little larger but not too much larger. (6 pts)

To permit the 2.5V amplitude requires adding 0.7 to itself until the sum exceeds 2.5V or 4 diodes will do it adding up to 2.8V. They have to be in position B because the input voltage is too small to be limited by even a single diode.

c. To show how your design works, assume that the voltage produced by the guitar pickup is 50mV. Plot the voltage observed by the Mobile Studio oscilloscope on the figure below. The 5V peak-to-peak signal is shown for reference. (This is the same figure shown at the beginning of this problem.) (8 pts)

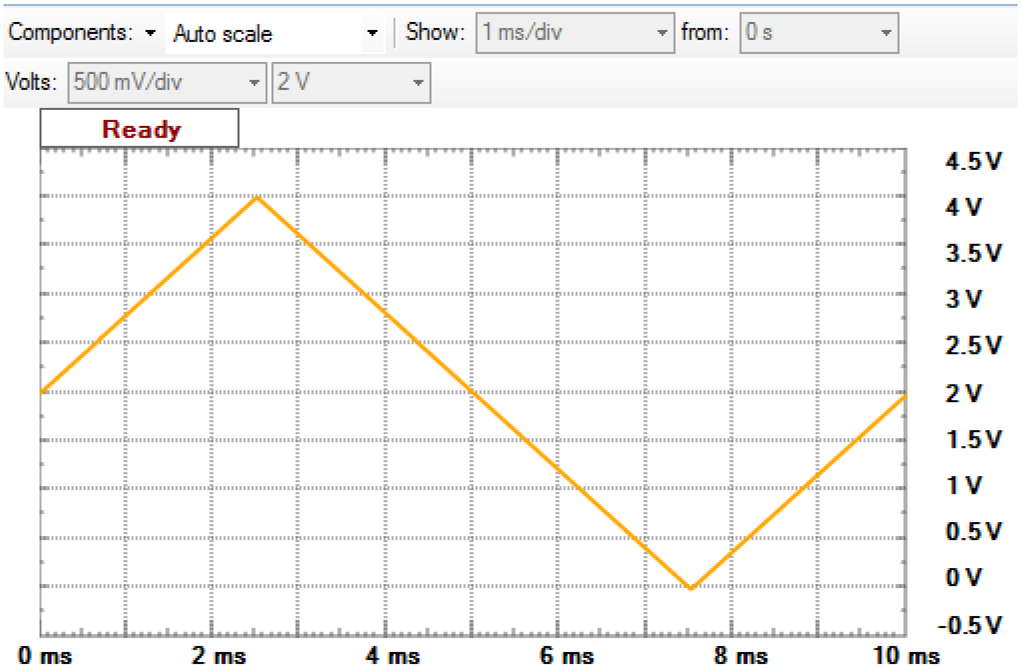




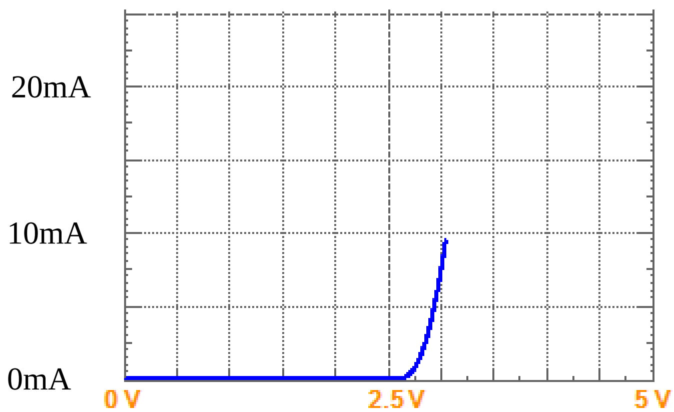
This is the PSpice result. The ideal calculation peaks at ±2.8V

Question V – LED: System Model (20 points)

A single blue or green diode is connected in series to a function generator through a 100Ω resistor. The function generator produces a triangular voltage with an amplitude of 2V, a DC offset of 2V and frequency of 1kHz, as shown below.



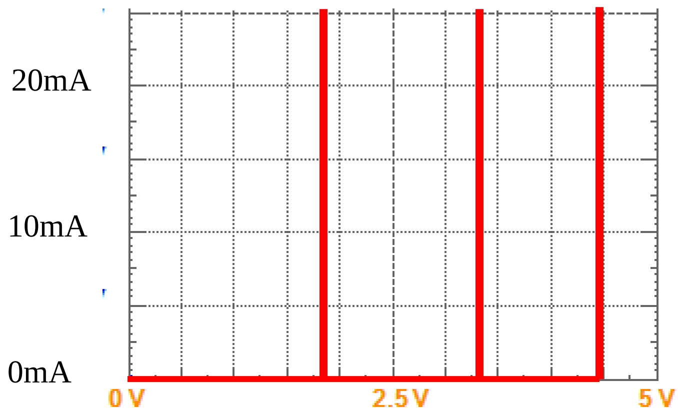
This circuit configuration is used to generate the following LED I-V characteristic.



In this problem, you are compare the results from ideal diode models, simulation and experiment. Note that this LED can handle a lot more than 10mA of current but the experiment was limited to accommodate LEDs that generate other colors.

Question V – LED: System Model (continued)

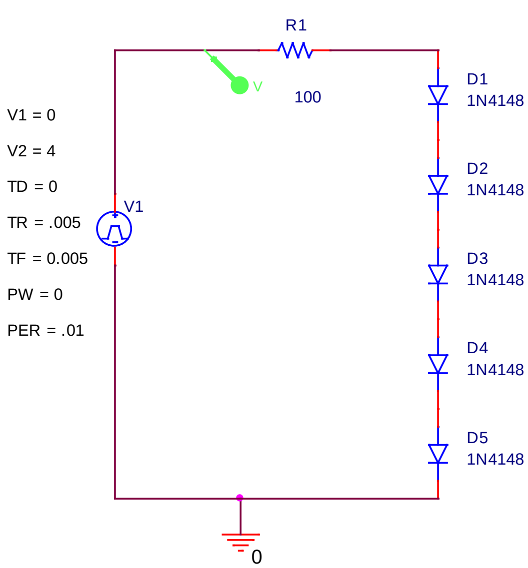
a. For three of the green and/or blue LEDs listed in the table in problem 2, carefully sketch the ideal I-V characteristic for the V_{on} model. The three LEDs should be chosen to show the range of possible values. Be sure to indicate which LEDs you have chosen. (6 pts)



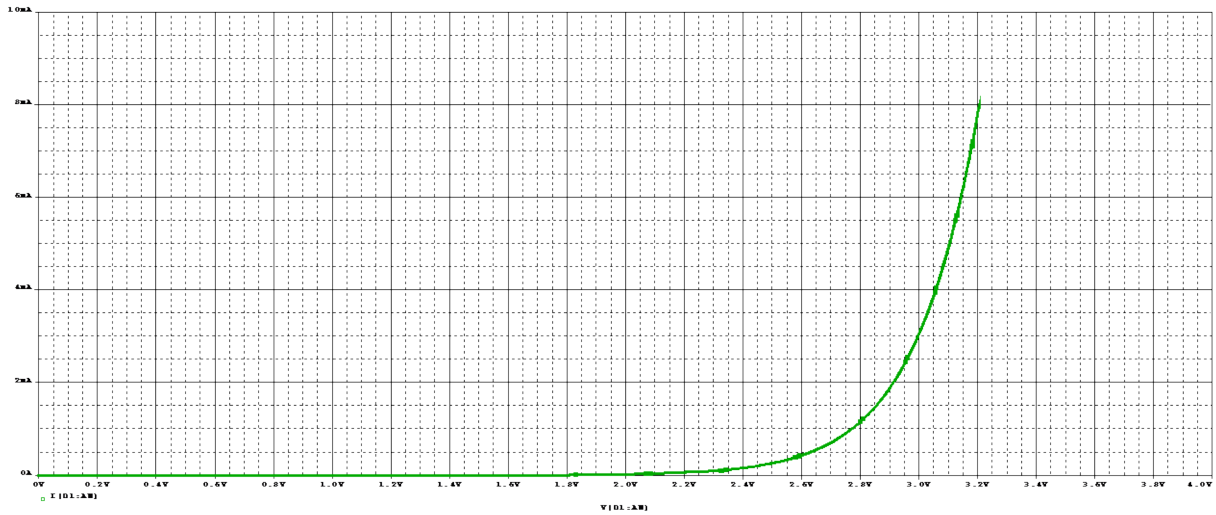
The three most different LEDs are Super Red, White and Blue (1.8, 3.3, 4.5) so there will be vertical lines at each of these voltages.

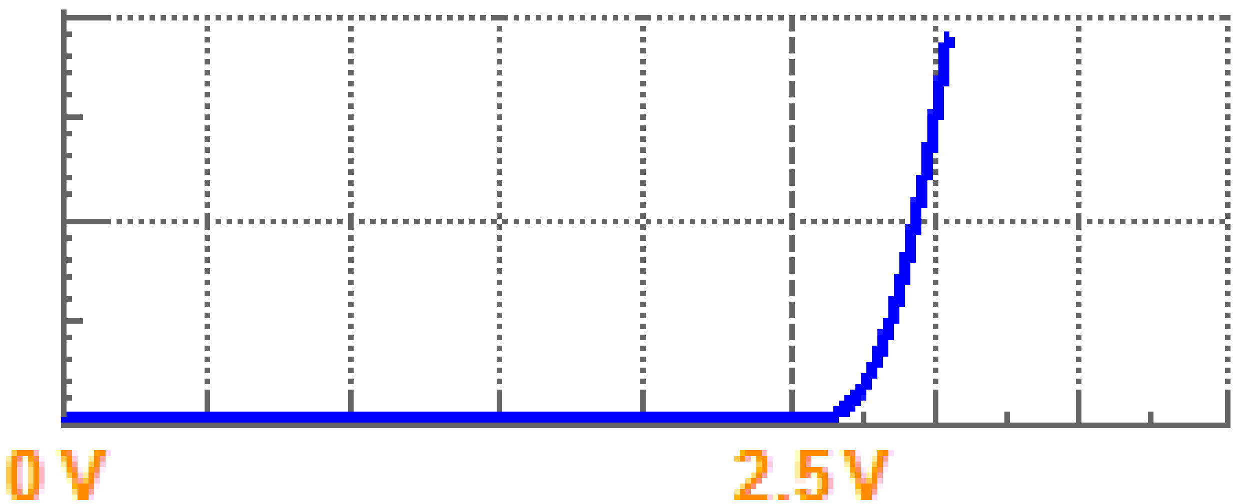
b. Selecting one of the typical green LEDs (forward voltage 3.5V), it is decided to try to model it with PSpice. Unfortunately, we do not have an LED model in our library, so we decide to try some 1N4148 diodes in series to achieve approximately the same forward voltage. How many 1N4148 diodes do we need for this purpose? Draw the circuit diagram below showing the voltage source, the resistor and the diodes. Be sure you include a ground somewhere in your diagram. (6 pts)

This requires 5 diodes so that 5x.7=3.5V and the circuit diagram looks like:



c. The output from PSpice, showing the I-V curve for the combination of 1N4148 diodes that produces a forward voltage of 3.5V is shown below. The vertical scale goes from 0 mA to 10mA and the horizontal scale from 0 to 4V. The experimental plot is also shown in expanded form to facilitate comparisons with the PSpice output.





In what ways are the two curves similar? (4 pts)

They begin to turn on around 2.5V and look like they will be fully on around the 3.5V of the LED. They also remain fully off for a significant range of voltages. These are two ways of saying the same thing. The total current drawn is around 10mA for the condition where they are as fully on as our voltage source will permit.

In what ways are they different? (4 pts)

The peak current for the PSpice model is a little less, the model begins to turn on before the actual device. The slope of the model in its on condition is less.

Can you explain any of the differences? (Extra credit)

One obvious difference is that the smaller slope of the model means that the maximum voltage observed is greater. This leaves less voltage across the current limiting resistor so that the current will be less, as it is.