Electrical Engineering 110L Circuits Measurements Lab
Lab 1: Resistors and Basic Instrumentation

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Lab Section: EE 110L Lab 1

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1 Objective

The objective of this lab is to practice with basic instruments such as the DMM and the DC shunt milliammeter. We will be using the DMM to measure the resistance and DC voltage within the lab and then use the DC shunt milliammeter to measure DC current in circuits. Our other objective is to understand how to operate the DC shunt milliammeter and its disturbance on currents and voltages in the circuit as measurement is taken with the device. By the end we should be competent with the lab devices and understand the color code and power rating for resistors.

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2 Theory

In this lab we will be using a resistor which is an element of the circuit that converts energy of electrons to heat. This is governed by the equation:

[1] $P = I^2R = V^2/R = VI$	|| I = current (A), P = power (W), R = resistance (Ω)
[2] $V = IR$	|| V = voltage (V)
[3] $I_{meter} = I*R_{shunt}/(R_{shunt}+R_{meter})$	|| (This equation will be use find maximum current I.)
[4] $V = (P*R)^{1/2}$	|| Max voltage can be applied to resistor (derive from [1])

Reading resistor's value will require understanding of the color values. This is the general equations that give the resistor's resistance. $R = (1^{st}2^{nd})\text{x}10^{3rd}\ \Omega \pm 4^{th}$

The 1^{st} denote the first color band, 2^{nd} denote the second color band and so on. Plugging in the values into the respective location will give the resistance and tolerance of the resistor.

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3 Procedure

Lab experiment 1:

Read resistor color code and find one within 47 to 50 k Ω. Find tolerance and power rating. Find next nearest value resistors with same tolerance. Measure the resistor's resistance with the DMM to find uncertainty and see if it is within its tolerance.

Lab experiment 2:

Obtain the necessary equipment and create a circuit. Things to consider during the process:

- voltage and current for you resistor and its power rating
- internal resistance of your milliammeter
- Find correct shunt for the circuit
- Draw complete circuit diagram and calculate power supply voltage

Finish power supply setup and turn it on and adjust voltage. Next measure the voltage using the DMM and adjust power supply until it reaches the measure resistor voltage. Find current and calculate V/R to compare. Repeat with three other voltages.

Lab experiment 3:

Replace resistor with the ¼ Watt 50 ohms – 100 ohms resistor. Now begin the experiment by increasing voltage by increments of 1 V. With the collected data graph R vs. V.

Lab experiment 4:

Replace current resistor with at least 100 ohms resistor but not over 500 ohm. Reset voltage until current is 0.8mA then measure voltage and current. Replace ammeter with a wire and measure the voltage drop.

Lab experiment 5:

Treating the light bulb as a resistive load we repeat the same method as before. This time there will be at least 10 different voltage points up to 6 V. plot V vs. I.

4 Prelab

Prob. 1: What is the maximum current you can read on the milliammeter with each shunt?

(R_m=43 ohms)

Shunt Resistance	Maximum Current
Small shorting block	1 mA
4.8 Ω	9.96mA
1.8 Ω	24.89mA
1.0 Ω	44.00mA
0.173 Ω	249.56mA
0.0862 Ω	499.84mA

Prob. 2:

Voltage	I_{100}	I_{1000}
1 Volt	10mA	1mA
2 Volts	20mA	2mA
3 Volts	30mA	3mA
4 Volts	40mA	4mA
5 Volts	50mA	5mA

Prob. 3:

	I	V_{43}	V_{47}	V_{100}
47 Ω	1/90A	43/90V	47/90V	-----
100 Ω	1/143A	43/143V	-----	100/143V

Prob. 4: (Added Question) What are the difference between light bulb resistor, thermistor, and photoresistor?
Light bulb resistors are good in producing light, thermistor's resistance vary greatly with temperature, and photoresistor's resistance decrease with increasing incident light intensity.

Prob. 5: Resistor are linear or nonlinear or both and why?
In the non-ideal world there is no such thing as a linear resistor and only nonlinear resistor exist. But in the simplified case resistor are both meaning that some remain approximately linear until a certain threshold where it becomes nonlinear.

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5 Data

Experiment 1:
Color: brown, brown, red, gold → Give resistor's resistance of R: $11 \times 10^2 \pm 5\%$ Ω the tolerance is 5% and power rating is ¼ Watt. The next nearest value resistors with the same tolerance are the 10 and $11k\Omega$.
The DMM recorded R to be 1101Ω. (Uncertainty done in Data Analysis)

Experiment 2:
The milliammeter has an internal resistance of 44.2Ω. When the DC generator generates 10.1V we obtain .86mA through the millimeter and 10.02 V through the resistor. Below are the measured and calculated values during this experiment.
The resistor resistance we pick up is green, blue, black, gold → 56Ω resistor with 5% tolerance but the DMM measure it to be **67.7Ω** which is not within the tolerance.
F.

	R_{shunt}	R_m	I_m	I_{total}
Measured Value	4.7+/-.05Ω	44.2+/-.05Ω	0.86+/-.005mA	9.10mA
Lowest	4.6Ω	44.15Ω	0.855A	8.803mA (calculated)
Highest	4.74Ω	44.24Ω	0.864A	9.101mA (calculated)

G.

Voltage (V)	Current (mA)	I_total (A)	Resistance (Ohms) = V/I
10.1+/-.05	0.86+/-.005	(8.78+/-0.05)E-03	1150+/-9
7.3+/-.05	0.63+/-.005	(6.43+/-0.05)E-03	1135+/-12
5.7+/-.05	0.49+/-.005	(5.00+/-0.05)E-03	1139+/-10

4.8+/-.05	0.41+/-.005	(4.19+/-0.05)E-03	1146+/-11

Experiment 3:

V_R (V)	$I_{milliammeter}$(mA)	I_{total} (mA)	Resistance (Ohms) = V_R/I_R
2.4+/-.05	0.14+/-.005	35.9+/-1.3	66.8+/-2.8
3.4+/-.05	0.20+/-.005	51.3+/-1.3	66.3+/-2.8
4.4+/-.05	0.25+/-.005	64.1+/-1.3	68.6+/-2.8
5.4+/-.05	0.32+/-.005	82.1+/-1.3	65.7+/-2.8
6.4+/-.05	0.38+/-.005	97.5+/-1.3	65.7+/-2.8
		Average Resistance:	66.6+/-2.8

The highest voltage in which we can still pinch the resistor is at 6.4V.
Explanation is in Data Analysis section.

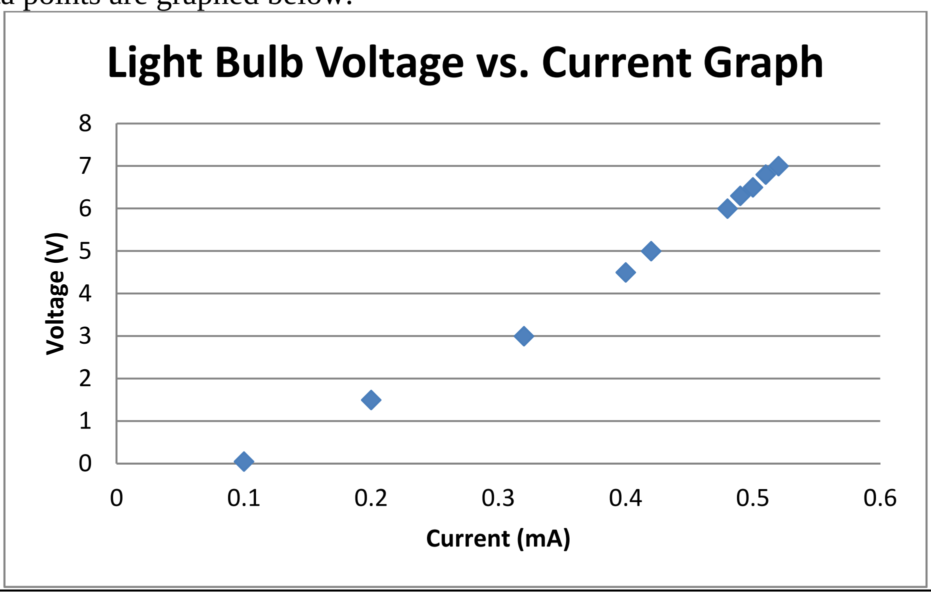
Experiment 4:

Resistor's resistance 200+/-20% Ω

- Measuring voltage across resistor only we get 1.560+/-.0005V.
- Measuring voltage and current across resistor we get 1.594+/-.0005V.

Experiment 5:

In this part of the experiment we measure the voltage and current at 10 different points. The resulting data points are graphed below.



6 Data Analysis

Experiment 1:
Uncertainty in measurement:

Value From	Resistance Ω	Uncertainty
Color Code	1100	1045-1155

DMM	1101	1100.5-1101.4

Yes the resistor is within its tolerance range. The largest safe voltage we can safely apply to the resistor is given by the equation [4].

$$V = (0.25*1101)^{1/2} = 16.59+/-0.8 \text{ V}$$

Experiment 2:
Look at data section experiment 2. The total current we obtained 9.1mA falls within the expected range that is in the I_{total} calculated column. For our experiment 2 part G our V/I data are very consistent and falls within the resistor's tolerance. The standard deviation for the 1.1kΩ resistor is 6Ω. This means that the values are really similar and close to a constant around 1.1kΩ. Note that the I_{total} can be calculated from equation 3 with some simple algebraic manipulation.

Experiment 3:
For our experiment 3 our V/I data are very consistent and falls within the resistor's tolerance of 5%. The measured value from the DMM is 67.7 Ω and the experimentally calculated value fall close it that value. The value average of all the measured resistance has only a 1.6% error when compared to the DMM measured value. The standard deviation is at 1.07 which is a small value as well meaning the measured value is consistent. This also go to show that V varies linearly with I.

Experiment 4:
There is a change in voltage since the ammeter has its own resistance. By placing the ammeter in series with the resistor there is a change in voltage since some of the voltage is spend in the ammeter. The one without the ammeter is correct. The voltage for the circuit with the ammeter is a different circuit compare to the one without the ammeter. The disturbance is most important when we try to measure the current and voltage at the same time. This will give us incorrect result.

Experiment 5:
The graph is definitely not a linear V=IR graph where R happens to be the light bulb's resistance. It appears that the resistance changes. This reason is probably because a light bulb is a light and heat producer. Its resistance changes as heat and light is produce due to high temperature difference.

7 Error Analysis

The general equation is F(x_1, x_2,…, x_n) so the error for F (identified as σ_F) would be given by the following error propagation equation:

$$\sigma_F = \sqrt{(\frac{dF}{dx_1}\sigma_{x_1})^2 + (\frac{dF}{dx_2}\sigma_{x_2})^2 + \cdots + (\frac{dF}{dx_n}\sigma_{x_n})^2}$$

Experiment 1:
Uncertainties are calculated from the tolerance. See section 6 Data Analysis Experiment 1. In this case the resistor's resistance was within the tolerance.

The error propagation equation was used to calculate for the error 16.59+/-0.008 V for the maximum voltage. (Assuming power is exact.)
% error = |1101-1100|/1100 *100%= 0.1% error of the actual label value.

Experiment 2:
The uncertainty is calculated and listed in the Data page (listed as lowest and highest possible values).

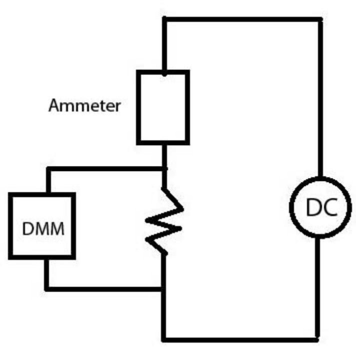
Experiment 3:
Check experiment 3 in data analysis section. Percent error and standard deviation are given there.

Experiment 4:
View data analysis section tables for error propagation calculation if any are required.

Experiment 5:
View data analysis section. Errors are calculated using the error propagation formula.

8 Discussion

1. That would give us about 7.5x10^-4 kWh and relates to about .009 cents. This is definitely not even close to our tuition. The light bulb did not violate Ohm's law since the resistance of the light bulb changes with temperature. But the relationship of V and I should still be linear.
2. This unusual spacing is to prevent students from inserting the shunt the wrong way and shorting out the circuit due to high current. The 3 plugs will stop the current from flowing and protect the ammeter once it is pulled out.
3. The highest voltage was 6.4V. Assuming the resistance is 67.7 Ω measured with the DMM is correct we have about .6 Watts. The power rating is ¼ Watts which was clearly over.
4. Again part 4 we obtain 2 values because of the ammeter taking a portion of the voltage from the overall. With the ammeter remove that is the correct voltage. The disturbance is most important when we try to measure the current and voltage at the same time. This will give us incorrect result voltage results.
5. The diagram below shows a circuit in which the ammeter will be affecting the voltage measurement.



9 Conclusions

In conclusion, we were able to become familiar with the lab equipment. We also verify that V varies linearly with I as long as resistance remains constant. In the light bulb case the resistance changes so Ohm's law was not violated. In the experiment we learn that measuring both current and voltage at the same time will lead to inconsistent voltages. The measurement for voltage and current should be done separately for accurate voltage measurement. Overall the experiment was a great success.