# ENGR 210/EEAP 240
Background

In the class lectures we have discussed the fundamental electrical quantities of voltage, current and resistance. Since these quantities are so important there are specialized instruments to measure these individually. One of the most useful instruments can measure all three quantities (as well as quite a few more) is called a digital multimeter (usually abbreviated to DMM). Labs 1 and 2 and computer animated labs which will carry you through the process of using the Digital Multimeter and a voltage source (a power supply) to measure voltage, current and resistance to verify Ohm's Law (Lab 1) and to determine the behavior of resistors connected in series and parallel (Lab 2).

The resistors you will use are physically cylindrical objects which are about 1/8-th of an inch in diameter and 1/2 inch long with a wire lead coming out of each end of the cylindrical body. The wires are for connecting the resistor into your circuit. The actual size of the resistor will depend upon its power handling capability — the resistors you will be using in the physical lab are typically rated at 1/8-th watt. A resistor's value is labeled on the cylindrical body using a color code as indicated below.

RESISTOR COLOR CODE
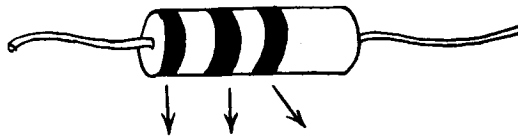
BLACK	0	0	x	1
BROWN	1	1	x	10
RED	2	2	x	100
ORANGE	3	3	x	1,000
YELLOW	4	4	x	10,000
GREEN	5	5	x	100,000
BLUE	6	6	x	1,000,000
VIOLET	7	7	x	10,000,000
GRAY	8	8	x	100,000,000
WHITE	9	9	x	-

AN OPTIONAL FOURTH BAND INDICATES TOLERANCE (ACCURACY)
GOLD= ±5% SILVER=±10% NO BAND INDICATED ±20%

Notes:
A graphical resistor color code "Resistance Calculator" is available on the ENGR 210 Web page (http://129.22.56.221/engr210.html) under "Tools."
A more detailed explanation of resistors, including how they are built, can be found in Thomas & Rosa, 2/e.

Pictures of the real lab equipment, its technical specifications and a very good tutorial on how to use the equipment can be found at the ENGR210 Web page. Click on "Workbench" — links to detailed tutorials of how the digial multimeter and power supply work are found immediately to the right of the picture of the HP 34401 DMM.

Aside from using a DMM and power supply you will also need to learn how to make electrical circuits. In this course you will use clip leads to connect the lab equipment to your

circuits which will be constructed on protoboards. Of course these will be simulated in the simulation and these are some differences between the simulation and the real lab. Real clips leads like you will use in the lab have a spring-loaded clip to hold a wire just like that shown below. To operate the clip lead you typically hold the clip between your thumb and forefingers and squeeze the clip in the direction shown below. When you do this a wire hook comes out of the tip. This hook can be put around a wire and, when you release your fingers, the spring-loaded clip pulls the wire against the plastic body of the clip lead providing a reliable electrical connection. (NOTE: These clip leads are really handy to have and you might want to consider purchasing some of your own. These and other tools can be purchased for your personal use from Electronic Stores in Glennan 309.)
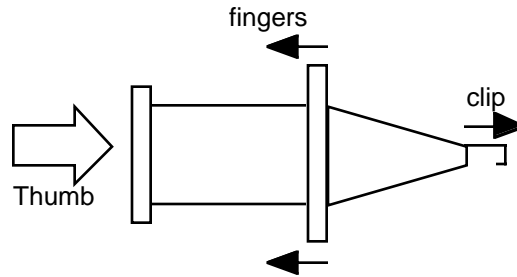
You will also use a variety of protoboards to construct your circuits in this class. A protoboard consists of many holes into which you can insert electrical components and wires to quickly make an electrical circuit without doing any soldering. A typical protoboard layout is shown below. The center section is used to connect your electrical components and integrated circuits; the two outer sections are typically used to make power supply connections. The holes in protoboards are normally 0.1-inch apart since this is a standard size for leads in integrated circuits. The holes are electrically connected internally by metal electrodes as shown below. Note that these electrical connections are not necessarily apparent on all protoboards boards. To help you out some of the electrical connections are often shown with colored (red or blue) lines scribed on the protoboard which is typically all white plastic. The electrical connections for a typical protoboard are shown as straight lines in the drawing below.
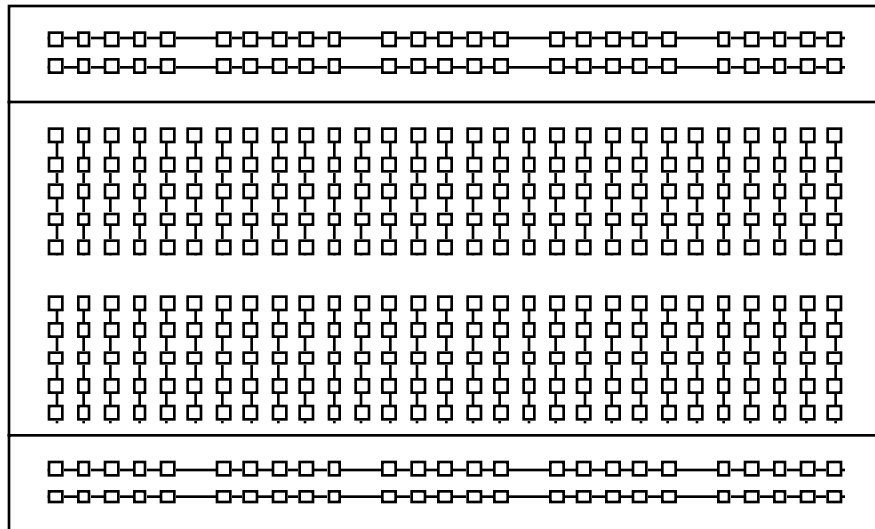
In a real protoboard you must be careful of the size of the wires you push into the holes. If the wire diameter is too large it can permanently damage the electrical connector in that hole.

Some protoboards also have a set of binding posts at their edge which can be used to hold wires for connecting to a separate power supply. These are called 5-way binding posts because they can hold wires, connectors or plugs in a variety of ways. Note that the color red always indicates a positive (+) lead and black a negative(-) or ground lead. On some protoboards these binding pots are electrically connected to the long sections of the protoboard to allow you to quickly make power supply connections. These are often indicated on the protoboard by colored dots or lines which correspond to the color of the connected binding post.

Labs 1 and 2 are installed on the computers in the Circuits Lab in Glennan 308. Physical access to the lab is by your CWRUid card and the account you can use on the computers is "guest" with no password. Use the machines on your right as you enter the lab.

For the next week or two while we are still enabling card access to the lab you can download the computer simulated labs from the ENGR 210 Web page to your computer and run them. They can also be downloaded to the Smith computer lab or any other lab and run there.

While doing the labs please take notes and answer the questions on the following pages. Note that Lab 1 and 2 should be kept separate and will be collected separately in class.

ENGR 210/EEAP 240
Lab1: Ohm's Law

Due: September 2, 1998

Lab procedure and questions:
1. Describe the procedure for turning on and using the E3631A power supply.

2. Describe the procedure for turning on and using the HP 34401A multimeter to measure voltage.

3. Draw the electrical circuit you have made with the resistor, power supply and multimeter. Be sure to show the polarity and magnitude of the measured voltage across the resistor.
Answer: 5.005 volts

4. Describe the procedure for using the HP 34401A multimeter to measure current. Note that you have to break the previous connection from the resistor to the negative (ground) side of the power supply to make a current measurement.

5. What was the measured current through the resistor? This resistor will later be called R2.
Answer: 0.1104mA

6. What was the calculated resistance of resistor R2? Answer: 45.335 kΩ

7. Describe the procedure for using the HP 34401A to measure resistance.

8. What was the measured resistance?
Answer: R2=45.568 kΩ

9. What was the percentage difference between the calculated resistance and measured resistance of R2?   NOTE: %error=(Rcalculated-Rmeasured)/Rmeasured*100%-100%
Answer: %error=(45.335-45.568)/45.568=-0.005*100%-100%=-0.511%

10. What was the measured value of resistor R1?
Answer: R1=10.057Ω

11. R1 is nominally a 10kΩ resistor. What is the color code for a 10k resistor?
Answer: Brown-Black-Orange

12. What was the measured value for resistor R3?
Answer: R3= 9.969 kΩ

13. For Kirchoff's Voltage Law experiment what were the measured values of Vr1, Vr2 and Vr3?
Answer: Vr1=0.7768 volts, Vr2=3.4721 volts, and Vr3=0.76040 volts.

14. What are the calculated voltages using the measured resistance values and the measured value of the voltage source?
Answer:
Vr1=10.057/(10.057+45.568+9.969)*5.005volts=10.057/65.594*5.005=.76378
Vr2=45.568/(10.057+45.568+9.969)*5.005volts=45.568/65.594*5.005=3.47696
Vr3=9.969/(10.057+45.568+9.969)*5.005volts=9.969/65.594*5.005=.76066

15. What was the calculated percentage error between the measured voltage Vr3 (using the multimeter) and the voltage calculated using the measured resistance values?
Answer: %error=(.76040-.76066)/.76066=-.00026/.76066=-0.000381=-0.04%

16. What was your calculated current through the circuit composed of R1, R2 and R3?
Answer: I=5.005volts/(R1+R2+R3)=5.005/65.594=0.07630mA

17. For the KCL experiment what was the measured value of current going through the resistors?
Answer: Ir1=0.2743 mA, Ir2=0.0492mA, and Ir3=0.2251mA

18. What were the calculated currents through R1 and R2?
Answer:
Ir2=Iin*R3/(R2+R3)=.2743mA*9.969/(9.969+45.568)=
    .2743mA*9.969/(55.537)=.04294mA
Ir3=Iin*R2/(R2+R3)=.2743mA*45.568/(9.969+45.568)=
    .2743mA*45.568/(55.537)=.22506mA

19. What is the percentage error for this measurement?

20. Calculate the equivalent resistance of R2||R3?
Answer: R2||R3=9.969*45.568/(9.969+45.568)=8.1795 kW

21. Using the equivalent resistance what is the calculated voltage across R1?
Answer: Vr1=5.005*10.057/(8.1795+10.057)= 5.005*10.057/(18.2365)=2.76014 volt