ELECTRICAL & ELECTRONICS ENGINEERING DEPARTMENT

PHYS 103 PHYSICS LABORATORY

Name:

ID:

Department:

Spring, 2013

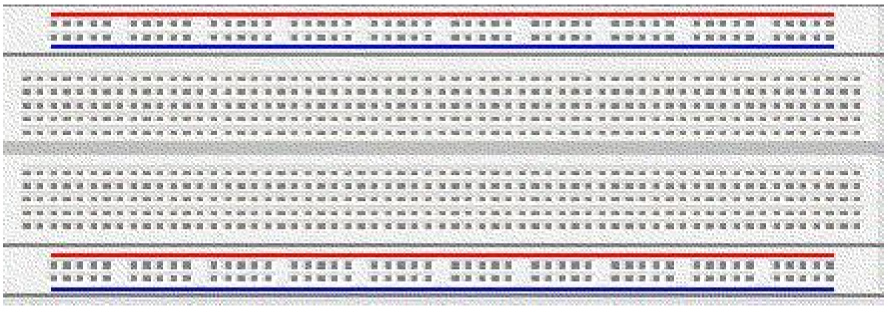
CONTENTS

INTRODUCTION TO BASIC TOOLS

BREADBOARD

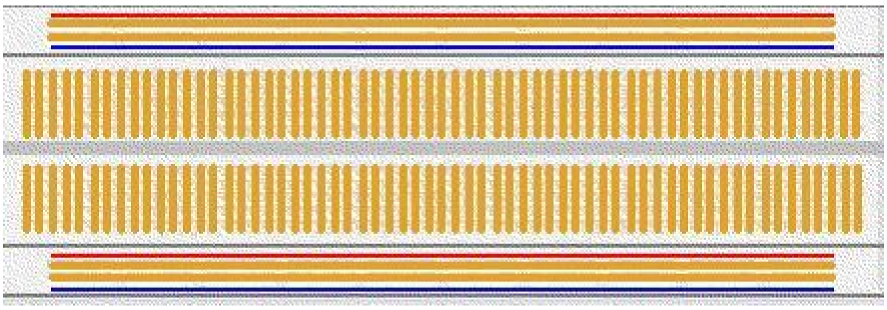
The bread board has many strips of metal (copper usually) which run underneath the board. The metal strips are laid out as shown below.

These strips connect the holes on the top of the board. This makes it easy to connect components together to build circuits. To use the bread board, the legs of components are placed in the holes (the sockets). The holes are made so that they will hold the component in place. Each hole is connected to one of the metal strips running underneath the board.



Each wire forms a node. A node is a point in a circuit where two components are connected. Connections between different components are formed by putting their legs in a common node. On the bread board, a node is the row of holes that are connected by the strip of metal underneath.

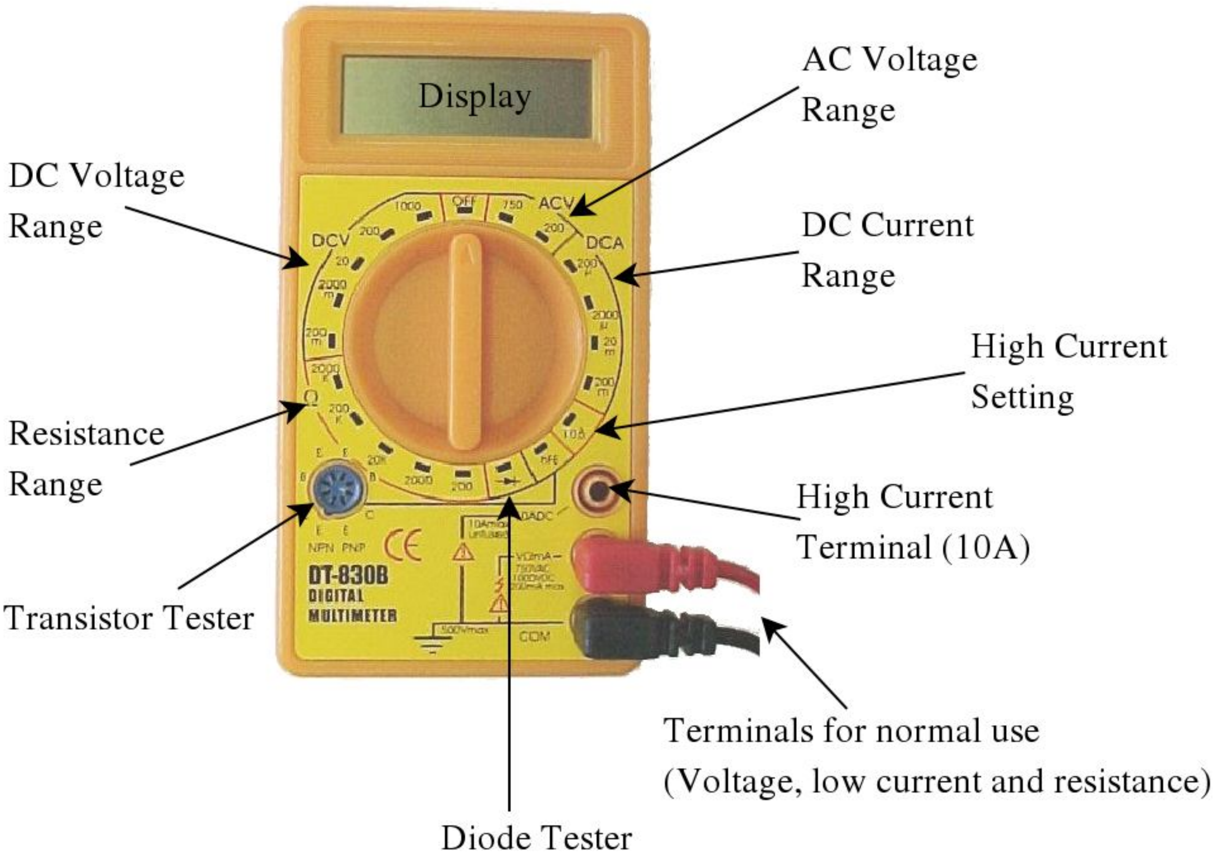
The long top and bottom row of holes are usually used for power supply connections.



The rest of the circuit is built by placing components and connecting them together with jumper wires. Then when a path is formed by wires and components from the positive supply node to the negative supply node, we can turn on the power and current flows through the path and the circuit comes alive.

MULTIMETER

A multimeter is used to make various electrical measurements, such as voltage, current, and resistance. Multimeters may also have other functions, such as diode, capacitor, transistor and continuity (short-circuit) tests. The descriptions and pictures are shown below.



When you are to use your multimeter, you should select the right range before connecting the meter to the circuit. If you have the meter connected in parallel (as a voltmeter) and you accidently switch to the current range then you will short circuit the supply and blow the fuse in the meter.

In addition, you ought to use the correct terminals - the high current terminal is only for measuring current > 200mA and must be used with the high current (10A) setting. Finally, the multimeter contains a fuse, if it has been connected to a circuit incorrectly then the fuse may have blown.

REFERENCE

- http://www.electronicsteacher.com/tutorial/using-a-breadboard.php
- http://pfnicholls.com/electronics/multimeter.html
- http://www.bhagirathpalace.com/view_offer.php?id=27

EXPERIMENTAL ERRORS AND UNCERTAININITY

No physical quantity can be measured with perfect certainty; there are always errors in any measurement. This means that if we measure some quantity and, then, repeat the measurement, we will almost certainly measure a different value the second time. However, as we take greater care in our measurements and apply ever more refined experimental methods, we can reduce the errors and, thereby, gain greater confidence that our measurements approximate ever more closely the true value.

ACCURACY & PRECISION

Experimental error is the difference between a measurement and the true value or between two measured values. Experimental error, itself, is measured by its accuracy and precision. Accuracy measures how close a measured value is to the true value or accepted value. Since a true or accepted value for a physical quantity may be unknown, it is sometimes not possible to determine the accuracy of a measurement. Precision measures how closely two or more measurements agree with other. Precision is sometimes referred to as repeatability or reproducibility. A measurement which is highly reproducible tends to give values which are very close to each other.

TYPES & SOURCES OF EXPERIMENTAL ERRORS

Experimental errors are inherent in the measurement process and cannot be eliminated simply by repeating the experiment no matter how carefully. There are two types of experimental errors: systematic errors and random errors.

Systematic errors are errors that affect the accuracy of a measurement. Common sources of systematic errors are faulty calibration of measuring instruments, poorly maintained instruments, or faulty reading of instruments by the user.

Random errors are errors that affect the precision of a measurement. The precision of measurements subject to random errors can be improved by repeating those measurements. Common sources of random errors are problems estimating a quantity that lies between the graduations (the lines) on an instrument and the inability to read an instrument because the reading fluctuates during the measurement.

SIGNIFICANT DIGITS

The least significant digit in a measurement depends on the smallest unit which can be measured using the measuring instrument. The precision of a measurement can then be estimated by the number of significant digits with which the measurement is reported. Unless the instrument manufacturer indicates otherwise, the precision of measurement made with digital instruments are reported with a precision of ±½ of the smallest unit of the instrument. For example, a digital voltmeter reads 1.493 volts; the precision of the voltage measurement is ±½ of 0.001 volts or ±0.0005 volt.

PERCENT ERROR

Percent error (sometimes referred to as fractional difference) measures the accuracy of a measurement by the difference between a measured or experimental value *E* and a true or accepted value *A*. The percent error is calculated from the following equation:

$$\% \, Error = \frac{|E - A|}{A}$$

PERCENT DIFFERENCE

Percent difference measures precision of two measurements by the difference between the measured or experimental values E_1 and E_2 expressed as a fraction the average of the two values. The equation to use to calculate the percent difference is:

$$\% Difference = \frac{|E_1 - E_2|}{\left(\frac{E_1 + E_2}{2}\right)}$$

MEAN & STANDARD DEVIATION

When a measurement is repeated several times, we see the measured values are grouped around some central value. This grouping or distribution can be described with two numbers: the mean, which measures the central value, and the standard deviation which describes the spread or deviation of the measured values about the mean.

For a set of *N* measured values for some quantity *x*, the mean of *x* is represented by the symbol $<x>$ and is calculated by the following formula:

$$\langle x \rangle = \frac{1}{N} \sum_{i=1}^{N} x_i = \frac{1}{N}\left(x_1 + x_2 + x_3 + \cdots + x_{N-1} + x_N\right)$$

where x_i is the *i*-th measured value of *x*. The mean is simply the sum of the measured values divided by the number of measured values.

The standard deviation of the measured values is represented by the symbol σ_x and is given by the formula:

$$\sigma_x = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} \left(x_i - \langle x \rangle\right)^2}$$

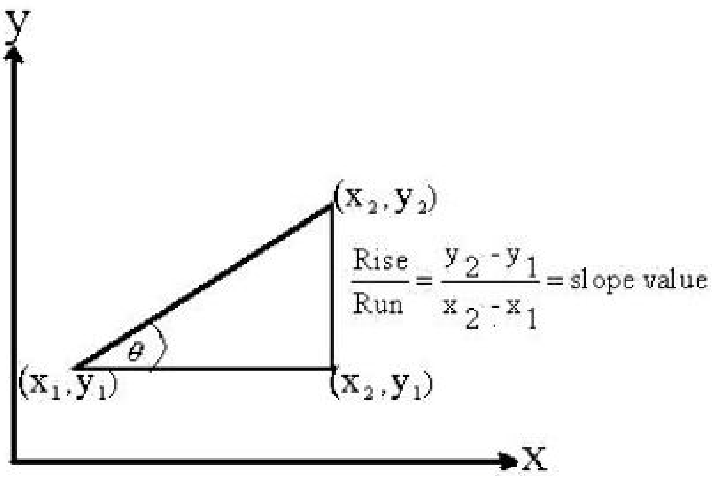
DRAWING EXPERIMENT GRAPHS

In most experiments you will be required to construct a graph. You can use Excel or other software packages to construct your graphs or millimetric papers when drawing by hand. All graphs (manual and electronic) have the following properties:

1. A good graph fills the whole page. The data points should extend across as much of the page as possible. This implies that there should be only one graph per page.
2. A good graph has a title that describes what is being plotted.
3. A good graph has axis labels that describe what is being plotted on each axis.
4. A good graph has tick marks both major and minor to indicate the divisions of both the x and y axis.
5. A good graph has axis units describing the units represented by the tick marks. Acceptable axis units are those that clearly label each axis with correct units corresponding to the measured quantity plotted along the axis. For example, for the x-axis 2*d* [*cm*] denotes that the quantity 2*d* is measured in *cm* and each major tick mark represents a multiple of centimeters scaled according to the graph page.
6. A good graph has evenly spaced tick marks, unless otherwise indicated by the lab instructor.
7. A good graph must clearly show the y-intercept plotted on the graph, that is, graph the point ($x = 0; y = b$), for b is the value of y when x = 0. Consequently, the continuity of the x and y axes must not be broken. Showing the y-intercept may be easier if the x and y axes are placed inside the graph-paper lines.
8. On a good graph, the numerical values of the slope and y-intercept are clearly written.
9. A good graph has the points used to measure the slope clearly indicated. These should be points on the line and not data points. The points used for the slope calculation should be marked differently from the data points. Choose points on the line as far apart as possible.

You are required to construct plots representing lines of best fit for your collection of data for every lab experiment. Your graphs will be linear functions for most experiments. There may be a few graph plots that make use of different mathematical functions, in which case your lab instructor will provide you with instructions for constructing the appropriate graph. Analysis by strict linear regression models and techniques are not necessary for physics lab reports. However, you should briefly discuss the “closeness” of the plotted data points to the line of best fit. You can do this simply by “eye-balling" the graph.

You are required to determine the slope and y-intercept of the line drawn. The slope and y-intercept should be determined from the line of best fit. Do not use the data points to calculate the slope and y-intercept of the line! Instead, to determine the y-intercept of the line measure the point of interception between the line of best fit and the y-axis. The rise-over-run method is a practical method used to calculate the slope. In review, to calculate the slope, choose two points on the line with the greatest separation. Draw a right triangle using as the hypotenuse the line of best fit. Determine the length of the line segment opposite theta, Θ (the rise) and the length of line segment adjacent to theta Θ (the run). The “rise” divided by the “run” determines the slope of the line.



The rise-over-run calculations as demonstrated in figure above must be performed for each graph presented with your lab report.

This method only works for first order equations, for instance, let’s say we are instructed to plot the height of the ball's drop, *h*, as a function of the square of the drop time of the ball, t^2 (*h* values are plotted along the y-axis and t^2 values along the x-axis). The theoretical values of slope and y-intercept are:

$$\begin{array}{ccccccc} h & = & \frac{1}{2}g & t^2 & + & 0 \\ \updownarrow & & \updownarrow & \updownarrow & & \updownarrow \\ y & = & m & x & + & b\,. \end{array}$$

Notice that by using the provided theoretical equation and the equation of the line, we are able to determine ½*g* and 0 as the theoretical slope and y-intercept values respectively of our graph.
The graphical analysis discussion will provide values for both the theoretical and actual slope and y-intercept measurements. A comparison between the sets of data can be performed by calculating the *percent difference* between the actual values and the theoretical values. The percent difference equation between slope values is:

$$\%\ difference = 100\% \times \frac{|\ theoretical\ slope\ value - experimental\ slope\ value\ |}{theoretical\ slope\ value}\,.$$

REPORTING & ANALYZING RESULTS

When a scientist reports the result of an experimental measurement of a quantity *x*, that result is reported with two parts. First, the best estimate of the measurement is reported. The best estimate of a set of measurement is usually reported as the *mean* $\langle x\rangle$ of the measurements. Second, the variation of the measurements is reported. The variation in the measurements is usually reported by the *standard deviation* σ_x of the measurements. The measured quantity is then known have a best estimate equal to the average, but it may also vary from $\langle x\rangle + \sigma_x$ to $\langle x\rangle - \sigma_x$. Any experimental measurement should then be reported in the following form:

$$x = \langle x \rangle \pm \sigma_x$$

Some of the experiments performed in this course are primarily qualitative (i.e. conceptual) rather than quantitative (i.e. containing several calculations). In these experiments, you will be asked to make predictions about the behavior of a system based on your physical understanding of the system. You will also discuss the reasoning behind your prediction. After discussing your prediction, and the reasoning behind your prediction, you will perform an experiment to test your prediction and record the results of this experiment. If the prediction does not agree with the experimental result, you will discuss any modification to the reasoning that led to the erroneous prediction. This cycle will then be repeated with a new set of circumstances which are similar, though not exactly the same. In this manner, a conceptual understanding of the physical system will be developed.

Most of the discussion written above about lab reports will not apply to these conceptual, or inquiry-based, experiments. For these experiments, the conclusions should instead discuss the cycle described above. In particular, a paragraph should be written *for each experiment*. Each paragraph should contain the following information:

1. Prediction: What was the prediction that was made about the system?
2. Reasoning: What was the reasoning behind the prediction (i.e. why did you make the prediction that you made)?
3. Experimental Result: What was the result of the experiment?
4. Analysis: (a) If the experiment agreed with you prediction, write a brief statement indicating this agreement. (b) If the experiment did not agree with the prediction, discuss what was wrong with the reasoning that led to the prediction that you made.

THEORY

Ohm's Law states that the current flowing from point A to point B in a conductor I is proportional to the difference in electrical potential ΔE between point A and point B. The constant of proportionality is called the electrical conductance G. Current is measured in amperes (A), potential difference in volts (V), and conductance in siemens (S). Hence, we can write,

$I = G \times \Delta E$

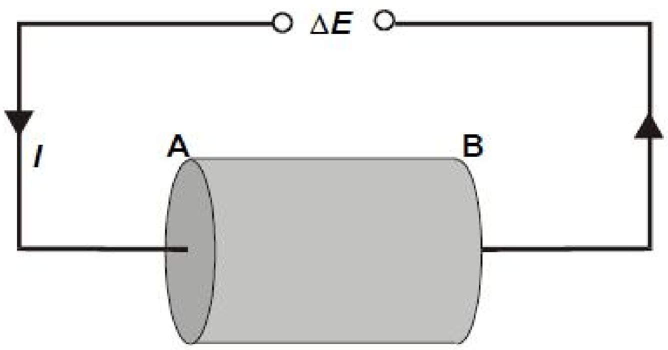
We also define an electrical resistance R, which is the inverse of conductance.

$R = 1 / G$

Resistance is measured in ohms (Ω). Hence,

$I = \Delta E / R$

Thus, if we take a resistive material sample with two flat faces A and B, and set a potential difference $\Delta E = E_A - E_B$ between its end faces, a current I will flow through the material from face A to face B. If we measure the current and the potential difference, we can calculate the resistance of the material sample.



- If the resistance is high, a given potential difference ΔE will only yield a small current I.
- If the resistance is low, a given potential difference ΔE will yield a high current I.

Imagine that the size of our wire sample now changes.
- If the length of the sample is doubled, one can see that the resistance of the sample to the passage of a current should also double.
- If the area perpendicular to the current flow doubles (the area of the end face in this example), there is twice the material for the current to pass through, the resistance of the sample to the passage of the current should therefore fall to a half of what is was before.

So the resistance (and therefore conductance) depend upon the size of the sample.

If we take the resistance per unit length and area, we can remove the effect of the dimensions of the sample. The value we obtain is then only a function of the property of the material and not its dimensions. The resistance per unit length and area is called the *resistivity* ρ, and can be expressed as,

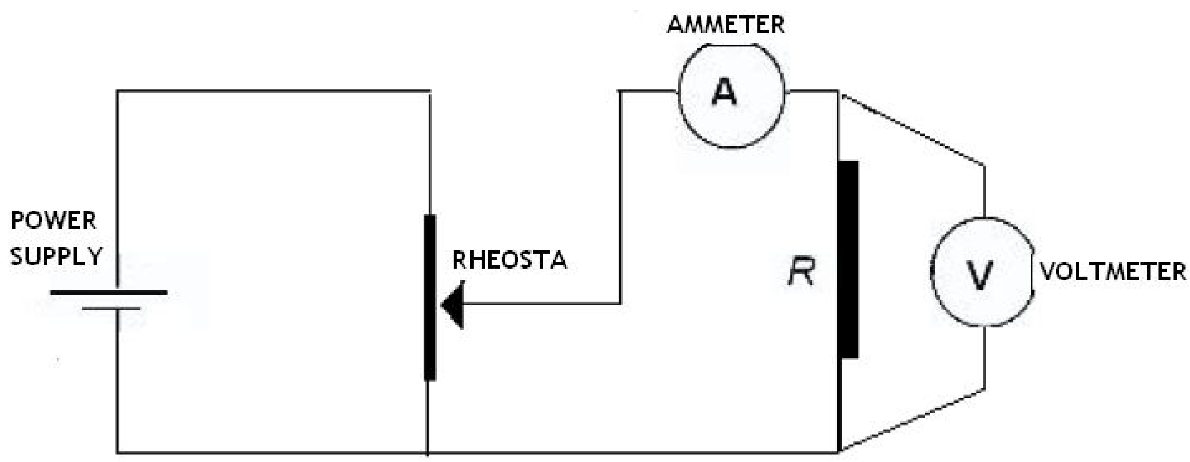
$$\rho = \frac{\Delta E}{I} \times \frac{A}{L}$$

where:

ρ = the resistivity of the sample (Ωm or ohm.m)
ΔE = the potential difference across the sample (volts, V)
I = the current flowing through the sample (amperes, A)
A = the cross-sectional area of the sample perpendicular to the current flow (m^2)
L = the length of the sample (m).

PROCEDURE

1) Construct the circuit given below on the breadboard. For R, four different wires will be given by instructor. Show your connections to your instructor before switching the power supply on.



2) Measure length and diameter of each wire.

3) Calculate cross-sectional area of each wire.

4) By adjusting rheosta set 6 voltage levels for each wire and measure current and voltage. Record your mesurements to the table below.

5) Calculate resistivity for each measurement.

6) Calculate mean value and standard deviation of resistivity findings.

Material	Resistivity (Ω m)	Conductivity (Ω^{-1}m^{-1})
Aluminum	2.8×10^{-8}	3.5×10^{7}
Copper	1.7×10^{-8}	6.0×10^{7}
Gold	2.4×10^{-8}	4.1×10^{7}
Iron	9.7×10^{-8}	1.0×10^{7}
Silver	1.6×10^{-8}	6.2×10^{7}
Tungsten	5.6×10^{-8}	1.8×10^{7}
Nichrome*	1.5×10^{-6}	6.7×10^{5}
Carbon	3.5×10^{-5}	2.9×10^{4}

7) Find actual resistivity values (depends on material) from table, and determine percent error of your measurements.

8) Plot V-I graphs for each wire, calculate resistivity using your drawings.

9) Discuss and conclude your observations.

1.	WIRE #	AREA (m^2)	LENGTH (m)	2.	WIRE #	AREA (m^2)	LENGTH (m)
	V(V)	I(A)	$\rho(\Omega.m)$		V(V)	I(A)	$\rho(\Omega.m)$
1.				1.			
2.				2.			
3.				3.			
4.				4.			
5.				5.			
6.				6.			
3.	WIRE #	AREA (m^2)	LENGTH (m)	4.	WIRE #	AREA (m^2)	LENGTH (m)
	V(V)	I(A)	$\rho(\Omega.m)$		V(V)	I(A)	$\rho(\Omega.m)$
1.				1.			
2.				2.			
3.				3.			
4.				4.			
5.				5.			
6.				6.			

THEORY

Circuit elements in an electrical circuit can be connected in series or parallel. For resistors in series the current is the same for all the resistors, but the voltage drop across each resistor is different. For resistors in series the total resistance R_T of is given by,

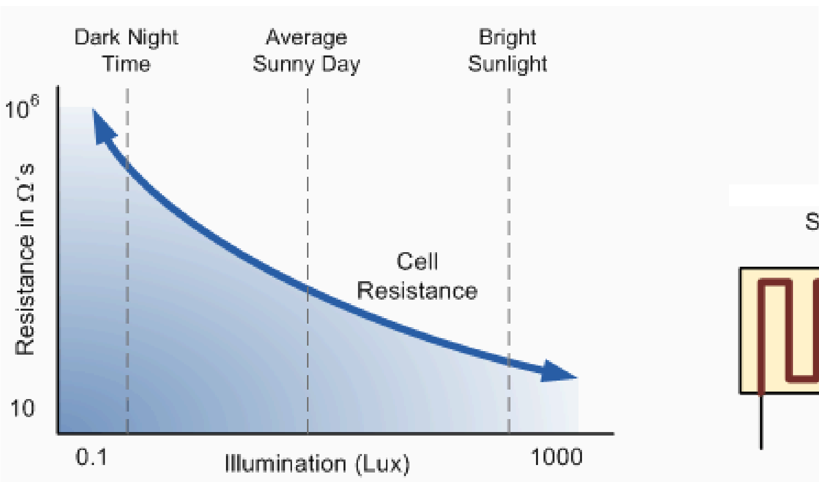
$$R_T = R_1 + R_2 + R_3 \qquad V_T = V_1 + V_2 + V_3 \qquad I_T = I_1 = I_2 = I_3$$

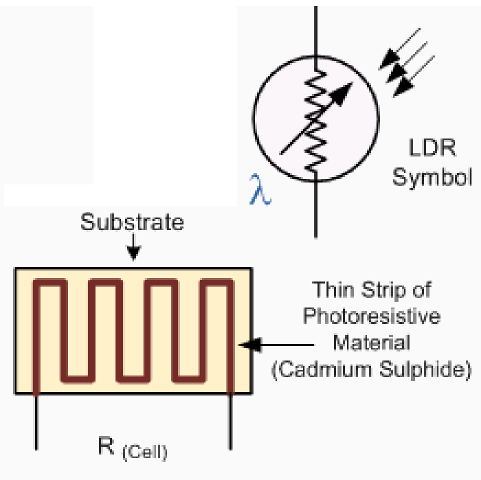
For resistors in parallel the current is different in each resistor, but the voltage across each resistor is the same. In this case the total resistance R_T is given by,

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad V_T = V_1 = V_2 = V_3 \qquad I_T = I_1 + I_2 + I_3$$

LDR: As its name implies, the **Light Dependent Resistor** (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material. The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination. Also, photoresistive cells have a long response time requiring many seconds to respond to a change in the light intensity.

Mainly, cadmium sulphide is used in the manufacture of photoconductive cells because its spectral response curve closely matches that of the human eye and can even be controlled using a simple torch as a light source.

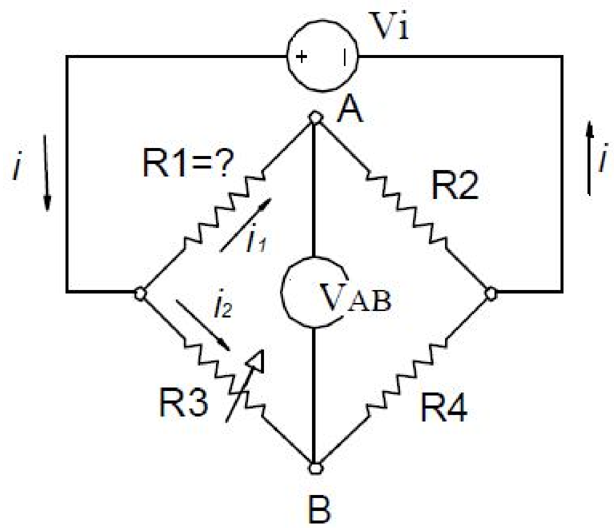




Wheatstone Bridge: A Wheatstone bridge is a measuring instrument which is used to measure an unknown electrical resistance by balancing the resistances in the two branches of a bridge circuit, one branch of which includes the unknown resistance.

In the circuit shown in figure below, let R_1 be the unknown resistance and R_2, R_3 and R_4 are resistances of known value and the resistance of R_3 is adjustable. If the ratio of the two resistances in the lower branch (R_3 / R_4) is equal to the ratio of the two in the unknown leg (R_1 / R_2), then the output voltage (V_{AB}) between the two midpoints will be zero and no current will flow between the midpoints. R_3 is varied until this condition is reached. Then unknown resistance,

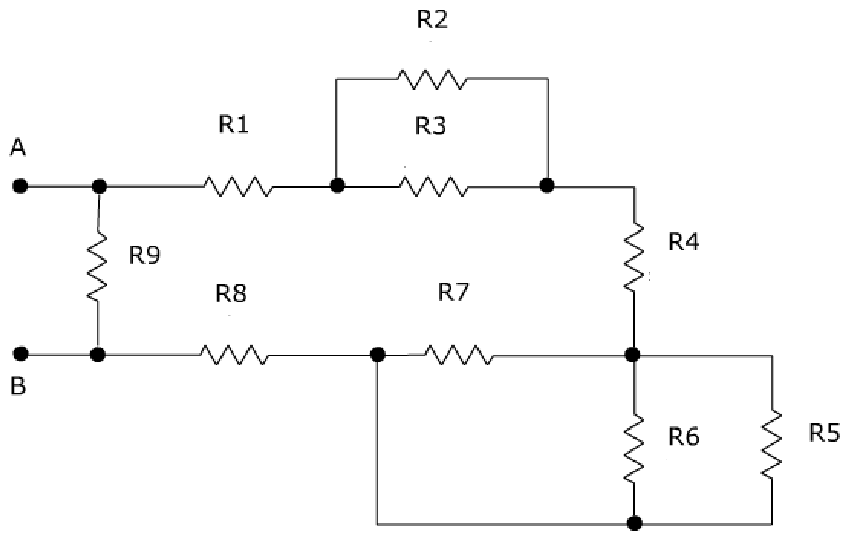
$R_1 = R_3 \times R_2 / R_4$.



In this experiment, a wheatstone bridge will be used to find the output voltage that corresponds to the values of the (LDR) that changes according to the light density (LUX) as well as to determine the resistance variation of thermistor due to temperature alterations.

PROCEDURE

1) Construct the circuit as shown, using a resistors given by the instructor on your breadboard.



2) Calculate total resistance with the color-coded generic values. Measure total resistance with your DMM. Calculate percent error.

3) Show your connection to your instructor before switching the power supply on. Keep the source voltage, between A and B, around 10V. Measure all 9 voltages of the circuit.

4) Verify your calculation of total resistance by using measured voltage values.

5) Construct the circuit as shown in figure with the devices that are given by your instructor, using a resistor box as R_3, an LDR as R1 on the breadboard. Show your connection to your instructor before switching the power supply on. Keep the source voltage around 10V.

6) By adjusting the resistor box, determine LDR's resistance at least for 3 lux levels. Use the relation given above.

7) Check your findings using an ohmmeter and determine percent errors of your calculations (3 errors for LDR).

8) Comment on the accuracy of Wheatstone-bridge measurement technique using your percent error calculations, is there any difference between error percentages of LDR?

9) Discuss and conclude your observations.

THEORY

Filament (bulb): An incandescent light bulb with a tungsten filament has a positive temperature coefficient, and therefore has a very low initial resistance when the power is first applied. As the temperature of the filament increases, the resistance of the filament increases also. The temperature of the resistor increases by increasing the applied voltage, since the power dissipated as heat is increased due to the relation, $P = I\,V$, where I is the current passing through the tungsten filament and V is the voltage applied across it. Resistivity and temperature relation is given by,

$$R = R_{\text{room temperature}}\,[\,1 + \alpha(\,T - T_{\text{room temperature}}\,)]$$

Where α coefficient for tungsten is, $4.5\ 10^{-3}$ [K^{-1}]

For metals, the number of free electrons is fixed. As the temperature increases, the amplitude of vibration of atoms/ions increases and collisions of electrons with them become more effective and frequent. As a result, current carrying electrons find more resistance in passing through and the resistance increases.

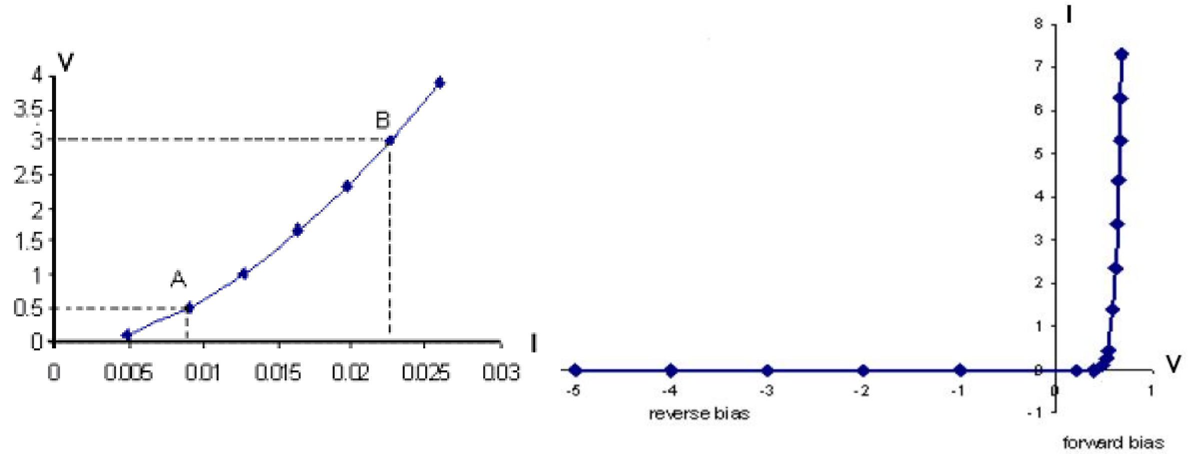


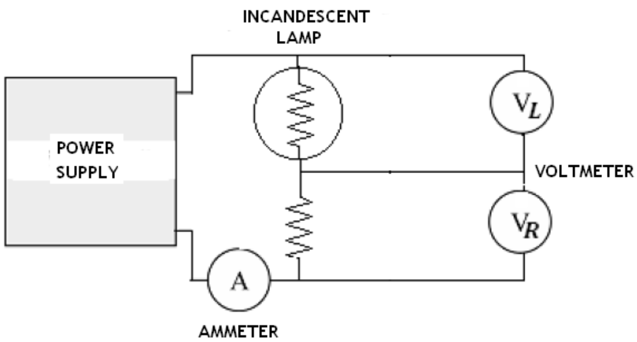
Figure on the left shows the voltage and current relation of a tungsten filament. From the figure, it is clear that the resistance of the filament increases with applied voltage and the filament has a dynamic resistance. The resistance at A and B can be found by using R = V / I relation at that particular points and you can prove that $R_B > R_A$.

Diode: Diode is a junction of P and N type semiconductors. In forward biasing, the P side of the diode is set at a higher potential than the N side. Usually this is achieved by connecting the positive side of battery to the P side and the negative of battery to the N side of the diode. During forward biasing the diode acts like a closed switch with a potential drop of nearly 0.6 V across it for a silicon diode. In reverse biasing, the N side of the diode is set at a higher potential than the P side. This can be obtained by connecting the positive of battery to the N side and the negative of battery to the P side of a diode. In reverse biasing, the diode will act like an open switch and there is no current flow.

Figure on the right above shows the forward and reverse bias characteristics of a silicon diode. From the graph, you may notice that the diode starts conducting when the forward bias voltage exceeds around 0.6 volts (for Si diode). This voltage is called threshold voltage.

PROCEDURE

1) Connect the circuit on your bread board as shown in figure below. If you do not have two multimeters use a single multimeter to measure V_R and V_L. Show your connections to your instructor before switching the power supply on. Keep the source voltage maximum 6V.



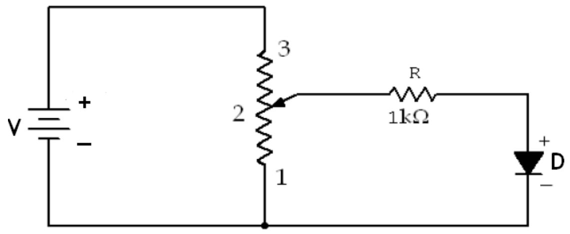
2) Fill the table with voltage measurements, then calculate I_L and R_L values.

3) Plot a graph of V_L versus I_L. Determine lamp's resistance at room temperature (This is the value where minimum voltage was applied) and the maximum value that you measured.

4) Measure the ambient temperature of the laboratory. Calculate the highest temperature of the lamp.

V_s (V)	V_R (V)	$I_L = \frac{V_R}{R}$ (A)	V_L (V)	$R_L = \frac{V_L}{I_L}$ (Ω)
1				
2				
3				
4				
5				
6				
7				

5) Construct the circuit as shown in figure below, using a potentiometer, 1 kΩ resistor and a silicon diode on the breadboard. Show your connection to your instructor before switching the power supply on. Keep the source voltage around 10V.



6) Adjust V_{12} to the indicated values in the table and measure V_R and V_D.

7) Reverse the direction of the power supply by interchanging terminals of your battery to obtain reverse biasing. This can also be achieved by interchanging the diode terminals. Repeat step 6 and record your results in table. Do not forget to show your connections to your instructor before switching the power supply on.

V_{12} (V)	V_R (V)	$I_D = \frac{V_R}{R}$ (A)	V_D (V)	$R_D = \frac{V_D}{I_D}$ (Ω)
0.2				
0.4				
0.6				
0.8				
1				
2				
3				
4				
5				
6				

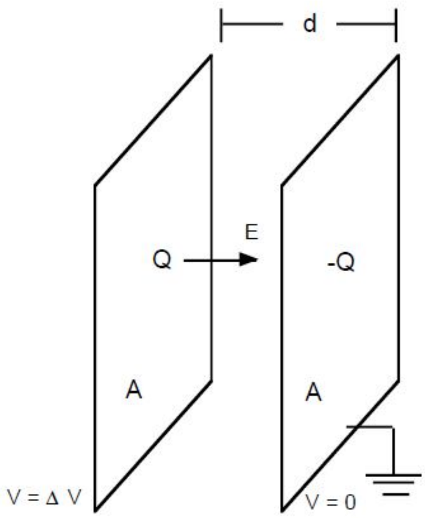
8) Plot I_D versus V_D for forward bias as well as reverse bias on a graph paper. Determine threshold voltage and calculate percent error between the theoretical threshold voltage.

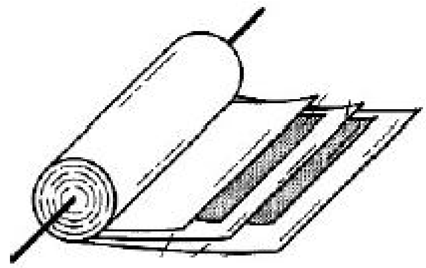
9) Discuss and conclude your observations.

EXPERIMENT 4 CHARGE & DISCHARGE OF A CAPACITOR

THEORY

A capacitor, often referred to as a condenser, is a simple electrical device consisting of two nearby conducting surfaces separated by an insulator. The capacitor can store charge of opposite sign on the two plates, and is of immense importance in the design of electronic devices. In a simple parallel plate capacitor as shown in drawing below, two nearby conducting plates are separated by an insulator between them. If the two plates are connected to opposite terminals of a battery, one plate acquires a positive charge Q and the other a negative charge $-Q$.

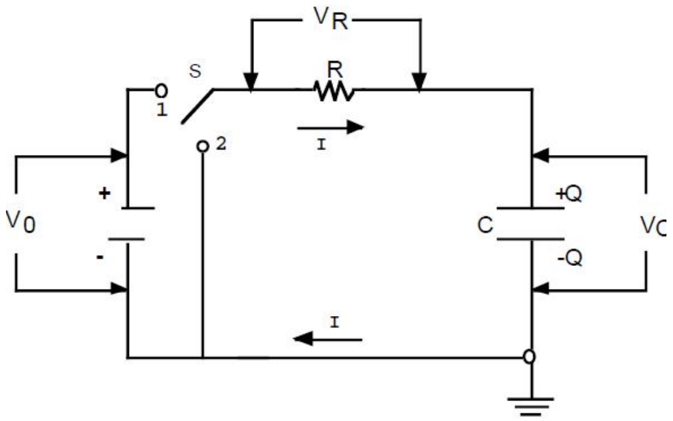


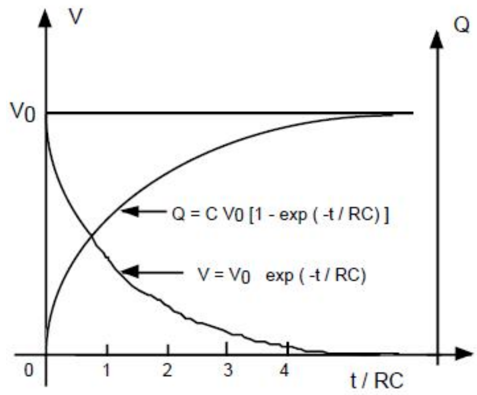


The electric field between the two plates, and therefore the potential difference between them, is proportional to the charge Q producing the field. The capacitance C, whose value depends on the detailed construction of the individual capacitor, is then defined to be the proportionality constant, $C = Q/V$, and its value states how much charge is stored per volt of applied potential. By convention, we take Q in this expression to be that at the positively charged plate, so that C is always positive. The unit of capacitance is the farad, named after Michael Faraday. The SI symbol for the farad is F, and 1 farad is equal to one volt per coulomb. It happens, however, that 1 F is a truly huge capacitance, and typical capacitors are more conveniently measured in micro-farads, with 1 μF = 1 x 10^{-6} F.

In order to charge the capacitor, a battery or generator must move charge from one plate of the capacitor to the other through a potential difference, thereby doing work. Thus a capacitor not only stores opposite charge on its two plates, but also stores energy. As we move charge through the circuit to build up the potential difference across the capacitor, the potential difference through which the charge must be moved at each instant is $V = Q/C$.

Suppose a capacitor in the circuit shown in figure below has charge $\pm Q$ on its plates. At time $t = 0$ the switch is moved to position 2 and electrons from the negatively charged plate become free to flow through the resistor to the positively charged plate. Charge conservation implies that the rate of charge leaving the capacitor to flow through the resistor is the charge per unit time, and is therefore the electric current *I(t)* passing through the wire and is equal to $V_C(t)/R = Q(t)/RC$, and that the rate of decrease of Q is thereby proportional to Q itself.





The rate of decrease of some physical quantity is proportional to its value still remaining, hence this condition implies that the quantity exhibits an exponentially decreasing dependence on time. Current, charge, and voltage are all found to follow the exponential decay as plotted above, and given by the expressions,

$$Q(t) = Q(0)\exp\left(\frac{-t}{RC}\right) \qquad V(t) = V(0)\exp\left(\frac{-t}{RC}\right) \qquad I(t) = I(0)\exp\left(\frac{-t}{RC}\right)$$

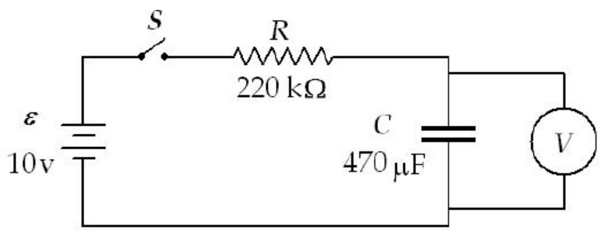
If, instead of starting with the capacitor uncharged, we begin with $Q(0) = 0$ and connect the battery, the time dependence of the charge on the capacitor as noted in the graph above, is

$$Q(t) = CV_0(1 - e^{-t/RC}).$$

As the capacitor becomes fully charged, the current approaches zero with the same time constant that applies when the capacitor is being discharged through the resistor. The quantity $\tau = RC$ is referred to as the time constant for the circuit.

PROCEDURE

1) Connect the circuit as shown in figure below (make sure that the lead of the capacitor at the arrow head side is connected to the ground). Show your connection to your instructor before switching the power supply on and make sure that the capacitor is completely discharged.



2) Close the switch *S*, and start the stopwatch. Record the time, t_1, corresponding to V_c reaching values indicated in table on the left. Reset the stopwatch.

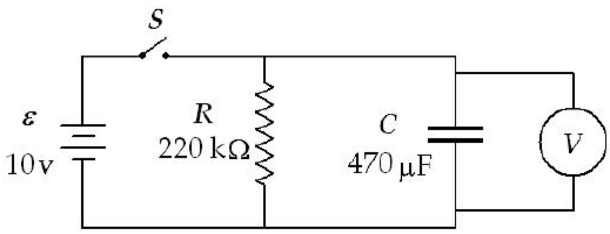
V_c (V)	t_1 (s)	t_2 (s)	t_{avg} (s)
0			
1			
2			
3			
4			
5			
6			
7			
8			

V_c (V)	t_1 (s)	t_2 (s)	t_{avg} (s)
10			
9			
8			
7			
6			
5			
4			
3			
2			

3) Repeat steps 1 and 2 and record the time as t_2. Calculate t_{avg}.

4) Plot a graph for V_c versus t_{avg}. Determine τ from your graph.

5) Connect the circuit as shown in figure below (make sure that the lead of the capacitor at the arrow head side is connected to the ground). Show your connection to your instructor before switching the power supply on.



6) Close the switch *S*. This will cause the capacitor to charge up immediately. Start the stopwatch and open the switch *S* simultaneously. Of integer values of V_c according to table on the right, record the time as t_1.

7) Reset the stopwatch. Repeat steps 5 and 6 and record the time as t_2. Calculate t_{avg}.

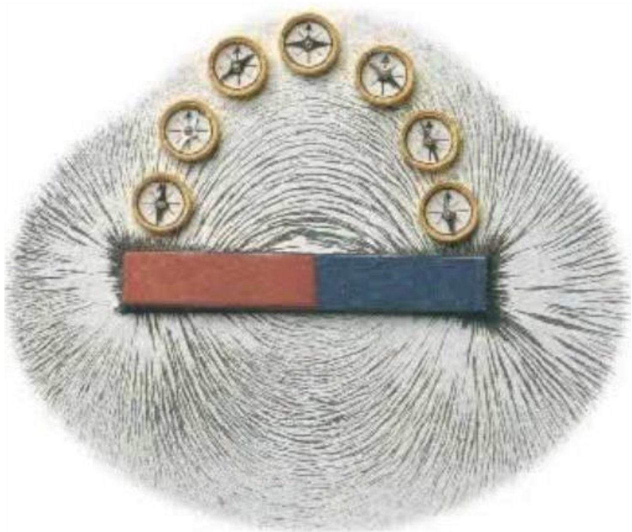
8) Plot a graph for V_c versus t_{avg}. Determine τ from your graph.

9) Calculate percent error between two τ values that you have determined above and between the generic value of τ.

EXPERIMENT 5 ELECTROMAGNETISM & INDUCTION

THEORY

Magnetic Field Lines: Magnetic fields are caused by moving charges – sometimes by charges moving on the atomic level (electrons moving around atomic nuclei, for example), and sometimes moving on a macroscopic scale, such as through the wires in an ordinary circuit. Similarly to how electric fields are both *produced by* and *act on* charged particles, magnetic fields are both *produced by* and *act on* moving charges. The units of measurement of magnetic field are Tesla and Gauss.



Magnetic field lines are a way to visualize the magnetic field. When drawn, the distance between them is an indication of the strength of the field. The closer they are, the stronger the field. For example, the number of lines per square centimeter is a measure of the strength of the magnetic field. Specifically, 1 Gauss is equivalent to 1 magnetic field line within 1 square centimeter. Also, the direction of the tangent to the field line is the direction of the magnetic field at that point and is the direction a compass would point. Some important facts emerge when one tries plotting lines of magnetic field such as,

- Lines NEVER cross.
- Lines are CONTINUOUS.
- Lines always form individual CLOSED LOOPS around the magnet.
- Lines have a definite DIRECTION from North to South.
- Lines that are close together indicate a STRONG magnetic field.
- Lines that are farther apart indicate a WEAK magnetic field.

Induction: The finding that electric current can produce magnetic fields led to the idea that magnetic fields could produce electric currents. The production of emfs and currents by the changing magnetic field through a conducting loop is called induction. Lenz's Law states that the induced emf (and current) will be in a direction such that the induced magnetic field opposes the original magnetic flux change.

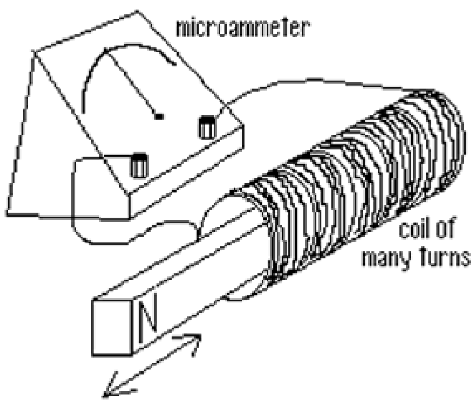
PROCEDURE

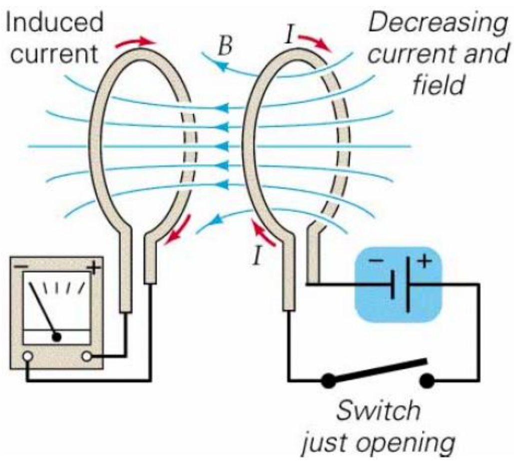
1) Place an U-type or a bar-magnet beneath a white A4 paper. Pour iron fillings onto the paper and observe formed magnetic field lines. Draw and record (i.e. by taking a photo) these magnetic field lines.

2) Now remove the paper and place small compasses around the magnet and observe variations of direction from one to another. Draw and record these directions.

3) Repeat steps 1 and 2 using an electromagnet (a simple electromagnet is a copper wire *wound around* a common *iron* core).

4) Michael Faraday made his discovery of electromagnetic induction in 1831, he hypothesized that a changing magnetic field is necessary to induce a current in a nearby circuit. To test his hypothesis he made a coil by wrapping a paper cylinder with wire. He connected the coil to a galvanometer, and then moved a magnet back and forth inside the cylinder. Faraday concluded that a moving magnetic field is necessary in order for electromagnetic induction to occur. Now, repeat Faraday's experiment by using the materials (magnet, coil and milliammeter) given by your instructor as shown in the figure below.

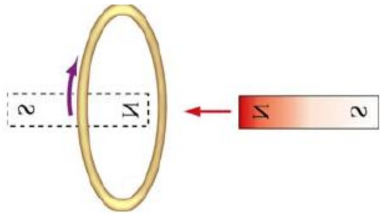




5) Connect given coils as shown above (right), and show your connection to your instructor before switching the power supply on.

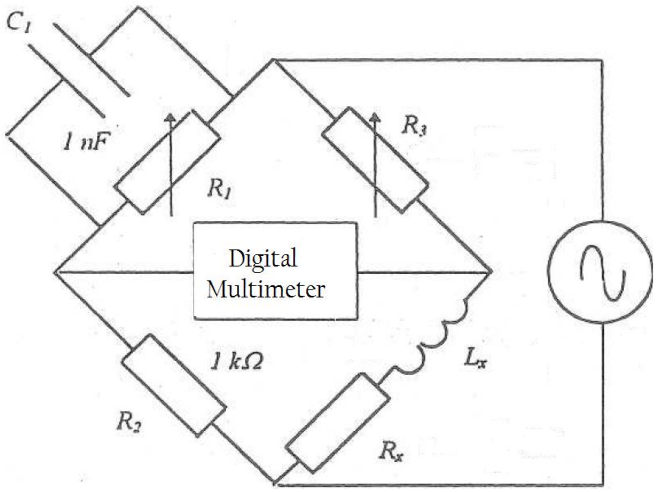
6) Form a table that contains induced current measurements of three different voltage levels (of power supply) at three different distances (between two coils).

7) As an example to illustrate how Lenz's law may be applied, consider the situation where a bar magnet is moving toward a conducting loop with its north pole down, as shown in figure,



The direction of the induced current can also be determined from the point of view of magnetic force. Lenz's law states that the induced emf must be in the direction that opposes the change. Therefore, as the bar magnet approaches the loop, it experiences a repulsive force due to the induced emf. Since like poles repel, the loop must behave as if it were a bar magnet with its north pole pointing up. In this part, you are going to try to observe that force by experiment, using the materials given by your instructor.

8) Measuring inductance of a coil requires a bridge circuit similar to the Wheatstone Bridge you have experinced in exp2. The circuit you will build to measure an unknown inductance is as given below.



Here, L_x is the unknown inductance and R_x is the resistance of the inductor. R_3 and R_1 are 100kΩ and 1MΩ potentiometers respectively.

Apply an alternating voltage to the indicated terminals and place your DMM as shown. Adjust R_1 and R_3 until you observe zero volts on the display of your DMM. Remaining part is straightforward. Use equations given below and determine R_x and L_x.

$$R_x = R_3 \frac{R_2}{R_1}, \qquad L_x = R_2 R_3 C_1$$

RESOURCES

1.) http://dept.physics.upenn.edu/~uglabs/lab_manual/ohms_law.pdf

2.)http://webstaff.kmutt.ac.th/~yuttapong.jir/teach/2-2010/cmm211/classnotes/YJech01.pdf

3.)http://www.fke.utm.my/mine/SEE2063/Chapter2%20DIode%20SEE2063.pdf

4.)http://faculty.kfupm.edu.sa/phys/mohamedk/phys102/lab/08_OHMS_Law_2.pdf

5.) http://www.imagesco.com/articles/photovoltaic/photovoltaic-pg3.html

6.) http://www.matni.com/Arabic/Elec-Info/Basic%20Electronics/Basic%20E8.htm(kondansatorrulo)

7.)MIT Physics Demos :http://www.flickr.com/photos/physicsdemos/3331510420/ (Solenoid)

8.)http://www.oberlin.edu/physics/catalog/demonstrations/em/toroid.html (Toroid)

LINKS

1. http://www.magnet.fsu.edu/education/tutorials/java/magwire/index.html
2. http://www.magnet.fsu.edu/education/tutorials/java/inductivereactance/index.html
3. http://www.magnet.fsu.edu/education/tutorials/
4. http://www.magnet.fsu.edu/education/tutorials/java/ac/index.html
5. http://www.magnet.fsu.edu/education/tutorials/java/electromagneticinduction/index.html
6. Asst. Prof. Dr. Numan Akdoğan GYTE: http://www.gyte.edu.tr/hebe/AblDrive/79354043/w/Storage/218_2010_1_631_79354043/Downloads/mm1.pdf
7. http://buphy.bu.edu/ulab/intro2/faraday.pdf
8. http://www.physics.sjsu.edu/becker/physics51/induction.htm
9. http://academicearth.org/lectures/electric-chargres-polarization-and-electric-force