ELECTRICITY 1

**Learning Objectives:**

Upon completion of these experiments, the student should be able to:

* operate a voltmeter to measure voltage or potential differences
* operate an ammeter to measure currents
* operate an ohmmeter to measure resistances
* identify the resistance value of a resistor using a resistor colour code
* set up simple electrical circuits
* use Ohm’s law to predict electrical values in a circuit
* identify the differences between series and parallel circuits

**Introduction**

This experiment is an introduction to electrical quantities and their measurement. These experiments will be deal only with direct current (DC), meaning current only flows in one direction. The electrical quantities to be investigated are:

**Electric Current, *I***: is the rate at which electrical charge flows past a point in the circuit. The unit of current is *ampere*, or *amp*, symbol A. 1 amp equals 1 coulomb (C) of charge passing a point in one second, i.e.

1 A = 1 C/s.

**Electric Potential or Voltage, *V***: in the case of a power supply or battery, can be thought of as the potential energy available to the circuit to move the charge. Potential is normally measured with reference to datum node, often the *ground* point or the negative terminal of a power supply. In this set of exercises, you will generally measure potential difference across a component, the difference in potential at either end of a resistor. Potential difference can be thought of as the amount of energy used in moving charge through the resistor. The unit is *volt*, symbol V. 1 volt equals 1 joule per coulomb, i.e.

1 V = 1 J/C.

**The DC Power Supply**

DC (direct current) power supplies will be used to supply the electricity to the circuits. The advantage of the power supplies is that the voltage supplied can be set to various values unlike batteries which are only available in set values. The power supplies have 3 terminals. By convention, the current comes out of the positive (+) terminal and returns to the power supply by the negative (-) terminal; the third terminal denoted by a *ground* symbol is important when multiple supplies are in use in the circuit and can be ignored in this lab. The power supply also has a meter. However, this meter is not necessarily accurate and precise settings should be made with a voltmeter.

**The Digital Multimeter**

Meters are used to measure current and voltage as well as other electrical quantities. Generally, measurement functions are combined into one instrument called a *multimeter*. A diagram of a typical multimeter is shown below.

OFF



V

V

A

A

COM

V·

A

mA

Function and

Range Switch

Test Lead

Connecting

Terminals

A multimeter has a dial switch by which the *function* (and sometimes range) are set for the required measurements. There are usually more than two *test lead connecting terminals* so the test leads must be connected to the appropriate pair; the *common* (COM) terminal is always used.

The basic steps to follow before connecting a multimeter to a circuit are:

1. Switch the function switch to the electrical quantity you wish to measure (voltage, current, or resistance) and set the *range* (not necessarily required in an *autoranging* meter) to a value greater than the suspected value in the circuit. If in doubt, start with the greatest range possible.
2. A test lead must be inserted in the corresponding terminal. There is usually one for voltage and resistance measurements, one for low current measurements and one for high current measurements. The other test lead is *always* connected into the COM socket. Consider the COM socket as the negative terminal of the meter in the upcoming circuits.

NEVER MAKE A RANGE OR FUNCTION CHANGE IN A multimeter WHILE CONNECTED IN OR TO A LIVE CIRCUIT.

# VOLTAGE Measurements

## Experiment #1

To get some practice with voltage measurements the voltage of two batteries will be measured.

1. Move the function switch to DC voltage. This is identified either with the abbreviation DC on the function switch or on the display or by the symbol
2. Connect or touch the **voltage** lead of the meter to the (+) or positive terminal of the battery.
3. Connect or touch the **common** lead of the meter to the (-) or negative terminal of the battery.
4. Record the voltage measurements of the D cell and the 9V battery.

**Experiment #2**

To measure the voltage across segments of a circuit a voltmeter is used as shown in the figure below. Note the circuit does not have to be disturbed. All that has to be done is to connect the voltage lead of the voltmeter to the (+) terminal of the device and the common lead of the multimeter to the (-) terminal of the device.

**(set to 3 V)**

power

supply

current

+

lamp

+

+

switch

+

+

D.M.M.



47 

**WHEN MEASURING THE POTENTIAL DIFFERENCE ACROSS A DEVICE ALWAYS CONNECT THE VOLTMETER IN *PARALLEL* WITH THE DEVICE.**

Set the power supply voltage to 3 volts. The meter on the power supply only gives an approximate voltage so attach the voltmeter to the output sockets of the power supply and set an accurate value. This does not harm the voltmeter. With the voltmeter measure the voltage across each of the devices in the circuit and the voltage from the power supply. Complete the table in the hand-in sheet. Compare the sum of all the voltages across each of the devices in the circuit with the voltage of the power supply.

**Current Measurements**

In this section some practice using the multimeter as an ammeter is provided. There is one caution that must be exercised with an ammeter:

**NEVER CONNECT *BOTH* LEADS OF AN AMMETER DIRECTLY TO THE TERMINALS OF A BATTERY OR POWER SUPPLY.**

To convert the multimeter into an ammeter, turn the function switch to DC current usually marked “A” or “mA”. Most meters use a different test lead socket for current. The current ranges are often given in milliamperes (mA) instead of amperes. You have no idea what the current will be in the next experiment so set the current range to its largest value just to be safe. If the range is too large disconnect one lead to the ammeter or turn off the power supply and change to a lower range.

**Experiment #3**

To measure the current in a circuit it is necessary to disconnect the circuit, insert the ammeter, and reconnect the circuit as shown below.

**(set to 3 V)**

+

ammeter

power

supply

current

+

lamp

+

+

switch

+

D.M.M.



47 

The current must flow into the current socket and out of the common socket of the ammeter. All the current to be measured must flow through the ammeter; there is no alternative path. The ammeter is, therefore, connected in *series*.

**AMMETERS ARE ALWAYS CONNECTED IN *SERIES* WITH THE DEVICE WHICH IS HAVING ITS CURRENT MEASURED.**

Measure the current through the circuit shown above for both positions of the switch. Move the ammeter to another part of the circuit and see if the current changes.

**Resistance Measurements**

Electrical Resistance, *R*: The electrical *resistance* of an electrical conductor is a measure of the difficulty to pass an electric current through that conductor. Resistance is determined by the voltage difference, *V*, across a material divided by the current, *I*, through the material. The equation is *R* = *V*/*I*. The electric unit of resistance is called an *ohm* (). 1  = 1 V/1 A.

**Ohm’s Law**

This relationship between voltage difference *V*, current *I* and resistance *R* is *Ohm’s Law*, stated as:

*V* = *IR*

With Ohm’s Law, knowing any two of voltage difference, current or resistance, it is possible to calculate the third quantity.

**Experiment #4**

Connect the circuit as shown below. Remember to set the multimeter as an ammeter. Set the power supply so as to read 1.0 V on the voltmeter. Measure the current through resistor #1 using the lowest range, likely the milliamp (mA) range. Use the measured voltage and current to calculate the resistance of the resistor. Enter the data on the hand-in sheet. Repeat the above procedure with the power supply set to 10 V.



**(set to 1 V then 10 V)**

**Experiment #5**

Use the colour code on the next page to read the resistance and tolerance of resistors #1, #2 and #3. Does the value of resistor #1 agree with the values found in Experiment #4?

**The Ohmmeter**

**Experiment #6**

1. **Disconnect** the resistor #1 from **all** other electrical devices, power supplies and meters, etc. NEVER CONNECT AN OHMMETER TO THE TERMINALS OF A POWER SUPPLY OR BATTERY. Ohmmeters supply their own power to make their measurements.
2. Turn the function switch to “ohms” or “”.
3. Connect two leads to the meter, one in the  socket, the other on the COM socket.
4. Connect a lead from the ohmmeter to each end of resistor # 1. Read the meter and note the units displayed: , k, M.
5. Use the ohmmeter to measure the resistance of resistors #1, #2 and #3. Record each of the values in the answer sheet.

# Resistor Colour Code

The coloured bands around one end of a resistor tell its resistance value in ohms. Each colour represents a number, as shown in the chart below. The first and second bands, nearest the end of the resistor, represent the first and second digits of the value; the third band represents the multiplier. A fourth band gives the tolerance rating\*.



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **COLOUR** | **1ST DIGIT** | **2ND DIGIT** | **MULTIPLIER** | **TOLERANCE** |
| Black | 0 | 0 | × 1 | - |
| Brown | 1 | 1 | × 101 | ± 1% |
| Red | 2 | 2 | × 102 | ± 2% |
| Orange | 3 | 3 | × 103 | - |
| Yellow | 4 | 4 | × 104 | - |
| Green | 5 | 5 | × 105 | - |
| Blue | 6 | 6 | × 106 | - |
| Violet | 7 | 7 | × 107 | - |
| Gray | 8 | 8 | × 108 | - |
| White | 9 | 9 | × 109 | - |
| Gold | - | - | × 0.1 | ± 5% |
| Silver | - | - | × 0.01 | ± 10% |



\*The manufacturer guarantees that the actual resistance is within the tolerance rating of the resistor’s specified value. The tolerance is not an uncertainty.

**SERIES Circuits and Resistance**

**Experiment #7**

Use the colour code to find a 1.5 k and a 3.3 k resistor. Measure their resistances accurately with an ohmmeter. Connect the circuit shown below.

**(set to 10 V)**

variable

power

supply

+

A

D

ammeter

volt

+

**-**

**-**

R

2

R

1

1.5 k



3.3 k



Adjust the variable power supply until Δ*VAD* = 10.0V as measured by the voltmeter. Set up the ammeter to measure in **milliamps**, measure the current *I* and calculate the total resistance of the circuit from



Compare the total resistance with the value found using the series resistance formula:

*Rtot* = *R1* + *R2*

**Parallel Circuits and Resistance**

**Experiment #8**

Connect R1 and R2 into a parallel resistance combination as shown below. Use the resistors from experiment #7 and set the variable power supply to 5.00V.



**(set to 5 V)**

Measure the total current *I* and measure the voltage change Δ*VAB*. Calculate the total resistance by



Calculate the parallel resistance using the parallel resistance formula:



Does *Rp* = *Rtot*? Does the parallel resistance formula work?

# Experiment #9

Connect the circuit as shown below. You will have to use the colour code to determine which resistors to use. To make the circuit easier to set up and measure, try to lay the resistors out so your circuit looks the same as the diagram.



**(set to 10 V)**

Set one of the digital multimeters so it becomes a voltmeter that will read at least 10 V. Use this voltmeter to set the variable power supply to 10 volts.

Measure and record *VAB*, *VCE*, *VDF*, and *VGH*. Remember all you have to do is touch the leads at the appropriate places to get a reading with a voltmeter.

Answer the questions in the hand-in sheet.

**Experiment #10**

Using the colour-code values of the resistors and the measured voltages from experiment #9, calculate the expected current for each resistor in the circuit. Also calculate the possible range of deviation of the current using the specified tolerance of the resistor.

Answer the questions in the hand-in sheet.

**Experiment #11**

Set the digital meter so it becomes an ammeter that will read at least 10 mA. Recall that the ammeter must be placed in the circuit such that it is *in series* with the component whose current you wish to measure. This means that parts of the circuit will have to be disconnected when placing the ammeter. Use the ammeter to measure the current through each resistor.

Answer the questions in the hand-in sheet.