INTRODUCTION TO ELECTRICAL EXPERIMENTS

Most electrical experiments require the use of delicate expensive instruments (galvanometers, ammeters, voltmeters) which must be handled with the sort of care one would give to an expensive watch or camera.

In the electrical experiments, it is necessary to be able to wire circuits quickly and completely. Here are a few simple rules to follow when wiring up a D.C. circuit:

1. DO NOT CONNECT TO THE BATTERY OR POWER SUPPLY UNTIL YOU HAVE CORRECTLY WIRED YOUR CIRCUIT AND HAVE HAD IT CHECKED BY THE INSTRUCTOR. THIS CAUTION APPLIES TO ALL ELECTRICAL EXPERIMENTS WITHOUT EXCEPTION.

If you are using a dry cell as a source of emf, leave one lead disconnected until the circuit has been checked. If you use a bench socket for a supply,

(a) have a switch in the circuit and leave it open, and
(b) do not plug into the socket until the circuit has been checked. Remember that an overloaded instrument can burn out in a fraction of a second.

2. The positive terminal of an ammeter or voltmeter must be connected to the positive terminal of the supply and similarly the negative terminal of the ammeter or voltmeter must be connected to the negative side of the supply.

AMMETERS MUST BE CONNECTED IN SERIES AND VOLTMETERS MUST BE CONNECTED IN PARALLEL IN A CIRCUIT.

3. The center of a dry cell is positive and the outside case is negative.

4. Resistors and switches have no polarity and therefore it does not matter which end is connected to the positive side of the circuit.

5. For the most part, capacitors and inductors have no polarity and can be treated like resistors. If some polarity is indicated then they must be connected positive-to-positive and negative-to-negative.

6. When using an ammeter or voltmeter always use the highest range first.

ELECTRICAL SYMBOLS USED IN PHYSICS 112 LAB MANUAL

Resistor Color Code Chart

Color	1st and 2nd Figures	Multiplier
Black	0	none
Brown	1	10
Red	2	100
Orange	3	1,000
Yellow	4	10,000
Green	5	100,000
Blue	6	1,000,000
Violet	7	10,000,000
Gray	8	100,000,000
White	9	1,000,000,000

Tolerance band: gold ±5%, silver ± 10%, no band ± 20%.

To read a resistance value, the first two bands stand for the first two significant figures, i.e. a number between 10 and 99. This two digit number is multiplied by 10 to the power indicated by the third band, for example if the first three bands are brown-black-red (by color code, 1-0-2), then the resistance is 10×10^2 or 1000 Ω

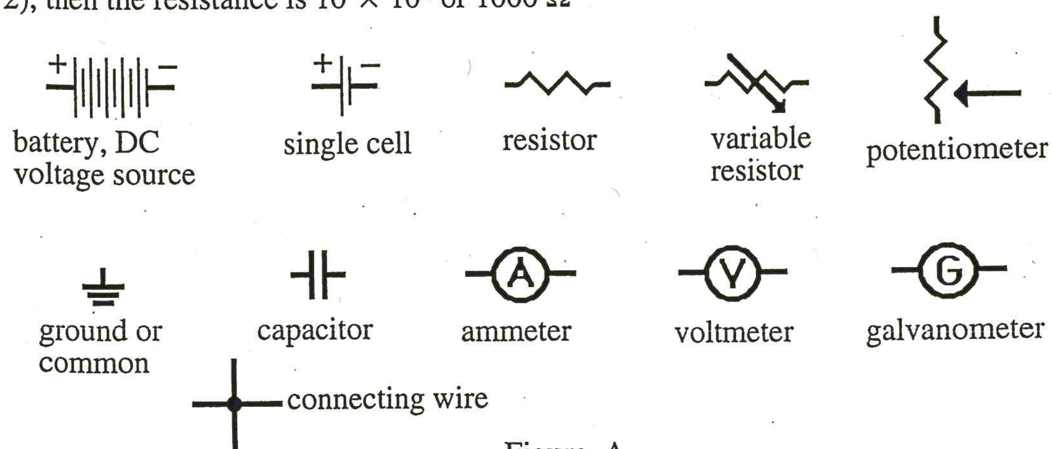

Figure A

OPERATING INSTRUCTIONS for MODEL EC-2 D.C. POWER SUPPLY

1. Connect unit into circuit observing correct polarity (instructor must check).
2. Set voltage control selector to minimum position (extreme counter clockwise).

CAUTION: Always return voltage selector to position "zero" when turning "ON" or "OFF" the power supply. This will prevent damage resulting from surge voltages.

3. Turn the "ON-OFF" switch to ON position.
4. Rotate voltage control selector to desired voltage or current values.

NOTE: The switch directly below the meter enables the operator to select the desired meter function.

QUANTITIES MEASURED IN ELECTRICAL EXPERIMENTS

An electric current consists of the flow of large numbers of electric charges along a conductor. The conductor usually offers some resistance to the flow, and therefore it is necessary to have a source of electrical energy or electromotive force (emf) in the circuit to keep the current flowing. In Physics 112 experiments, the source of emf will be either a dry cell or an E.C.-2 power supply. In setting up the experiments it is necessary to have a complete circuit because the electric current passes completely around it and through the source of emf - the latter simply serves to replace the energy which is lost by the current against the resistance of the circuit.

The following symbols and units are used:

Current	(I)	- amperes,
emf/Voltage	(E) or (V)	- volts,
Resistance	(R)	- ohms.

The three quantities are connected by the equation (Ohm's Law):

$$V = IR \ .$$

In order to carry out quantitative experiments in electricity, it is also necessary to have instruments to measure these three quantities. The basic instrument is the 'galvanometer'. This may be modified to form an 'ammeter' to measure current, or to form a 'voltmeter' to measure voltage, or an 'ohmmeter' to measure resistance.

GALVANOMETER:

The galvanometer is a sensitive current measuring instrument. The "moving coil" type used in this laboratory consists of a small coil or wire pivoted between the poles of a permanent magnet as shown in Figure 1. When a current passes through the coil, the coil acts as a small magnet and tries to line itself up with the field of the permanent magnet. This swings the attached pointer across a scale. A small spring (not shown in the figure) tends to prevent this motion, and when no current flows through the coil it holds it in such a position that the pointer is at the zero on the scale.

Since the magnetic torque of the movable coil is directly proportional to the current flowing through it, and since the restoring torque of the spring is proportional to the angular deformation then the deflection of the pointer over the scale will be proportional to the current.

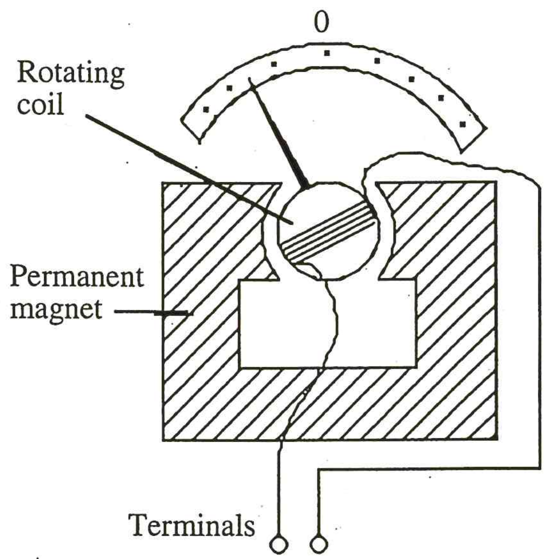

Figure 1. Center zero galvanometer.

The direction of pointer movement for direct current instruments depends upon which way the current flows through the coil. The zero-current position of the pointer on the galvanometers may be placed at the center of the scale to allow for current flow in either direction. Alternatively, the zero-current position may be at one side to allow a greater current range, but in only one direction.

AMMETER:

To measure larger currents than can be passed directly through the coil of a galvanometer it is usual to add a parallel by-pass or 'shunt' resistance which carries the greater part of the current and only permits a small (but accurately known) proportion of the current to pass through the coil itself (Figure 2). The instrument is then known as an ammeter.

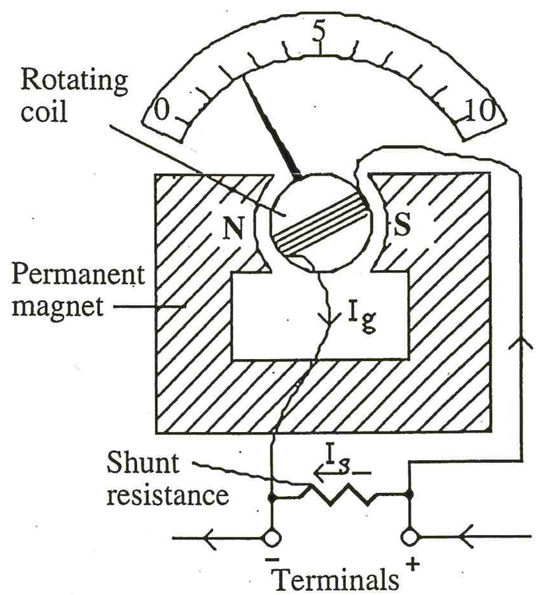

Figure 2. Ammeter.

The value of the shunt resistance (R_S) required is calculated as follows:

$$V = I_g R_g = I_s R_s \ ,$$

or

$$R_s = R_g I_g / I_s = R_g I_g / (I - I_g).$$

E.g. if the galvanometer

resistance (Rg) is 10 ohms, the maximum coil current is 0.001 amps, and it is required to measure up to 1 amp., then

$$R_S = \frac{10\Omega \times 0.001A}{1A - 0.001A} = 0.01001\Omega$$

Some of the ammeters provided in this laboratory have the zero at the left end of the scale and the current must be sent through the instrument in the correct direction or it may be damaged. These ammeters have three current ranges, i.e. three shunt resistances are provided inside the case, and there are four terminals. The one marked + must be connected to the positive side of the supply and the other connection made to one of the other terminals.

ALWAYS CONNECT INITIALLY TO THE HIGHEST AMP. RANGE. WHEN YOU HAVE ENSURED THAT THE CURRENT DIRECTION IS CORRECT AND DETERMINED THAT IT IS SAFE TO DO SO YOU MAY RECONNECT TO A SUITABLE LOWER CURRENT RANGE.

VOLTMETER:

The voltmeter is a device used to measure the potential difference or emf between two points. It essentially is a galvanometer with a high resistance connected in series with the rotating coil. This high resistance results in a low (but well known) current through the coil. The scale can then be calibrated in volts. Usually voltmeters are constructed with several different resistances built in to allow for scale selection.

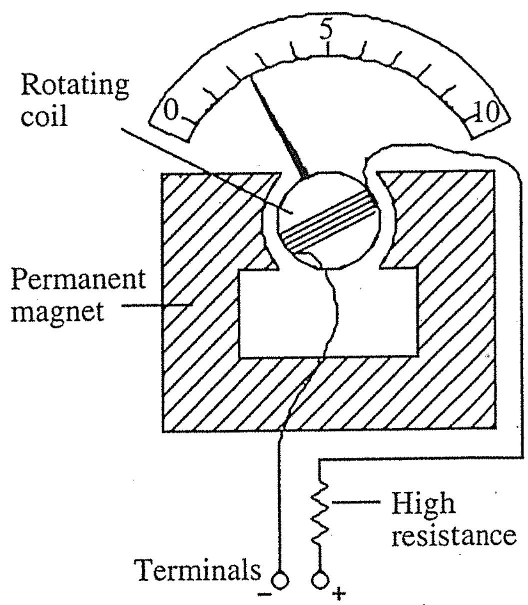

Figure 3. Voltmeter

The voltmeter must always be connected in parallel across a source of emf. The multi-range voltmeters provided for this laboratory have three series resistances built into the case and four terminals. The one marked + must be connected to the positive of the supply and negative connection must be made to one of the other terminals.

ALWAYS CONNECT INITIALLY TO THE HIGHEST VOLT TERMINAL. WHEN YOU HAVE ENSURED THAT THE CONNECTIONS ARE CORRECT AND DETERMINED THAT IT IS SAFE TO DO SO, YOU MAY CONNECT TO ONE OF THE LOWER VOLTAGE RANGES.

OHMMETER:

A galvanometer which has been converted into a voltmeter by the addition of a series resistance can be converted into an ohmmeter by the further addition of a dry cell. In Figure 4, G is the galvanometer, R_G is the series resistor which converts G into a voltmeter, and B is a dry cell of internal resistance R_B.

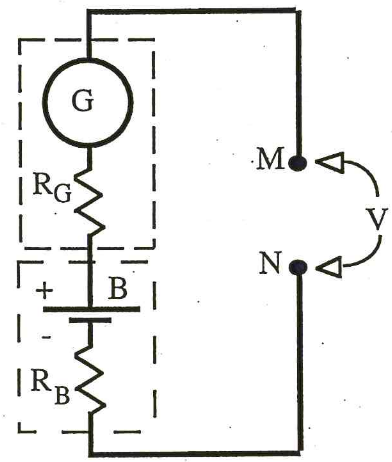

Figure 4. Ohmmeter

Suppose that the total resistance, $R_T = R_G + R_B$, is such that when the terminals MN are shorted G gives full scale deflection of the galvanometer. If now a resistance of R_x ohms is placed across MN, the meter will give less than a full scale deflection because the same potential will send less current through $(R_T + R_x)$ than it sends through R_T alone. This deflection is not linear but changes much more slowly as the resistance gets larger.

DIGITAL MULTIMETER:

The digital multimeter (DMM) combines the function of a voltmeter, an ammeter, and an ohmmeter into one single unit. The basic component of the DMM is a digital voltmeter that uses a dual slope or voltage-to-frequency converter to change the unknown voltage to a digital read-out. To measure current, a current-to-voltage converter (a precision resistor network) is placed in front of the digital voltmeter. The unknown current, when passing through this current-to-voltage converter, produces an IR drop (voltage) which is measured by the digital voltmeter. This measurement is then converted to an appropriate current reading in the digital display. Similarly, a resistance-to-voltage converter is used to measure resistance. Here a constant current is used to measure the IR drop across the unknown resistance. Again this voltage is measured by the digital voltmeter and displayed in resistance reading.

The digital multimeter (DMM) used in this lab course is the Advance DMM2 or its equivalent and is capable of measuring resistance, AC and DC current and voltage. It has two sets of push button controls: the range switches and the mode switches. The range switches set the maximum range of the measurement and an indicator neon marked O/L on the lower left of the display will be illuminated if the measurement is over this maximum value. The mode switches are for selecting the DMM's function and there are six push buttons. 'V' is for measuring voltage, 'Ω' is for measuring resistance and '200 μA' is for measuring current up to a maximum of 200 μA. The other three push buttons are: '~' for AC quantities, '+' '-' for DC measurements.