

PHYSICS 102 LAB 1: MEASUREMENT TECHNIQUES FOR THE PHYSICS OF ELECTRICITY
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SPRING, 2005

THEORETICAL DISCUSSION

Electric Potentials and Currents: Throughout much of the semester we will be making measurements of electric potential V and current I . This laboratory will explain these quantities and introduce you to the apparatus and techniques that we will use to produce and measure potentials and currents. The electric potential V is the potential energy per unit charge at some point in space. If a charge q is placed at a point at which the potential (relative to some reference point) is V , it will have a potential energy U (relative to the reference point) given by

$$U = qV$$

The SI units of charge are Coulombs, and the SI units of potential are Volts. The SI units of energy are, of course, Joules, so that 1 Coulomb placed at a potential of 1 Volt has a potential energy of 1 Joule. The absolute value of potential, like the absolute value of energy, is arbitrary: only differences of potential are physically meaningful and measurable. For this reason, one always measures the potential difference between two points in space, or two points on a circuit. This has important practical consequences, and it is important enough to repeat, with emphasis.

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The electric grid provided by the power company (in our case, Progress Energy) maintains a fixed reference point for potential, which it defines as the zero of electric potential. This zero is called the ground. You may have noticed that many of your electric plugs have three prongs. Three-prong plugs are called grounded plugs; the rounded plug in the bottom center of the plug is connected to the electric company's ground potential. The potential of the ground plug is very close to the electric potential of the surrounding earth. It is sometimes known as "earth ground".

The electric current I is the rate at which charge flows past a point. If an amount of charge Δq flows through a point in a time Δt , then the electric current through that point is

$$I \equiv \frac{\Delta q}{\Delta t}$$

The SI unit for current is the Ampere. Since the SI unit of time is the second, and the SI unit for charge is the Coulomb, it follows that 1 Ampere = 1 Coulomb per second. Since current is the flow of charge past a single point, it follows that in order to measure current, one must break into the circuit at that point and connect the current measuring device so that the charge flows through it. This is also important enough to repeat, with emphasis:

One always measures the electric current I at a single point in a circuit and connects the current measuring device so that the charge flows through the device.

You can avoid a lot of grief, bad results, and broken equipment just by remembering the following two rules for measuring potentials and currents:

1. Measure a potential difference *across* two different points in a circuit.
2. Measure a current *through* a single point on a circuit.

Multimeters: Devices that measure electric potential are called *voltmeters*. Devices that measure electric current are called *ammeters*. It is very common for a single instrument to incorporate both a voltmeter and an ammeter. It may also be able to perform other types of electrical measurements. A device which combines several different electrical measurement functions is called a *multimeter*. Figure 1A depicts the function and range selection options for one of the multimeters used by the Physics Department in the introductory labs. These multimeters can perform 5 different types of measurements; DC Voltage, DC Current, AC Voltage, AC Current, and Resistance. DC is an abbreviation that stands for “direct current”. AC is an abbreviation for “alternating current”. [1] All of your labs this semester will use DC potentials and currents. You can select the function and the measurement range by rotating the central dial till it points to the desired function and range. Each range setting is labeled by the maximum value measurable on that setting. For instance, on the DC current range setting labeled by $200\ \mu$, one can measure a direct current from $0\text{--}200\ \mu\text{A}$ ($0\text{--}200 \times 10^{-6}$ Amperes). On the DC voltage setting labeled by 2, one can measure a DC voltage from $0\text{--}2$ Volts. The lower the range setting, the greater the sensitivity and resolution. In general, you should use the lowest range setting that is greater than the size of the signal that you expect to measure. If you attempt to measure a signal which exceeds the maximum for that range, the display screen of the multimeter will either flash, or display the value 1. If this is the case, you must increase the range setting until you observe a credible reading on the display.



Figure 1A



Figure 1B

FIG. 1: Function and scale selection and input connections for departmental multimeters

Figure 1B shows the input connections for the departmental multimeters. The inputs used to connect the multimeter to the circuit depend upon which quantities you wish to measure. The input labeled 10 A is used only for measuring very large currents. You will not need it for this course. The multimeters used by the department for this course have an unfortunate energy saving feature that turns off the multimeter if it is not manipulated for a (very short) period of time. When it turns off, the screen simply appears blank, and you may think that there is something wrong with your measurement. In fact, the device has simply turned itself off. In order to resurrect it, you should turn the power button off and back on again. If you still have no reading on the screen, something else may be wrong; perhaps the battery is dead.

Power Supplies: A power supply is a device that supplies electrical current at a selectable output potential.

The power supplies that you will use this semester are DC power supplies, meaning that they only supply DC potential and current. A picture of one of the power supplies used in the introductory laboratories is shown in figure 2. The output terminals are labeled $-$ and $+$. The potential at the positive terminal is higher than the potential at the negative terminal by an amount shown on the voltage display. Some of the power supplies have digital displays and some of them have meters. In neither case is the display value accurate enough for your use in the labs. If the potential across or current through a circuit is required by one of the labs, you should always use a multimeter to measure it rather than relying on the value shown on the display. The output potential may be adjusted by turning the fine and course voltage adjustment knobs. As you might expect, the course control allows large, but imprecise, adjustments to the voltage, whereas the fine control allows much smaller, but more precise adjustments. The current controls will have been set prior to your labs by the lab manager or one of his or her assistants so as to limit the maximum amount of current output by the supply. The purpose of this limit is to prevent damage to the equipment and to students. *Leave the current control knobs alone!* If the red light directly underneath the current control knobs is lit up, that means that you have attempted to exceed the maximum current limits set on the supply. Once this limit is exceeded, you will not be able to turn the voltage up any further. If this happens, turn the output voltage on the supply down and notify your instructor.

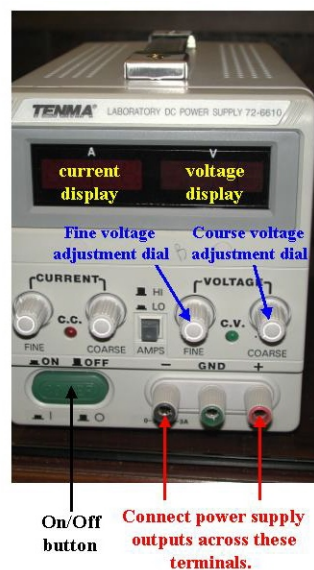


FIG. 2: Departmental DC power supply

The Breadboard: A breadboard is a device for quickly making temporary electrical circuits. It consists of a set of input and output terminals which can be connected by means of jumper wires to a field of small sockets. Underneath the plastic (insulating) cover of the breadboard, various subsets of the sockets are connected to one another. The breadboards used by the department have 4 input/output terminals. The internal connections of these breadboards are shown in figure 3. All sockets enclosed by a box in the figure are electrically connected together.

Circuit Diagrams: Figure 4 shows a typical circuit diagram containing three circuit elements, a voltmeter, an ammeter, and a power supply. The voltmeter is measuring the potential difference across circuit element 1, and the ammeter is measuring the current through circuit element 2. It's important to understand a couple of things about circuit diagrams. The first is that the circuit itself will not necessarily look anything like the diagram. The diagram is an abstract version of the circuit that tells you how things are connected together. The actual circuit will likely look a lot messier. The second important thing to note is that all points that are not separated by circuit elements or junctions are in fact equivalent. Thus, points *A*, *B*, and *C* are all essentially the same point. Likewise, points *D* and *E* are really the same point on the circuit: they could be

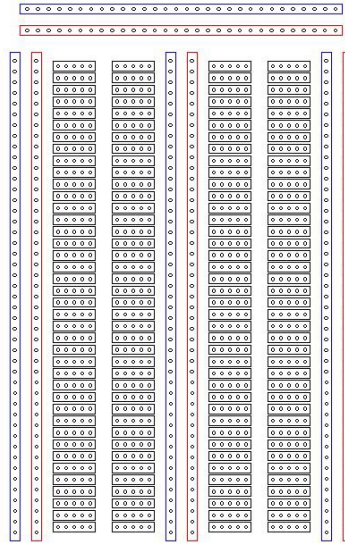


FIG. 3: Internal connections of the Physics Department's breadboards

connected together and nothing in the circuit would change.

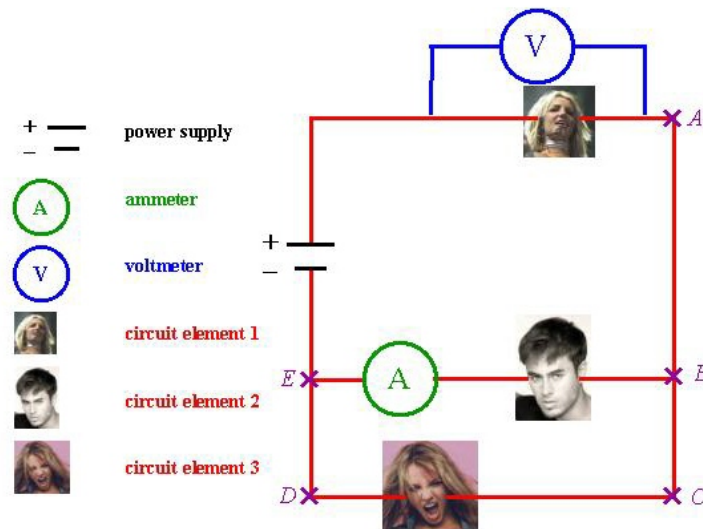


FIG. 4: A typical circuit diagram

PROCEDURE

1. Assemble the circuit shown in figure 5.
2. Measure and tabulate:
 - the current I_1 through circuit element 1

- the potential difference V_1 across circuit element 1, and
- the power supply voltage V_S

as you slowly raise the power supply voltage through the values $V_S = 0.2, 0.6, 1.0, 2.0, 3.0$, and 4.0 V. Use the most sensitive voltage and current scales possible on each step.

3. Plot I_1 vs. V_1 . Note that this means that the potential is on the x -axis (abscissa) and the current is on the y -axis (ordinate).

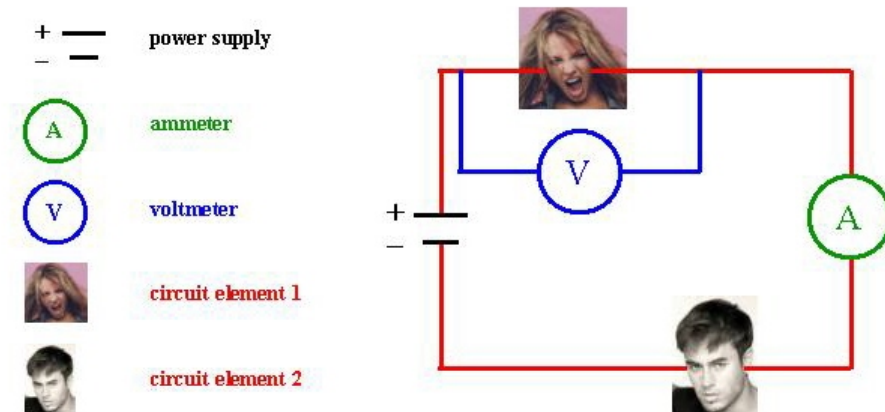


FIG. 5: The experimental circuit

[1] DC potentials and currents are constant in time. AC potentials and currents vary in time, often quite rapidly.