Appendix D: Equipment

ELECTROSTATIC PAPER AND ACCESSORIES:

To investigate electric fields with the electrostatic paper, you need to do the following:

- Lay the electrostatic paper flat. .
- Distribute the pieces of metal (called "electrodes") on the paper, in the configuration whose field you wish to examine. The tips of the long brass rods may also be used as electrodes, to create point-like charges.
- Connect the electrodes to a source of charge. This is done by connecting a wire from the positive ("+") side of the battery or power supply to one electrode and the wire from the negative ("–") side to the other as shown in Figure 1.
- You may wish to place a wooden block on top of the brass rods to increase contact pressure with the paper. This can increase the magnitude of the electric field created on the paper

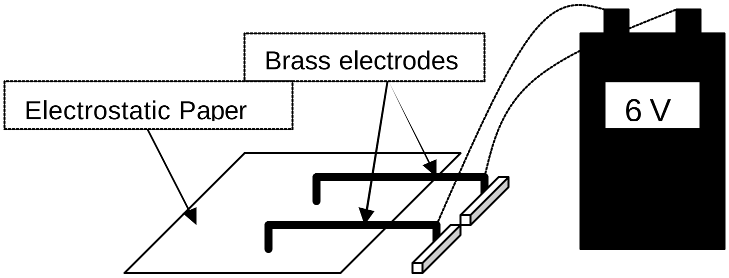


Figure 1: Electrostatic paper Setup
(wooden block not shown)

To measure the electric field from the charged electrodes, you will use a probe connected to a digital Multimeter set to measure volts (see Figure 2, below). For best results, turn the DMM to measure in the two-volt DC range, as indicated in Figure 2.

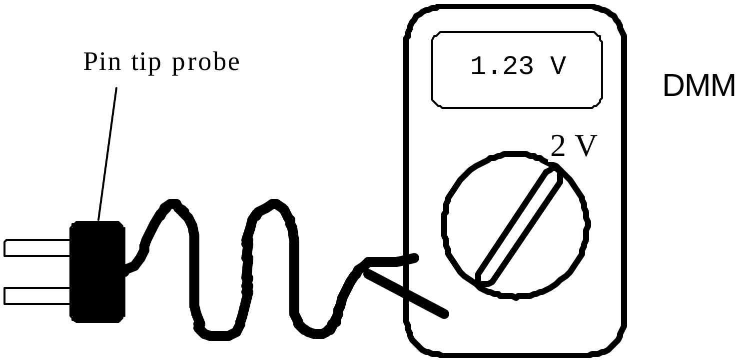
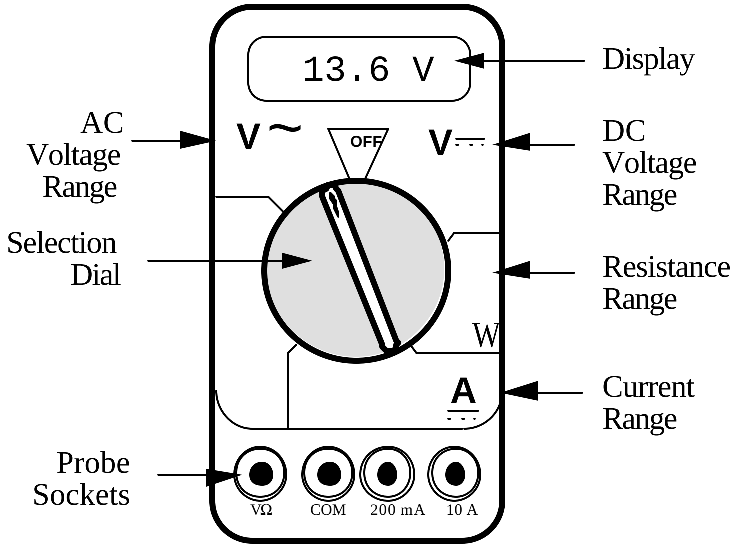


Figure 2: Electric Field Probe

THE DIGITAL MULTIMETER (DMM)

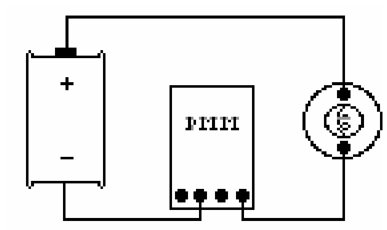
The DMM is a common piece of lab equipment that can be used to measure various electrical quantities, most often current, resistance, and potential. The DMM's you will be using are capable of measuring both "direct current" (DC) and "alternating current" (AC) circuits. Be careful about knowing which type of measurement you need to make, then set your DMM accordingly. Some DMM's might be slightly different from the one pictured to the right.



The DMM can measure currents anywhere from 10 amps to a microamp (10^{-6} amps). This versatility makes the DMM fragile, since measuring a large current while the DMM is prepared to measure a small one will certainly harm the DMM. For example, measuring a 1 ampere current while the DMM is on the 2 milliamp scale will definitely blow a fuse! If this happens, your instructor can change the fuse. However, if you damage the DMM beyond repair, you will have to finish the lab without the DMM.

Measuring Current:

1. Set the selection dial of the DMM to the **highest** current measurement setting (10 amps). Insert one wire into the socket labeled '10A' and a second wire into the socket labeled 'COM'.
2. Attach the DMM into the circuit as shown below:

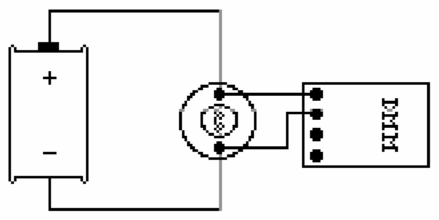


To measure current, the DMM must be placed in the circuit so that all the current you want to measure goes **through** the DMM.

3. If no number appears while the DMM is at the 10A setting, move the wire from the 10A socket to the 200mA socket and then turn the selection dial to the 200 milliamp (200m) setting. If there is still no reading, change the dial to the 20 milliamp setting, etc.
4. When you have taken your measurement, return the DMM selection dial to the highest current setting (10 amps) and move the wire back to the 10A socket.

Measuring Voltage:

1. Set the DMM selection dial to read DC volts (V⎓). Insert one wire into the socket labeled 'V?' and a second wire into the socket labeled 'COM'.
2. Set the selection dial of the DMM to the **highest** voltage measurement setting. Connect the two wires from the DMM to the two points between which you want to measure the voltage, as shown below.



To measure voltage, the DMM must be placed in the circuit so that the potential difference across the circuit element you want to measure is **across** the DMM.

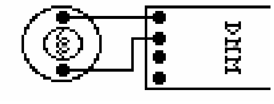
3. If no number appears, try a different measurement scale. Start at the highest voltage scale and work your way down the scales until you get a satisfactory reading.

Measuring Resistance:

The element whose resistance you are measuring ***must*** *be free from all other currents (due to other batteries, power supplies, etc.) for the DMM to work.* That means you must **remove** it from a circuit.

To measure resistance:

1. Set the DMM selection dial to measure ohms (Ω). Insert one wire into the socket labeled 'VΩ' and a second wire into the socket labeled 'COM'.
2. *Make sure that the circuit element whose resistance you wish to measure is free of any currents.*
3. Attach the wires across the circuit element, as shown in the example below.



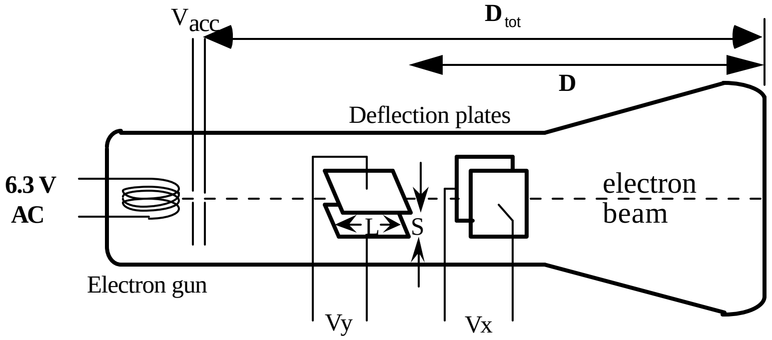
4. If no number appears, try a different measurement scale. Use a logical method that covers all scales, such as beginning at the largest scale (20 MΩ) and working your way down.

CATHODE RAY TUBE (CRT) AND ACCESSORIES:

Use of the cathode-ray tube and its relatives is widespread. It is the heart of many familiar devices, from your computer monitor to your television. The following is a sketch of the tube you will be using and its connections.

Figure 3:
Cathode Ray Tube.

D = 7.4 cm
L = 2.0 cm
S = 0.30 cm
D_{tot} = 9.6 cm



How the CRT works:
Within the electron gun:

- A thin filament (represented above as a coil of wire), similar to a light-bulb filament, is heated by a current. When the CRT is operating, this filament can be seen as an orange, glowing wire. This hot filament ejects slow-moving electrons.
- Some slow electrons drift toward the high-voltage “acceleration plates.” These plates are labeled as Vacc in Figure 3. The electric field between the charged plates accelerates the electrons to high velocities in the direction of the fluorescent screen. The final velocity of an accelerated electron is much greater than its initial “drift” velocity, so the initial electron velocity can be ignored in calculations.

After the electron gun:

- Before hitting the screen, the high-velocity electrons may be deflected by charged plates along the length of the CRT. These charged plates are usually called the “x-deflection” and “y-deflection” plates.
- When the electrons reach the end of the tube, their energy causes the material that coats the end of the tube to glow. This material is similar to the material inside fluorescent light bulbs. The end of the CRT is called the fluorescent screen.

To supply the necessary electric potentials to the CRT you will use a power supply. The power supply provided has the proper potential differences to heat the CRT filament and to accelerate the electrons. The power supplies we use also have built-in circuit breakers. Should you attempt to draw too much current from your power supply, it will shut itself off with an audible “click.” If this happens, check to make sure all of your wires are connected properly, then press in the small white button on the side of the power supply.

Note that the CRT and power supply come as a set, and many of the connections are color-coordinated to avoid potentially damaging misconnections. You will also have an assortment of batteries, which will be used to control the electric field between the CRT x- and y-deflection plates.

WARNING: You will be working with equipment that generates large electric voltages. Improper use can cause painful burns. To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply.

To properly connect the CRT to the power supply:

1. Turn the power supply off.
2. Connect the power supply ports marked “AC 6.3V” (they are green; the voltage differs slightly from one supply to another, but should be clearly marked) to the ports marked “HEATER” or “FILAMENT” on the CRT (these are also green).
3. Connect the appropriate accelerating potential across the cathode and anode. For instance, if your experiment calls for a 500 volt accelerating potential, connect the cathode to the port marked “–250 V” (which may be black or white) and the anode to the port marked “+ 250 V” (which is red). This gives a total potential difference of 500 volts.
4. Turn the power supply on.

RESISTOR CODES

A resistor is a circuit element manufactured to have a constant resistance. The resistance of a resistor can be determined by the color bands (see the chart below) printed on the resistor according to the following rule:

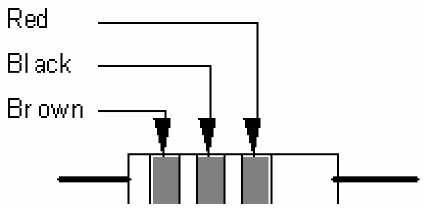
$R = (\text{first color number})(\text{second color number}) \times 10^{(\text{third color number})}\ \Omega$

The fourth color band tells you the tolerance of the resistor: gold means ±5% tolerance, silver means ±10% tolerance and no fourth band means ±20%.

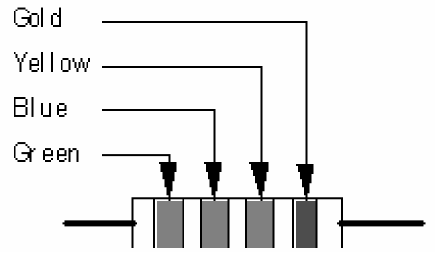
Some resistors have a fifth color band, which represents the reliability of the resistor, and can just be ignored for the purposes of these labs.

Color	Number
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Examples:



$R = 10 \times 10^{2}\ \Omega \pm 20\%$



$R = 56 \times 10^{4}\ \Omega \pm 5\%$

SORENSEN POWER SUPPLIES

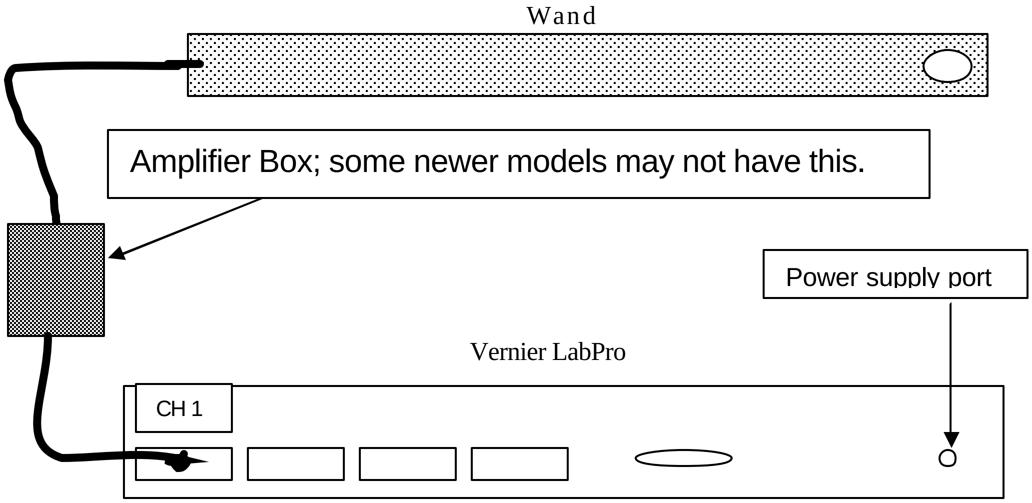
The Sorensen power supply is an all-purpose power supply for the production of constant currents and voltages. The front area consists of 3 areas, the top, middle and bottom. At the top is the main display that reads either current in Amperes or voltage in Volts. There is a switch there that allows you to switch between them. The current and voltage controls are located in the middle. On the right side is the voltage controls for constant voltage (C. V.) mode, and on the left are the current controls for the constant current (C. C.) mode. For each mode there are two knobs, a coarse control knob for large changes and a fine control knob for smaller, more precise changes. In between the constant current and constant voltage knobs is a switch that allows you to toggle from high currents to low currents. **It is highly recommended that you use only the low current mode.** At the bottom of the front is the green power button, and the outputs (positive, negative, and ground).

This power supply normally operates in the constant voltage mode. As such, you can only change the voltages by using the constant voltage (C. V.) knobs. **In the event that too much is being pulled from the power supply (as in a short), it will automatically switch to the constant current mode, where the amount of current flowing is greatly reduced.** This is a signal that something is amiss with your circuit, which you should attempt to rectify.

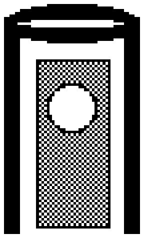
THE MAGNETIC FIELD SENSOR (HALL PROBE)

To measure magnetic field strength, you will need a measurement probe (the magnetic field sensor) and an interface to the computer. Each of these components is described below.

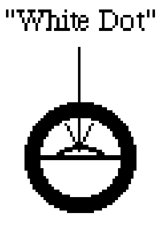
The magnetic field sensor is composed of the wand, the amplifier, and the Vernier LabPro. These parts are sketched below.



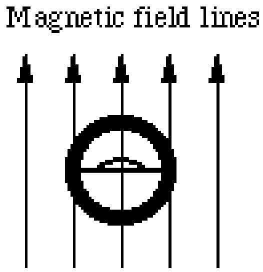
The ***Wand*** is a hollow plastic tube with a Hall effect transducer chip at one end (shown above as the circle on the right hand end of the wand). The chip produces a voltage that is linear with the magnetic field. The maximum output of the chip occurs when the area vector of the white dot on the sensor points directly toward a magnetic south pole, as shown below:



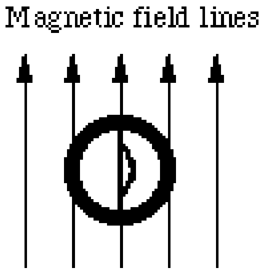
Top View



End View



Orientation for maximum reading



Orientation for zero reading

The ***LabPro*** allows the computer to communicate with the wand. In order to measure magnetic fields, the wire leading out of the wand must be plugged into the LabPro port labeled "CH 1". The LabPro itself should be plugged into the modem port of the computer. The LabPro turns on automatically when its power supply is plugged in. A green light on the top of the LabPro indicates that it is on.

The ***Amplifier*** is contained in a small box and allows you to measure a greater range of magnetic field strengths. The switch on the box is used to select the desired amplification. The **low** amplification setting is used to measure *strong* magnetic fields. The range of the sensor in low mode is about ±64 gauss. The **high** amplification setting is used to measure *weak* fields. The range of the sensor in high mode is around ±3.2 gauss. The actual range will vary from one magnetic field sensor to another. Note: 1 tesla = 10^4 gauss, the magnetic field of the earth is approximately half a gauss. **Some newer models do not have an amplifier box. In these cases there is a switch on the wand itself with the ranges labeled. Also note that on newer models, the "White Dot" is in a different location. This means you will have to hold the wand differently to make sure that the dot is perpendicular to the magnetic field.**