Commonly-Used Instruments

Abstract

This appendix describes some of the common instruments used in the laboratory.

BNC/BANANA ADAPTOR

A BNC/Banana adaptor allows one to plug a BNC connector into something with Banana plugs (such as a DMM). Note that one side of the adaptor has a little "ear" marked **GND** (the "bump" on the left side of the adapter in Figure 1). This side is ground and connects to the outer conductor of the BNC connector (and thus the outer conductor of the coaxial cable).

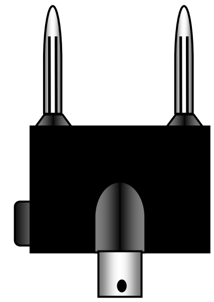

Figure 1: BNC/Banana Adapter

COAXIAL CABLE (with BNC connector)

The coaxial cable actually is ***two*** wires: one inner conductor which runs down
the center of the cable and an outer wire (also called the Shield or Ground). Consider it to be like a flexible metal pipe with a wire running down the center.

All the coaxial cables used in this lab have a latching connector at the end which is called a BNC connector.

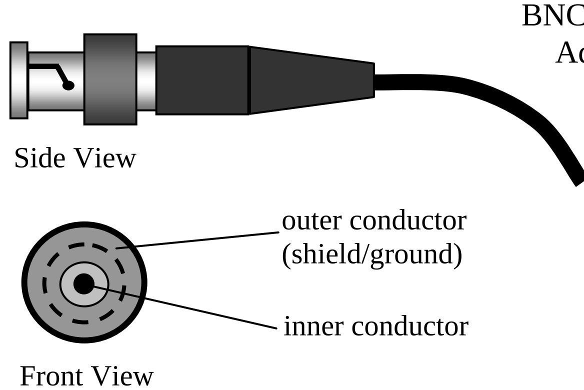

Figure 2: BNC Connector attached to a Coaxial Cable

DIGITAL MULTIMETER (DMM)

A Digital MultiMeter is the swiss-army knife of electrical measurement tools: it can serve as a voltmeter (to measure voltage, or electrical potential), an ammeter (to measure current), or an ohmmeter (to measure resistance).

First decide whether you want to measure voltage, current, or resistance. Turn the dial into that area. Note that if you are measuring voltage or current, there are separate positions for DC and AC. If you are unsure about which you are using, ask a lab instructor. (Batteries and the little numbered wall plugs are DC, the 110 volt wall outlets are AC.)

- DCV: DC Volts
- ACV: AC Volts
- DCA: DC Amps (current)
- ACA: AC Amps (current)
- Ω: Ohms (resistance)

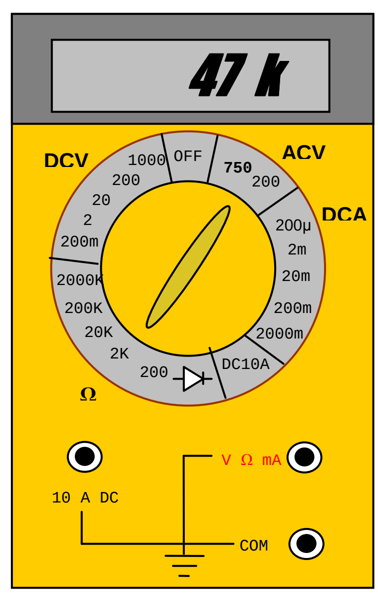

Figure 3: Digital MultiMeter (DMM)

Within that area, you are to select the *range*. In general, one tries to use the lowest possible range. For example, if you have a circuit which uses a 1.5V battery, you know that at no point in the circuit will there be more than 1.5V. Therefore, you would choose the lowest range which is still greater than 1.5V, which is 2V.

VOLTAGE	CURRENT	RESISTANCE
1000 V	2000 mA (2A)	20 MΩ
200 V	200 mA (0.2 A)	200kΩ
20 V	20 mA or 10 A (see below)	20 kΩ
2 V	2 mA	2 kΩ
200 mV (0.2 V)	not used	200 Ω

If you do not have any idea what your range should be, you should start at the largest range. For example, you might have to measure a current and not really know how large it will be. You would then start with the 10A range (which is discussed below). If the current measured below 2A (2000 mA), you could then switch to the 2000mA range or lower, as appropriate.

Selecting which jacks to plug your wires into can be a bit confusing at first. If you are using the DMM as a voltmeter, an ohmmeter, or as an ammeter with a current less than 2A, connect the ground (also called "common") wire into the center jack marked **COM** and the positive wire into the jack labeled **V-Ω-mA**. A negative voltage or current reading indicates that the positive and negative wires are reversed.

***** If you are measuring a current between 2A and 10A, plug the ground (negative) wire into the jack marked **COM** and the positive wire into the left jack marked **10A DC**.

UNCERTAINTY: The uncertainty of the DMM can normally be considered to ± ½ the smallest shown place value, if the number is not varying. For example, if the DMM is consistently reading 8.97 volts, then the smallest place value is 0.01 volts. Therefore, the uncertainty is 0.005 volts, yielding a measurement of (8.97 ± 0.005) volts. If, on the other hand, the DMM reading is fluctuating between 8.97 and 9.02 volts, the measurement would be (9.00 ± 0.03) volts.

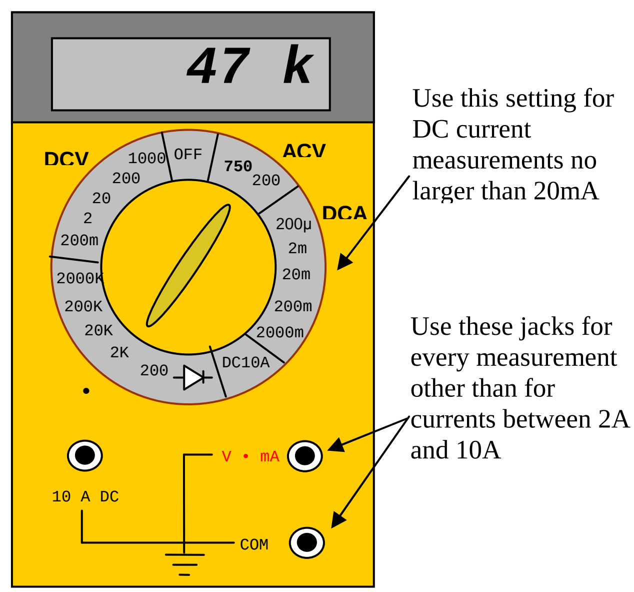

Figure 4: DMM Settings

KNIFE SWITCH

The knife switch simply closes or opens a circuit by making or breaking contact between two metal blades. Note that there are two "double throw" switches, one on each side, each of which is entirely independent of the other. Each switch is called "double throw" because there are two ways to "throw" the switch.

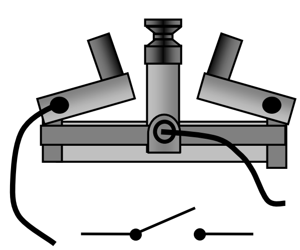

Figure 5: Knife Switch, open

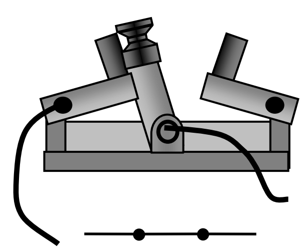

Figure 6: Knife Switch, closed

MICROMETER SCALE

The micrometer scale consists of a rotating dial outside a fixed shaft. The fixed shaft is most commonly graduated in twentieths of a centimeter, as shown in Figure 7. Note that the gradations are laid out so that they can be considered to be millimeters (above the center line) and "half-millimeters" (below the center line).

The rotating dial is most commonly graduated in hundredths of a millimeter (the dial turns once per half-millimeter, and there are 50 graduations per turn, yielding 100 gradations per millimeter.)

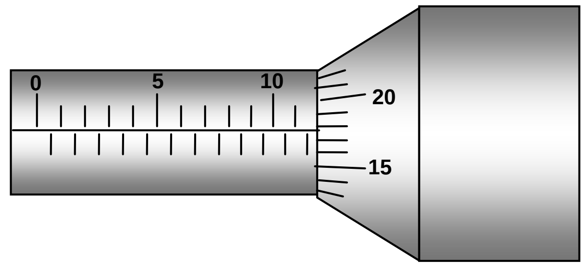

Figure 7: Micrometer Scale

Before reading the micrometer, check to see what the gradations of the shaft and rotating dial are; if they are not as described above, then the following procedure will be correct, but the fractions will change appropriately.

To read the micrometer scale, first determine the last visible marking on the fixed shaft. In Figure 7, the last visible gradation is the "half-millimeter" after 11, so begin with a measurement of 11.5 mm. Add to that the number of hundredths indicated on the rotating dial by the center line. In Figure 7, the center line points between 17 and 18 hundredths; we can estimate it to be 17.8 hundredths of a millimeter (0.178 mm). So, adding that to the first value yields 11.5 mm + 0.178 mm = 11.678 mm.

UNCERTAINTY: Of course, no measurement is complete without an associated uncertainty! There are two primary causes for uncertainty when reading a micrometer: the uncertainty in estimating the last digit (the 0.008 mm in the example above) and the uncertainty in the position of the instrument with the micrometer scale. The uncertainty in the last digit will be largely based upon how much experience you have reading precision scales - a beginner might claim to be able to have estimated the previous value of 8 ± 3 [yielding a final measurement of (11.678 ± 0.003) mm], while someone with more experience might be able to estimate the final digit to 8 ± 1 [yielding a final measurement of (11.678 ± 0.001) mm].

The uncertainty in the position of the instrument is very much a function of the instrument itself and whatever is being measured. For example, if the micrometer screw is being used in the measurement of something somewhat flexible (say a soft plastic), one might be able to rotate the micrometer screw a bit and not know exactly when the micrometer first touch the edge of the plastic. This uncertainty in the position of the micrometer screw for a "correct" measurement must be reflected in the reported measurement.

RHEOSTAT or POTENTIOMETER

A rheostat or potentiometer is just a resistor with a wiper that slides along the resistor, allowing you to change the resistance between the ends and the wiper. Notice that as the resistance between one end and the wiper increases, the resistance between the other end and the wiper decreases (the resistance between the two ends is fixed). For most of the labs, only one end and the wiper will be used (e.g., note in Figure 1 of Lab E-2, **Joule's Law**, the schematic drawing shows one end not connected to anything).

Sometimes both ends are used to make a *voltage divider*, as in Lab Q-3, **The Photoelectric Effect**. A voltage divider is just two resistors in series, where as one resistance increases, the other decreases. You can easily picture how a voltage divider works by considering the two extremes where the wiper can be in Figure 9. Consider the left end to be at some voltage, **V** (perhaps 1.5 volts), and the right end to be at **0** volts. If the wiper is all the way to the left, it is touching the left end, and there is no resistance between it and the left terminal. Therefore, the wiper is at the same voltage as the left terminal: **V** (1.5 volts, in this example). If the wiper is all the way to the right, there is no resistance between it and the right terminal, and is therefore at the same voltage: **0** volts. As you slide the wiper between the two ends, its voltage will be between the two extremes: between **V** (1.5 volts in this case) and **0** volts. At the halfway point, it should be **V/2** volts, hence the name *voltage divider*.

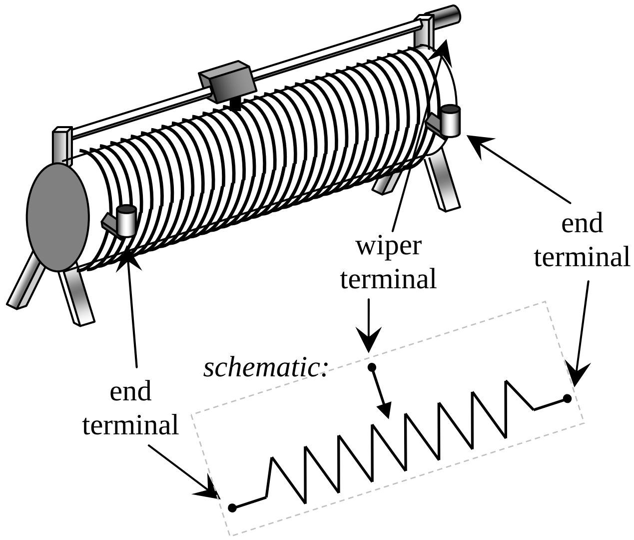

Figure 8: Rheostat (or Potentiometer)

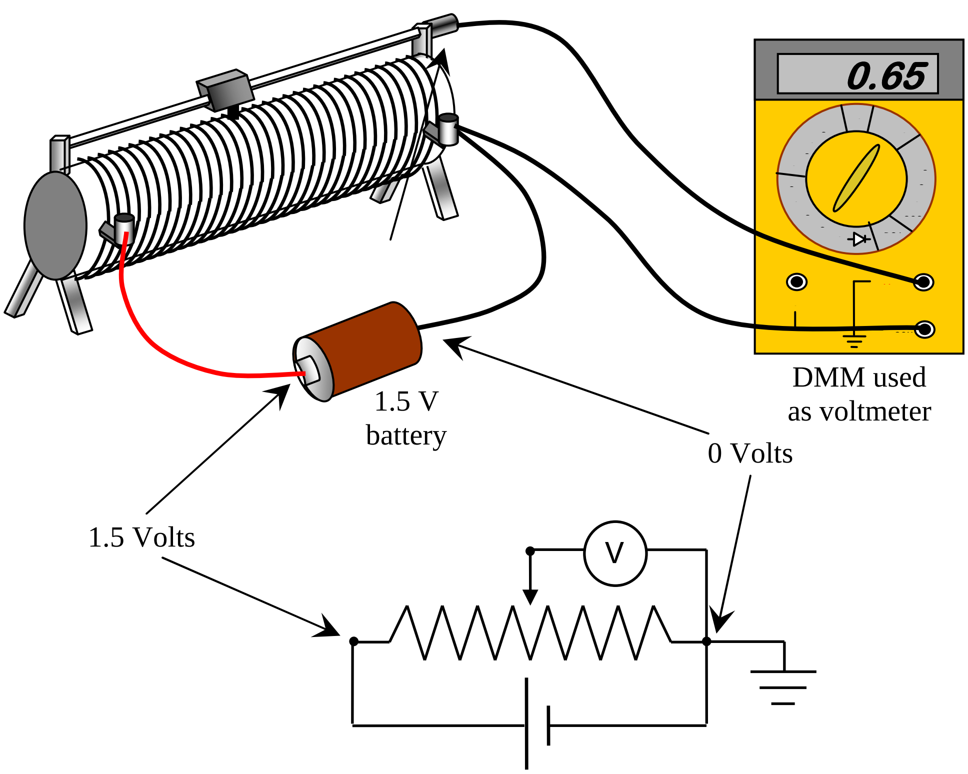

Figure 9: Voltage Divider

VERNIER SCALE

The vernier scale most often appears on calipers, as in Figure 10, but can appear on any moving device.

The scale consists of a fixed rule (the center shaft in Figure 10) and a sliding vernier rule.

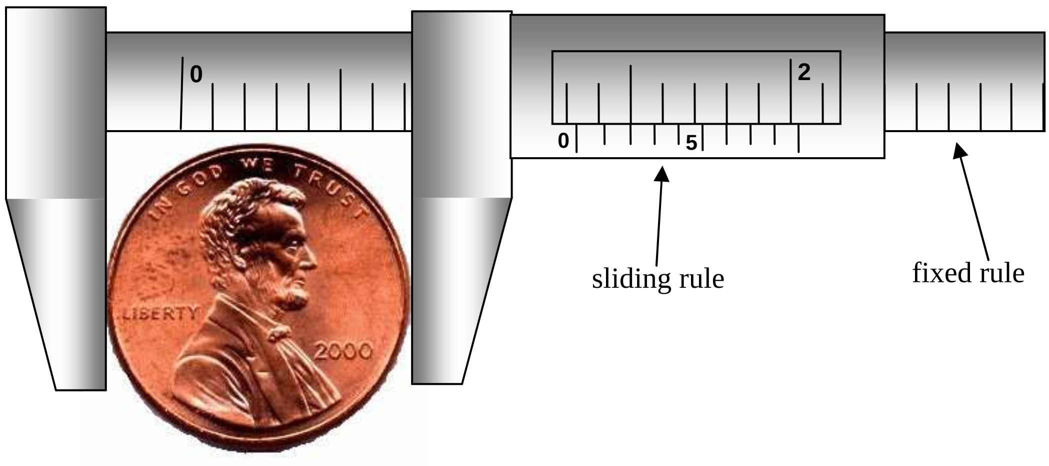

Figure 10: Vernier Scale

To read the scale, first determine how each rule is graduated. In Figure 10, the fixed rule is graduated in tenths of a centimeter and the sliding vernier rule is graduated in hundredths of a centimeter. Next, look at where the zero mark on the sliding rule appears on the fixed rule. In Figure 10, see that it appears just a bit after the 1.3 cm mark (the 1 is hidden behind the caliper jaw). Therefore, we know that the measurement is " 1.3 something." Now, look for the gradation on the sliding rule that best lines up with a gradation on the fixed rule. In Figure 10, it is the 2 gradation on the sliding rule. Therefore, the digit in the hundredth's place is a 2, yielding a measurement of 1.32 cm.

UNCERTAINTY: The two types of uncertainty in reading a vernier scale are uncertainty in the determination of the last digit and uncertainty in "how correct" the placement of the scale is. The uncertainty in the last digit is normally ± ½ the place value of the last digit if you are confident of which gradation on the sliding rule lines up best with a gradation on the fixed rule. For example, in Figure 10, there is little question which gradation lines up best, so the uncertainty would be ± 0.005 cm, since the last place value is a hundredth of a cm. Sometimes, however, two lines appear to equally well lined up, in which case the uncertainty would be ± the place value of the last digit. Therefore, if one were uncertain whether the 2 or 3 lined up best, one might determine the measurement to be (1.32 ± 0.01) cm or (1.33 ± 0.01) cm.

The uncertainty in "how correct" the placement of the scale is a function of the instrument itself and whatever is being measured. For example, in Figure 10, if the disc being measured is somewhat flexible (perhaps it is made with a soft plastic), one might be able to get the caliper jaws to close a bit more. Say that by applying a bit more pressure it closes the jaws to read 1.29 cm. Then the measurement would be (1.30 or 1.31 ± 0.02) cm.