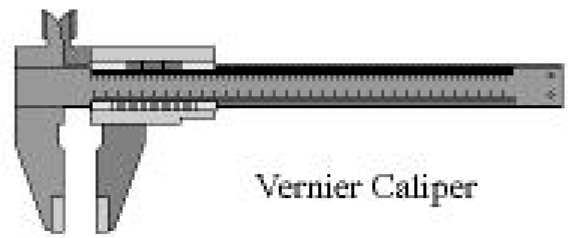
Measuring Instruments

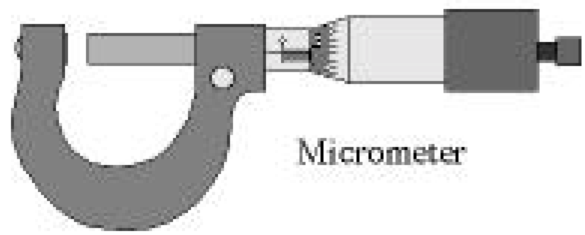
Calipers

The Vernier Caliper and the Micrometer Caliper, pictured here, are instruments for making precise measurements of length.



A vernier is an auxiliary scale that can be moved relative to a fixed scale; the vernier provides a way of accurately interpolating between scale divisions on the fixed scale.

The micrometer is a delicate, high precision instrument and should be treated with great care. DO NOT OVERTIGHTEN THE DRUM when making measurements. A small knob at the end of the instrument provides a means of tightening the instrument properly. To use the micrometer, place the object to be measured between the jaws and gently tighten the drum until the jaws contact the object, then twist the small knob at the end of the drum until a clicking sound is heard. The micrometer may now be read.



Your instructor will show you how to use these correctly. There is also a java applet that shows you how to read the scale on Vernier calipers at: http://www.phy.ntnu.edu.tw/java/ruler/vernier.html

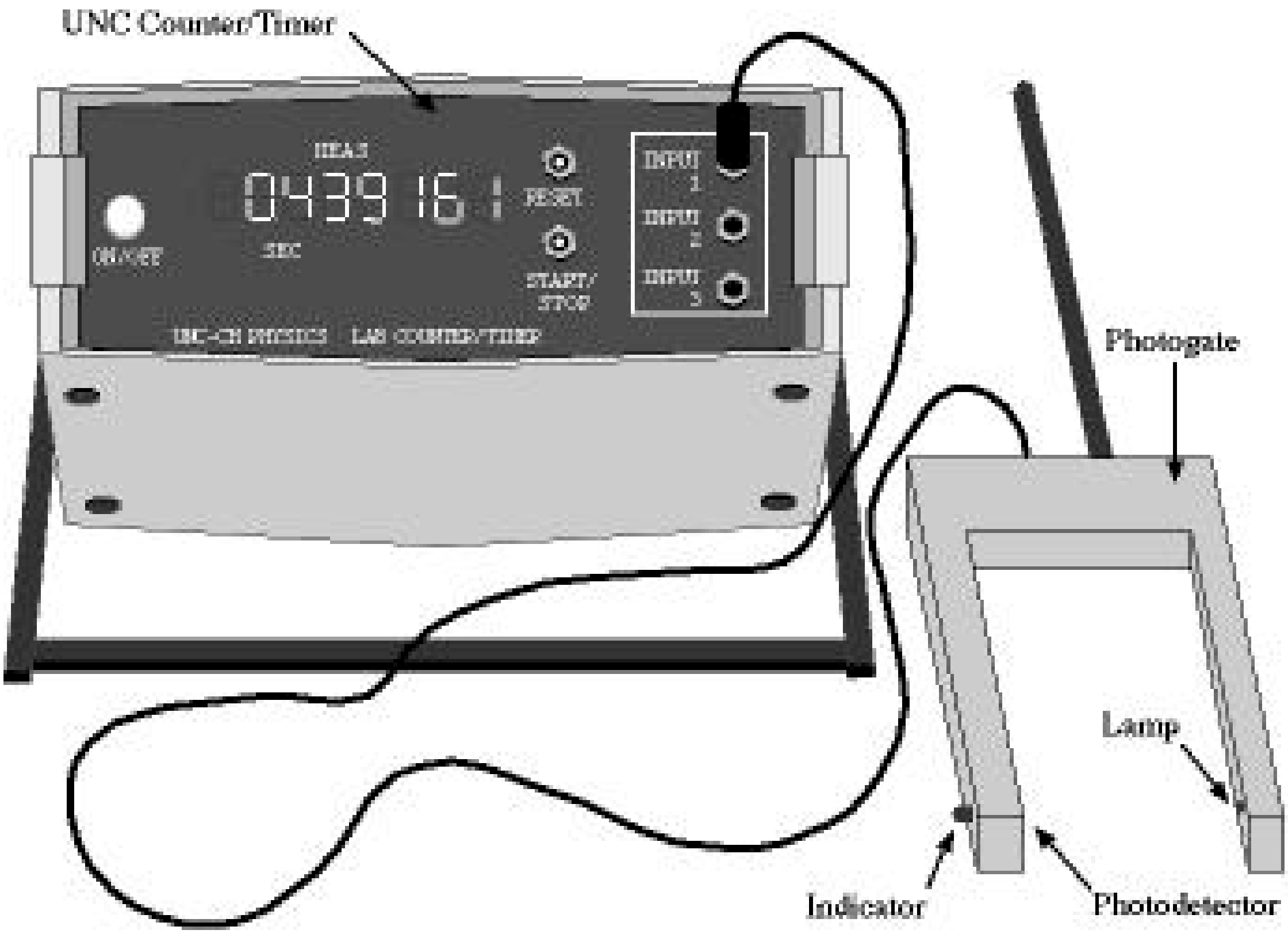
Balances

The balance you will use in the laboratory is a modern, digital balance. Pressing the ON/TARE button will re-zero the machine. After the 0.0 g is seen on the readout, you may place your mass on the balance. These balances are delicate instruments and should never be overloaded. 4,000 g is the operating limit.

The Lab Counter/Timer

In many of the exercises in this manual, you will be called upon to measure time intervals and frequencies (number of events occurring in a given time interval). Your laboratory is equipped with a Lab Counter/Timer that uses microelectronic chips and a quartz-crystal time standard to measure time intervals and frequencies in a variety of ways to great precision. The instrument is easy to use, and the following brief outline should provide a sufficient introduction to allow you to make many kinds of measurements with the counter/timer.

The power switch turns the counter/timer on or off. The display shows the numerical value of the time interval or frequency most recently measured; while a measurement is being made, the display shows the results of the previous measurement until the current measurement is completed. A decimal point and one or more units indicators make reading the display easier. All time intervals are displayed in seconds, all frequencies in Hz (events/second). A reset button ‘zeroes’ the display and prepares the counter/timer for a new measurement. In normal operation, it is not necessary to reset the instrument; it will begin a new measurement automatically. A ‘measurement-in-progress’ indicator lights when the instrument is in the process of making a new measurement. When no connection is made to the inputs, the start/stop button causes the counter/timer to perform the function of an ordinary stopwatch with the elapsed time displayed in seconds to a precision of 1 millisecond. The inputs allow the counter/timer to be connected to transducers, devices that convert physical quantities (such as light intensity or sound level) into the electrical signals necessary to actuate the counter/timer. The choice of the input to which a transducer is connected selects the function (period, timer-interval, frequency, etc.) that the counter/timer will carry out.



An example of an application of the counter/timer is the measurement of the period of a pendulum. We need to measure the time between the beginning of one full swing of the pendulum and the beginning of the next swing. In order to measure this time, it is necessary to inform the counter/timer when each swing begins. This information can be obtained from a transducer called a photogate. This U-shaped device has a lamp on one side and an electronic photodetector on the other. As long as light can travel from the lamp to the detector, an electronic circuit is kept closed; when the light beam is interrupted, the circuit is opened. The photogate used in this laboratory, sketched below, has an indicator lamp to help you determine when the light beam has been interrupted. The sketch shows the arrangement for measuring the period of the pendulum.

The photogate is plugged into Input #1 on the counter/timer, which causes the instrument to measure the time interval between the interruptions of the light beam (and thus the period of the pendulum). The position of the photogate must be carefully adjusted so that the beam is broken once and only once on each swing. When the time interval function on the counter/timer is used, the display indicates time in units of seconds to a precision of l microsecond. Note that the display numerals are arranged in groups with a units indicator beneath. As the measurement is repeated, some of the digits will remain the same, while some will change following each measurement. In general, you should record all digits that do not change and the first digit that does change; all digits to the right may be ignored. For example, a series of measurements of the period of a pendulum might yield the following data in seconds:

1.093468	1.093571
1.093342	1.093510
1.093441	1.093396

The data show that the period is slightly greater than 1.093 seconds, since these digits remain unchanged for all measurements. The next digit changes from one measurement to the next, and its average value gives a good estimate of the period, accurate to 0.0001 seconds, of 1.0935 seconds. The right-hand two digits are not significant, since there is uncertainty in the preceding digit; these digits need not be recorded for this measurement.

Other transducers are available in the laboratory for measurements of different types. These devices will be introduced in laboratory exercises later in this manual. The counter/timer can measure time intervals in several ways, and can measure frequencies and total number of events. These functions are selected by connecting transducers to the appropriate inputs; all functions are summarized as follows.

COUNTER/TIMER Function Summary

INPUTS USED	FUNCTION	REMARKS
None	Stopwatch	Start/stop with front panel switch.
#1	Period	Measures time between breaking of lamp beam.
#2	Δ time	Useful for velocity measurements.
#3	Frequency	10 MHz limit.

The Multi-Meter

Fluke 77

Radio Shack

Micronta

Two of three multi-meters are provided for this lab, the Fluke 77, the Radio Shack, and the Micronta. The operation of these multimeters is quite similar, so we will only discuss the Fluke 77. The large central knob is used to determine the type of measurement that is made. The types of measurements that can be made are *ac* voltage ($\tilde{\mathrm{V}}$), *DC* voltage ($\overline{\mathrm{V}}$), *DC* voltage below 300 mV (300 $\overline{\mathrm{mV}}$), resistance (Ω), *ac* current ($\tilde{\mathrm{A}}$) and *DC* current ($\overline{\mathrm{A}}$). The sensitivity of the meter can be selected by pressing the yellow button on the center of the knob. The meter has four-digit accuracy. Pressing the yellow button can shift the decimal point or you can use the autorange function that automatically sets the decimal point. You should always use the most sensitive scale possible and obtain the maximum number of significant figures.

At the bottom of the multi-meter are four jacks. These are used to connect the object being measured to the mutimeter. To measure *DC* volts, *ac* volts, and ohms, use the two jacks labeled "VΩ" and "COM". When measuring voltages, the "VΩ" jack (red) is positive and the "COM" jack (black) is negative. To measure *ac* or *DC* currents, use the "10A" or the "300mA" jack and the "COM" jack. The "300mA" jack is for measuring currents less than 300 mA, and the "10A" jack is for measuring currents greater than 300mA and less than 10A. When measuring currents, a fuse protects the meter. If you suspect that your meter is not functioning properly, have the instructor check the fuse.

The accuracies of the multimeters are given below:

Fluke 77	**Radio Shack / Micronta**
DC Voltage: ± 1%	*DC* Voltage: ± 1.5%
DC Current: ± 2%	*DC* Current: ± 2.5%
Resistance: ± 1%	Resistance: ± 2%