A. Light Meter. Besides acting as a source of light, a light-emitting-diode (LED) can also act as a light detector. If the LED is illuminated by an external light source, electron-hole pairs will be created in the semiconductor of the LED due to photon excitation and a small current will be generated in the diode. The circuit below uses an op-amp current-voltage converter to measure the small current from the diode.

Construct the circuit shown below using the LF356 op-amp in your parts kit (remember to hook up the +15V and -15V power as shown). Since we will not need high precision in this experiment, you do not need to measure the resistor value with the LCR meter or worry about uncertainties in the component values. Wire the op-amp output to one of the BNC pin sockets and use a BNC coaxial cable to connect to a digital voltmeter. Measure the output voltage of the circuit under four conditions: (a) Room light; (b) Darkness (use a black cloth to cover the LED); (c) LED illuminated by a red flashlight or keychain light; (d) LED illuminated by a white or blue flashlight or keychain light. [Try to make the brightness of the light shining on the LED about the same in cases (c) and (d)]. From the voltage measurements, determine the current in the diode in conditions (a), (b), (c) and (d).

How do you explain the difference in current between cases (c) and (d)? [Hint: the LED we are using as a light detector emits green light when used as a light source.]

When you are finished, remove the LED and the 3.3 MΩ resistor, but keep the LF356 op amp wired since you will need it in part B.
B. Diode Experiment. The circuit shown below will allow you to plot the current versus voltage characteristic of a diode. (We actually use a transistor connected to form an effective diode.) As discussed in class, the op amp is configured as a current-to-voltage converter. If we measure the voltage (relative to ground) at points A and B for various settings of the potentiometer, we can obtain the voltage across the diode as $V_A$ and the current through the diode as $V_B/R_F$. Use two digital voltmeters, one to measure the potentials at point A (relative to ground) and the second to measure the potential at point B in the circuit.

Have the instructor check your circuit before powering up. Start with the 1K potentiometer set to give a $V_A$ reading of zero; the voltage $V_B$ should be very small as well. Then, adjust the 1K “pot” until $V_B$ reads about 1 V (the corresponding $V_A$ reading should be about −0.6V). Record the exact $V_A$ and $V_B$ values. Continue to take exact $V_A$ and $V_B$ values while adjusting the pot to increase $V_B$ by about 0.5 V for each new datapoint. (Note that $V_B$ will "saturate" or limit at about 12 V, and you need to stay below the saturation voltage.) Record the uncertainties in your results as appropriate. We will assume the temperature of the "diode" to be room temperature, and the instructor will have an electronic thermometer reading room temperature.

The current $I$ through the diode is related to the voltage $V_A$ across the diode by the equation:

$$I = I_0 \left( e^{V_A/kT} - 1 \right)$$

(1)

where $I_0$ is the “reverse saturation current.” If you use voltages whose absolute values are such that $e^{eV/kt} >> 1$, you can make an approximation which will let you linearize Eqn. 1 by taking natural logs on both sides of the equation. (Do your voltages meet this condition?) You can then use the Plot1 script to make a least-squares straight-line fit to the data on a semi-log graph (ln $I$ versus linear $V$). You should be able to use the slope of this fit to obtain an estimate of Boltzmann's constant $k_B$ and its uncertainty. Compare your value with the accepted value.

Write up and turn in a "Measurement Report" on this measurement. You can use Microsoft Word or GEdit as a word processor, the word processor in StarOffice, or TEX if you prefer. Be sure to include a publication quality plot as part of the report.
C. Digital Electronics - Counter. Assemble the binary counter circuit shown below. The 7493 IC needs +5V on pin 5 and ground on pin 10. (Use only +5V and ground for the digital circuits; do not use the 15 V supplies. Also, please do not turn on power until circuit is fully assembled and checked.) Note that the reference to "LED Input" means to connect to the logic indicators on the prototype board. The “PB1” connection is to the “Normally Closed” terminal of pushbutton #1 on the prototype board. Set the function generator to the lowest possible output frequency and use its TTL output to drive the counter. Observe the binary counting sequence and record your observations in your lab book.

What is the fastest clock rate for which your eye can resolve the blinking of the least-significant bit LED (rather than just seeing the LED as continuously on)?
D. Analog to Digital Conversion. Assemble the analog-to-digital converter circuit as shown below. (Also, hook up a good digital voltmeter to monitor the input voltage.) Set the clock frequency to 100 kHz initially (although you can experiment with slower clock rates later if you like). Turn the control on the 10 K pot and observe the state of the logic indicator display. Record your findings in your lab book. What is the theoretical voltage resolution, or quantum, of this converter? (Note that the input range is 0 to +5 volts, and you should be able to figure out the number of bits used.) What is the experimental value of the voltage quantum? (Note that you may get a better answer here by measuring the voltage change needed to sweep through 10 quanta.)

What is the digital reading when the external voltmeter reads zero? When the external meter reads 2.50V? When the external meter reads 5.00V (or as close to 5.00 V as you can get)?

Please be careful in removing this chip; use a “chip puller” or a small screwdriver to pry it out, or have the instructor help.