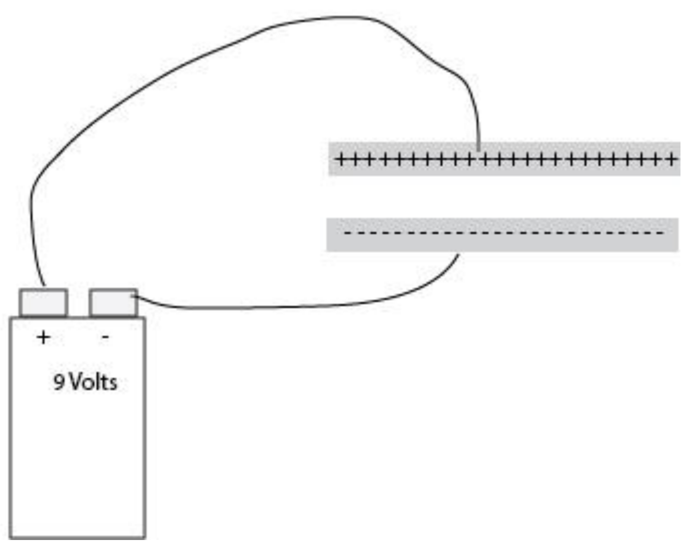
As we are now clearly out of synch with the lecture part it is good to start the lab with emphasizing that lecture and lab are not synchronized and that for most of the rest of the semester the lab is ahead of the lecture. So students need to prepare at home for the lab assignments.

Today's lab is about capacitors. Explain what a capacitor is: It consist of two conductors that are separated by an insulator. Capacitors are used in electronics to store charge and store energy. They are different from a battery in that no chemical reaction has to take place to store the energy in the capacitor.

The most used capacitor is a parallel plate capacitor. It consists of two conducting (metal) plates that are separated by an insulator. This insulator can be air, paper, oil, or a plastic. In this lab you will do measurements on a capacitor that uses overhead sheets as an insulator.

When a capacitor is connected to a battery, charges flow from the battery to the capacitor plates. Positive charge will accumulate on the plate that is connected to the positive pole of the battery and negative charge will accumulate on the pole connected to the negative pole of the battery. So after a little while the capacitor is charged. Draw the following figure on the black-board.



Now you can explain to the students that once the capacitor is charged there is an electric field between the plates of the capacitor. This field is pointing from the positive plate to the negative plate. The electric field between the plates of the capacitor is constant and depend on the charge on the plates. When discussing Guass' law they learned that the electric field above a charged conductor is proportional to the surface charge density on the plate:

$$E = \frac{\sigma}{\varepsilon_o} \qquad [1]$$

Where sigma is the surface charge density on the metal in C/m^2. We learned that this field is independent of the distance to the plate. Since a parallel plate capacitor consist of two charged plate, one positively charged and one negatively charged, the total field between the plates can be found by superposition. It is clear that this total field is constant.

They also learned in class that equipotential lines are perpendicular to the electric field. So the equipotential lines for a capacitor are parallel to the plates and are actually equipotential surfaces. If we assume that the negative pole of the battery is grounded, then the negative plate will be at zero volt. The positive plate will be at 9 volt and correspond to the 9 volt equipotential surface. Somewhere half way between the plates, is a plane that is the 4.5 volt equipotential surface.

Since the electric field is constant between the plates, it can be calculated from the battery voltage and the distance between the plates. Note that last week we learned that E and V are related according to the following expressions:

$$E = -\frac{dV}{dx} \qquad [2]$$

So now it is clear that you can put more charge on the capacitor by using a battery with a larger voltage. Note that from above equation (2) it should be concluded that doubling the battery voltage will result in doubling the electric field (assuming that the distance between the plates is not chaged). But doubling the field will also double the charge on the plates of the capacitor (equation 1). The amount of charge that you can put on a battery depends on the voltage of the battery you connect to the capacitor. So for a capacitor the charge on the plates is proportional to the electric field between the plates, which is proportional to the electric potential across the plates. As V is proportional to Q, the ratio of Q over V is a constant that only depends on the geometrical dimensions of the capacitor and the material between the plates. We call this ratio the capacitance:

$$\frac{Q}{V} = C$$

The unit of capacitance is Fahrad or Coulomb/Volt.

Doubling the voltage across a capacitor will double the charge on the plates.

We will learn in class how one calculate the capacitance from the geometrical dimensions of the capacitor. For a parallel plate capacitor the capacitance is given by:

$$c = \varepsilon_O \frac{A}{d}$$

Where A is the surface area of the plates and d is the distance between the plates. εo is of course the dielectric constant of vacuum. If the material between the plates is not vacuum but for example plastic, we have to multiply this expression by kappa, the dielectric constant of the material.

If you connect two capacitors to a battery you of course can store twice the amount of charge on the plates. Draw two capacitors in parallel to a 9 volt battery. Ask the students whether or not they expect that the total amount of charge on the capacitor plates is larger or smaller? So rather than thinking of two capacitors connected to one battery we can think of a bigger capacitor, i.e. the equivalent capacitor connected to the battery. Explain what it means if two capacitors are connected in parallel. Present the equivalent equation for two capacitors in parallel, i.e.

$$C_{equivalent} = C_1 + C_2$$

Now draw two capacitors in series connected to a 9 volt battery and ask them whether or not they expect that the total amount of charge will be larger or smaller. Note that the voltage drop is now divided over each capacitor, so each capacitor now only carries half of the voltage. So the charge stored on each capacitor is half the charge is only one capacitor was connected to the battery. The total amount of charge that flows from the battery into this circuit is thus only half. So in this case the equivalent capacitor is less, i.e.

$$\frac{1}{C_{equivalent}} = \frac{1}{C_1} + \frac{1}{C_2}$$