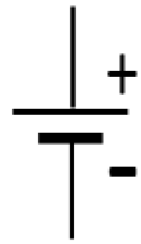
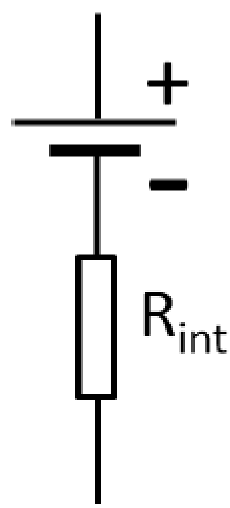
Homework 15.

Ideal and real voltage source.

Last class we discussed batteries. The function of an electrical battery is to create voltage difference (or, simply, "bias") between two terminals to which the battery is connected. To show the battery at an electrical scheme we will be used the common sign shown below:



If you take a look at a battery, say, a standard AA battery – you will find the mark "1.5V". One might think that this battery maintains the voltage between its terminals as 1.5V no matter which circuit is connected to the battery. A simple experiment will demonstrate that it is not true. If you will connect a small lamp to the battery and measure the voltage between the battery terminals as the lamp is working you will see that the measured voltage is less than 1.5 volts. The difference between "advertised" voltage and the measured voltage will be higher if the resistance of the connected circuit is low. So the behavior of a real battery is different from this of an ideal voltage source which will maintain the specified voltage between its terminals "no matter what". To describe the real voltage source an additional parameter is needed. It is called "internal resistance" R_{int}. Now, a real battery can be represented as the combination of ideal voltage source with zero resistance and resistor R_{int} connected in series. Unfortunately, they cannot be separated. (I'd be glad to cut off R_{int} and have ideal voltage source! :)).



Now, if we will connect the terminals of a battery with a piece of wire (please do not do this – you will discharge the battery) the current in the wire will be limited by the internal resistance of the battery. The lower R_{int}, the more "powerful" is the battery and the more current it can provide. The voltage of the ideal voltage source "inside" the battery is called ***electromotive force*** (emf). In spite of the word "force" is used it is voltage and is measured in volts!

As we connect multiple batteries in series, we obtain a new voltage source with the emf and internal resistances equal to the sum of emf and internal resistances of all the connected batteries. In this case we increase the voltage, but we also increase the internal resistance, so the maximum current which the new "battery" can provide does not change. If we connect the batteries in parallel, we do not increase the emf (it stays the same), but we reduce internal resistance of the new source.

Problems:

1. You have 4.5V battery (we can say" the battery with emf of 4.5V"). When you connect a lamp to the battery, the measured voltage on the battery is just 4V and the current in the circuit is 0.25A. Find internal resistance of the battery. Make a drawing of the circuit.

2. You measure voltage of a battery (without any external circuit connected) and obtain 6V. Then you connect a resistor to the battery and the measured voltage drops to 3V. Explain the effect. What voltage will the voltmeter show if you will connect another resistor which is identical to the first one

a) parallel to the first resistor?

b) in series with the first resistor?

Make a picture.

3. How you would measure internal resistance of an AA battery? If you have a multimeter try to measure one.

4. How many AA batteries (V=1.5V, take the internal resistance as you have measured in problem 3, if you could not do this take 4 Ohms) you need to start a car? To do this we need voltage of 15V and current of ~ 400A.