Name: Section: last printed: 10/22/2009 8:15:00 AM

Lab 7: Measuring currents, voltages, resistances.

Equipment: voltmeters, a-meters, DMM, switches, batteries, electric leads of various lengths, alligator clips.
Variable resistor boxes.
When measuring current with the DMM's note that you have to have to use the red mA plug. Follow the pink color code to set your maximum current according to 100, 1000, 2000. The multiplier is mA. This means that if you press the 2000 key you are measuring up to 2000mA, or 2.00A. In some DMM's the fuse for these values are blown. You can still use the 10A key all to the right of the scale, provided that you use the red unfused current plug to the right.
The analog ammeter measures currents from 10 mA to 3 Amps. The top scale has 300 subdivisions, from 0 to 30; the lower scale has 100 sub divisions, marked from 0 to 10. If you use the 1A scale, make your readings on the lower scale, where one subdivision (indicated by a vertical black line-mark) equals 1/100 A.

Error calculations: The DC power supply has an internal resistance of 0.1 Ω, the analog ammeter has an internal resistance of r=0.11 Ω. The DMM's internal resistance as voltmeter is 10 M Ω.

DMM accuracy: as ammeter it is 0.3%I +1unit of the last digit read, as voltmeter its is 0.1%V +1unit of the last digit read. If you use the 2A scale, the uncertainty is 0.5%+1. Example: we read on the DMM V=130.8V; the absolute error is ΔV=0.1%·130.8=0.1308V, the last digit read is 0.8; one unit of the last digit is 0.1, therefore ΔV=0.1308+0.1=0.2308V, which we round to 0.2 V. The final result is therefore:

$V = (130.8 \pm 0.2)V$. We use a maximum of 1 significant figure for the absolute error in our final result. For intermediate calculations we carry 2 significant figures.

The relative error can now be determined: $\frac{\Delta V}{V} = \frac{0.2}{130.8} = 0.2\%$

Here is an example for current measurement:

$$I = 3.94A; \Delta I = 0.3\% \cdot 3.94 + 0.01 = 0.0118 + 0.01 = 0.02128 \Rightarrow 0.021$$

$$I = (3.94 + 0.02)A$$

The final relative error is therefore: $\frac{\Delta I}{I} = \frac{0.021}{3.94} = 0.53\%$

(0.1) $$R = \frac{\Delta V}{I} = \frac{130.8}{3.94} = 33.2\Omega; \frac{\Delta R}{R} = 0.7\%$$

Pay attention to the following:
Do not leave the batteries hooked up. When measuring currents with the DMM start out with the 10A setting, then switch successively to lower mA settings. If you know the applied voltage and the resistor, you can and should estimate the expected current and use the appropriate setting. (e.g. 10 Volts and 100 Ohms will lead to a current of 100mA.)
The voltage measurement occurs in parallel with the resistor. The Ammeter is inline (in series).
Interrupt your circuits between measurements so that your circuit is not heating up unnecessarily.
As the internal resistance is of the order of 1 Ohm, use more than 5 Ohms in your circuits.

Before measuring a voltage or a current estimate the value you are expecting and set the meter to the exptected range. Example: $10V$ and $1k\Omega$ lead to a current of $\frac{10V}{1000\Omega}=10mA$

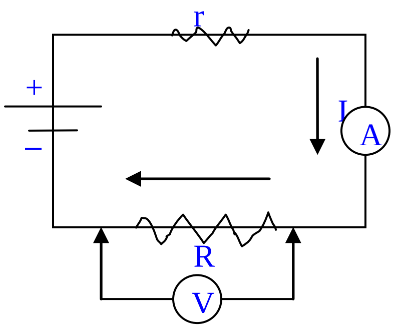
Perform all error calculations.
Compare the errors measured by you, with the stated errors on the resistor boxes. (This applies only to the plastic transparent boxes, which have a stated uncertainty of 0.1%.)
Note that the internal resistance of the analog ammeter is in series, whereas the internal resistor of the analog voltmeter is in parallel. The mrasured value of R would therefore be smaller by 0.1 Ohms.)

1) Measure the internal resistance of a battery:
Measure the voltage drop across a 10 Ohm resistor. (For larger resistors like 1000 Ohms and higher, the difference between ΔV *and* ε becomes negligible. This means we cannot determine r using such high resistor values.) Note that older batteries can have significantly higher internal resistances. The internal resistances vary also a little with the current. In other words, only for fresh batteries can you expect the same internal resistance for different loads.

Measure the emf. Note: measure the terminal voltage and the emf without much time delay. The battery heats up quickly and makes your result unreliable.) Measure the current in the circuit. Determine the internal resistance r of the the emf (battery.)

$$\Delta V = RI = \varepsilon - rI \Rightarrow r = \frac{\varepsilon - \Delta V}{I}$$

ΔV is the terminal voltage of the battery in the closed circuit (a current is flowing). ε **is the emf of the battery, measured with the circuit open.**
If R is of the same order of magnitude as the internal resistance of the battery, this will affect your results. The emf of the battery is the voltage measured without an exterior resistor applied. The internal resistance of the DMM is 10 MΩ *so that there is practically no current flowing through the battery while performing this measurement*. (Most of the current flows through the branch with the least resistance.) With our nominal 6V batteries you will find values around 5.8 V for ε . When you measure the voltage ΔV with a current flowing through a 10 Ohm resistor you may get something of the order 5.2 V and a current of 0.5A.



$\boxed{\Delta V = \varepsilon - rI}$

Example: ΔV=RI=5.16V; ε=5.89 V, I=0.500A yields r=1.146 Ohms.
Error calculations:

$$\Delta(\Delta V) = 0.1\%\Delta V + 0.01 = 0.01V$$

$$\Delta\varepsilon = 0.01V$$

(1.2) $$\Delta I = 0.3\% I + 0.001 = 2.5E-3 \approx 0.003 = 3mA$$

$$\frac{\Delta r}{r} = \frac{0.02}{5} + \frac{3}{500} \approx 0.01; \Delta r = 0.01\Omega$$

Therefore : $r = (1.15 \pm 0.01)\Omega$

2) **Checking the accuracy of resistor values**:

Use the twelve volt power supply. Measure the output voltage with the DMM. Set it to a value between 10.0 and 12.0 Volts. **Measure the voltage**.

Set up simple circuits with the resistors below.

Use resistors of 20, 50, 100 Ohms (metal box and decadic box) in your circuit. **Measure the current in each circuit** and compare the theoretical $R = \frac{\Delta V}{I}; \frac{\Delta R}{R} = \frac{\Delta(\Delta V)}{\Delta V} + \frac{\Delta I}{I}$ with the experimental values. (Don't keep the circuit connected for long to avoid overheating of the circuit.

Show: ΔV measured, I measured, R calculated with expected %error and % error between the nominal value R_n and the measured value R $\left|\frac{R_n - R}{R_n}\right| \cdot 100\%$

3) **Ohm's law**:

Use a 10Ω or 20 Ω resistor in the two following experiments in which you determine the relationship between current and voltage in a circuit. Make sure you don't allow the circuit to heat up.

Increase the voltage of the variable power supply from 1 to 12 volts in **10 approximately equal steps.** Measure the voltage and the current in the circuit and record these values.

Plot voltage versus current in Excel, linear trendline, put the equation on the line and determine the slope of the graph. It should equal the resistance. Find the percent difference between your measured slopes and the resistor values of the resistor boxes.