ELE2EMI 2007
Laboratory 1:
Meter Insertion Errors

July 30, 2007

Submission of Reports

After each laboratory, you are allowed a week to write up a formal report documenting your:

- procedure
- results
- answers to the questions
- any comments of your own on the laboratory

The exact format of the report is at your discretion, but make sure that it is as complete (and comprehensible) as possible.

You are expected to submit the report at the commencement of the following week's laboratory session.

Late reports are marked down by 10% per day. Medical certificates and affadavits will be taken into account, but *vague* expressions such as "has a medical condition" are **not** sufficiently precise to merit serious consideration: so make sure your doctor writes a competent, accurate description of your condition. To formalise the request, I recommend you use a special consideration form obtained from Margaret North's office (PS2.118).

Preamble on Instruments

As lecture 1 emphasised, instruments are useful but imperfect tools. Their accuracy and degree of precision depend on many factors: the properties and condition of the system being measured and of the instruments, the ambient environment, sources of interference, the way we connect the instruments, and how we perform the readings, among others.

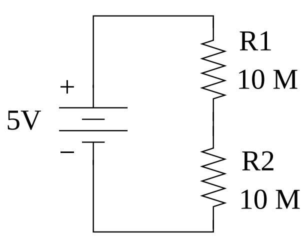
1 Meter Insertion Errors

Components and Equipment

1. Notebook, pen, pencil, eraser, sharpener
2. Breadboard
3. 2×10 MΩ resistors
4. 2×10 kΩ resistors
5. Multimeter
6. 5V dc supply
7. Leads
8. Single strand hookup wire

1.1 Voltage divider 1

Study the circuit diagram in the following figure.



Question: **Calculate the voltage across each resistor.**

Kirchoff's Voltage Law (KVL) tells us that the sum of these voltages equals the supply voltage. Let's confirm this experimentally.

Construct the voltage divider circuit shown above.

1. Measure the supply voltage.
2. Measure the voltages across R1 and R2.
3. Record the voltages in this table.

Quantity	Theory	Experiment
Supply Voltage	5V	
Voltage across R1		
Voltage across R2		

Question: **Do the measurements agree with what you calculated?**

Question: **Does the sum of the measured resistor voltages equal the supply voltage?**

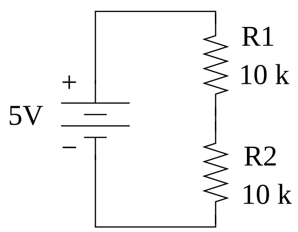
Question: **Can you think of reasons for any discrepancy?**

Hints:

1. KVL is correct.
2. The errors are too large to be accounted for by the small error in the multimeter, or by the tolerances of the resistors.
3. Therefore, some assumption is wrong. **What assumption?**

1.2 Voltage Divider 2

Now we'll repeat the experiment, but with this different circuit:

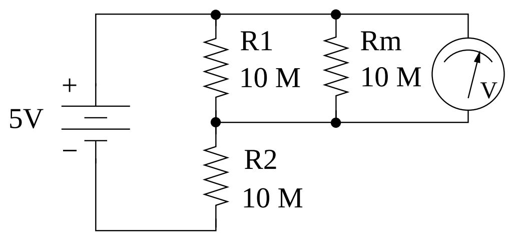


Quantity	Theory	Experiment
Supply Voltage	5V	
Voltage across R1		
Voltage across R2		

Question: **How do these measurements compare to the theoretic values?**

1.3 Remodelling the first circuit

The circuit diagrams were missing something: the *multimeter*! We're using it as a voltmeter, so a suitable model is an ideal voltemeter in parallel with a resistive impedance. Let's suppose that this meter resistance, R_m, is 10 MΩ. If this is accurate then the diagram for the circuit when we measure R1 is:



Using the above circuit diagram as your theoretic model, redo the calculations for the voltages across R1 and R2 and compare them to the experimental results for the voltage divider with the 10 MΩ resistors.

Quantity	Theory	Experiment
Supply Voltage	5V	
Voltage across R1		
Voltage across R2		

1.4 Remodelling the second circuit

In the space below, draw a model for the 10 kΩ divider experiment that takes the multimeter into account:

Now recalculate the theoretic voltages, and compare with the experimental results for this circuit:

Quantity	Theory	Experiment
Supply Voltage	5V	
Voltage across R1		
Voltage across R2		

Question: **What is the internal impedance of an *ideal* voltmeter?**

1.5 Times Ten Probes

Question: In the second year laboratory, the oscilloscopes are typically equipped with *times ten* $(10\times)$ probes. One of their functions is to *increase the effective input impedance of the oscilloscope by a factor of* ***ten***. Based on your experience in this laboratory, **why is this advantageous?**

1.6 Ammeter measurement theory

We've learnt about insertion error when measuring voltage. Insertion errors also occur in measurements of **current**.

Question: How do you connect a multimeter in a circuit to make a *current* measurement? **In series, or in parallel?**

Question: **What is the internal impedance of an *ideal* ammeter?**

Question: **What is a simple model for a real (nonideal) ammeter? Draw it in the space below.**

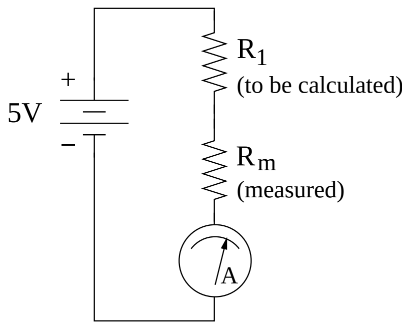
Question: **What effect will a nonideal ammeter have on the current measurements you take?**

Question: **Does Kirchoff's Current Law (KCL) apply when the ammeter is non-ideal? Explain.**

Set one multimeter to measure current on the 20 mA scale. Borrow another meter and use it to measure the first meter's resistance R_m. Record this value in the table.

Ammeter scale	Resistance R_m
20mA	

Suppose that you are measuring *current* through a resistor R_1 in a circuit such as this:



Define the ammeter insertion error as

$$\epsilon_I = \frac{I_t - I_m}{I_t}$$
$$= 1 - \frac{I_m}{I_t}$$

where I_t is the current through R_1 if the ammeter were ideal, and I_m is the current recorded on our actual meter.

What are the formulas for I_t and I_m as functions of the supply voltage $E = 5V$ and the resistances R_1 and R_m?

$$I_t =$$

$$I_m =$$

What is the formula for I_m/I_t in terms of the resistances R_1 and R_m?

$$\frac{I_m}{I_t} =$$

Substitute this expression into the insertion error formula:

$$\epsilon_I =$$

Now invert it to find an expression for R_1 as a function of insertion error and R_m:

$$R_1 =$$

Using the measured value for R_m, **calculate the values of R_1 that correspond to each of the insertion errors in this table, and calculate the currents I_t and I_m.**

Insertion Error	R_1 value	$R_1 + R_m$	Ideal current I_t	Nonideal current I_m
1%				
10%				
50%				