PHYS 2426

Enginerring Physics II

EXPERIMENT 0

BASIC ELECTRICAL MEASUREMENTS AND ERROR ANALYSIS

I. INTRODUCTION

The objective of this experiment is to familiarize the student with the measurement of basic electric circuit quantities, their SI units and how to perform error propagation calculations due to the instrumental uncertainty in the measured quantities.

II. APPARATUS

A 6 V battery, a decade resistance box, two multimeters, a stop watch and connection wires.

III. EXPERIMENTAL PROCEDURE

1. Before you wire the circuit, use the voltmeter to measure the battery emf $\mathcal{E}$ (electromotive force) and record it with its uncertainty. The battery emf is the potential difference (voltage) between the battery terminals when it is not connected to an external circuit. The SI unit of emf is the volt, V.

$$E \pm \delta E =$$

2. Calculate the relative uncertainty in this measurement, round it off to one significat figure and record it as a percent (multiply by 100).

$$\frac{\delta E}{E} =$$

3. Set the resistor decade box to $1000\,\Omega$ and use the ohmmeter to measure the value of the resistance and record it with its uncertainty. The SI unit of electrical resistance is the Ohm, Ω.

$$R \pm \delta R =$$

4. Calculate the relative uncertainty in this measurement, round it off to one significant figure and record it as a percent

$$\frac{\delta R}{R} =$$

5. Wire the circuit as shown in Figure (1). The ammeter (which measures the electric current) should be connected in series with the battery and the decade resistance box (the electric current should run through the ammeter) while the voltmeter (which measures potential difference or voltage) remains external to the circuit. You touch the voltmeter leads to the points between which you want to measure the voltage. This is a very important difference between the functions of the voltmeter and the ammeter and the ways they are used to perform measurements.

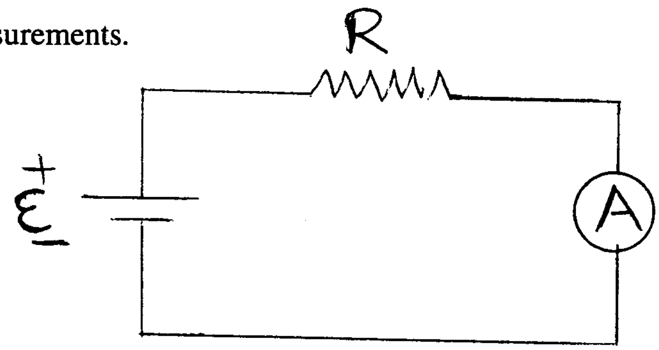

Figure (1)

6. Measure the electric current in the circuit and the voltage of the battery and record them with their uncertainties. The SI units of current and voltage are the Ampere, A and the volt, V, respectively. Note that the multimeter may give you the current reading in milliamperes, mA. $1\,\text{mA} = 0.001\,\text{A}$.

$$I \pm \delta I =$$

$$V \pm \delta V =$$

   This voltage is the terminal voltage of the battery. Is it smaller or larger than the emf?

7. Calculate the relative uncertainties in both of these measurements, round them off to one significat figure and record them as a percent

$$\frac{\delta I}{I} =$$

$$\frac{\delta V}{V} =$$

8. Calculate the electric current using the equation

$$I = \frac{V}{R}$$

This equation is known as **Ohms Law**.

9. Calculate the percent difference between the measured and calculated values of the elctric current.

$$\%\text{difference} = \frac{|I_{\text{measured}} - I_{\text{calculated}}|}{\left(\frac{I_{\text{measured}} + I_{\text{calculated}}}{2}\right)} \times 100 =$$

10. According to the rules of propagation of uncertainty, the relative uncertainty in I can be calculated as follows:

$$\frac{\delta I}{I} = \frac{\delta V}{V} + \frac{\delta R}{R}$$

This calculated relative uncertainty is larger than the relative uncertainty calculated directly from the measurement of I in (7). The above rule always adds the relative uncertainties and therefore sets up an upper limit on the calculated relative uncertainty.

11. Calculate the electrical power provided by the battery to the circuit (don't forget the units)

$$P_{\text{provided}} = IV =$$

12. Calculate the relative uncertainty in the power

$$\frac{\delta P_{\text{provided}}}{P_{\text{provided}}} = \frac{\delta V}{V} + \frac{\delta I}{I} =$$

13. Calculate the power lost in the resistor (this electrical power is converted to heat)

$$P_{\text{lost}} = I^2 R =$$

The power provided by the battery should be approximately equal to (in fact just a bit larger than) the power lost in the resistor. The difference between them is the power lost in the leads and connectors which is usually relatively small and is usually neglected.

14. Calculate the relative uncertainty in the power lost, round it off to one significant figure and record it in percent.

$$\frac{\delta P_{\text{lost}}}{P_{\text{lost}}} = 2\frac{\delta I}{I} + \frac{\delta R}{R} =$$

Note that the relative uncertainty in I is multiplied by 2 since I is squared in the power expression.

15. Close the circuit and allow it to run for a time period of about 20 s. Use a stop watch to measure this period and record it with its uncertainty

$$t \pm \delta t =$$

16. Calculate the electric charge, Q, which goes through the circuit in this period of time. The SI unit of electric charge is the Ampere$\times$ second and this is called Coulomb and is abbreviated C.

$$Q = It =$$

17. Calculate the relative uncertainty in the charge

$$\frac{\delta Q}{Q} = \frac{\delta I}{I} + \frac{\delta t}{t} =$$

18. Calculate the amount of electrical energy, U, provided by the battery to the circuit (don't forget the units)

$$U = P_{\text{provided}} t =$$

19. Calculate the relative uncertainty in the energy

$$\frac{\delta U}{U} = \frac{\delta P_{\text{provided}}}{P_{\text{provided}}} + \frac{\delta t}{t} =$$

IV. QUESTIONS

1. What is the largest relative uncertainty you have calculated in this experiment?

2. Is this a resonably small relative uncertainty? If your answer is yes then the multimeter is precise enough for our purposes and when we encounter errors much higher than the uncertainties encountered here, then these errors are caused by other sources which we must look for.