Laboratory session 2 – Uncertainty calculations

Introduction

Below you will find all the necessary formulae for calculating the uncertainty in each value for all 3 of the experiments in lab session 2.

The first set of formulae are those that you may need to use in one or more of the experiments.

Uncertainty in manufactured components - resistor

The uncertainty associated with the resistance of a resistor is 1% of the value of the component.

$$\delta R = 0.01R \ \Omega \qquad \textit{Eqn. 1}$$

Where;
$R =$ the value of resistance in Ω

Uncertainty in manufactured components - capacitor

The uncertainty associated with the capacitance of a capacitor is 1% of the value of the component.

$$\delta C = 0.01C \ \mathrm{F} \qquad \textit{Eqn. 2}$$

Where;
$C =$ the value of capacitance in F

Uncertainty in measurements of voltage

The uncertainty associated with measurements of voltage δV can be calculated using the following equation;

$$\delta V = \sqrt{\left(\frac{0.25}{\sqrt{6}}\right)^2 + (0.01V)^2} \ \mathrm{V} \qquad \textit{Eqn. 3}$$

Where;
$\delta V =$ uncertainty associated with measured voltage in V
$V =$ the value of voltage in V

Uncertainty in measurements of current

The uncertainty associated with measurements of current δI can be calculated using the following equation;

$$\delta I = \sqrt{\left(\frac{0.01}{\sqrt{6}}\right)^2 + (0.01I)^2} \ \mathrm{A} \qquad \textit{Eqn. 4}$$

Where;
$\delta I =$ uncertainty associated with measured current in A
$I =$ the value of current in A

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Uncertainty in measurement of time (t)

The uncertainty associated with the measured time, t, can be calculated using the following equation;

$$\delta t = \sqrt{\left(\frac{0.005}{\sqrt{3}}\right)^2 + (0.1)^2 + (0.001t)^2}$$

Eqn. 5

Where;

$\delta t =$ uncertainty associated with time t in s

$t =$ the value of time t in s

Experiment 1 – Uncertainty in Predicted Current

The uncertainty in the predicted current can be calculated using the following formulae.

$$\delta I_p = \sqrt{\left(\frac{\delta V}{R}\right)^2 + \left(\frac{V\delta R}{R^2}\right)^2} \qquad \textit{Eqn. 6}$$

Where;

$\delta I_p =$ uncertainty associated with the predicted current in Amps

$\delta V =$ uncertainty associated with the measured voltage in Volts

$\delta R =$ uncertainty associated with the resistor R in Ω

$V =$ the value of the voltage in Volts

$R =$ the value of the resistance of resistor R in Ω

Experiment 2 – Uncertainty in Predicted Current

The uncertainty in the predicted current for both the series and parallel circuits can be calculated using the following formulae. Note that R here represents combined resistance of the two resistors, the uncertainty of which is calculated differently for the two different circuits.

$$\delta I_p = \sqrt{\left(\frac{\delta V}{R}\right)^2 + \left(\frac{V\delta R}{R^2}\right)^2} \qquad \textit{Eqn. 7}$$

Where;

$\delta I_p =$ uncertainty associated with the predicted current in Amps

$\delta V =$ uncertainty associated with the measured voltage in Volts

$\delta R =$ uncertainty associated with the combined resistance of the resistors in Ω

$V =$ the value of the voltage in Volts

$R =$ the value of the combined resistance of the resistors in Ω

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Experiment 2 – Uncertainty in Total Resistance for a Series Circuit
The uncertainty in the combined resistance for the series circuit can be calculated using the following formulae.

$$\delta R = \sqrt{(\delta R_1)^2 + (\delta R_2)^2} \qquad \textit{Eqn. 8}$$

Where;
$\delta R =$ uncertainty associated with the combined resistance of the resistors in Ω
$\delta R_1 =$ uncertainty associated with resistance of resistor R_1in Ω
$\delta R_2 =$ uncertainty associated with resistance of resistor R_2in Ω

Experiment 2 – Uncertainty in Total Resistance for a Parallel Circuit
The uncertainty in the combined resistance for the parallel circuit can be calculated using the following formulae.

$$\delta R = \sqrt{\left(\left(\frac{R_2}{R_1+R_2}\right)^2 \delta R_1\right)^2 + \left(\left(\frac{R_1}{R_1+R_2}\right)^2 \delta R_2\right)^2} \qquad \textit{Eqn. 9}$$

Where;
$\delta R =$ uncertainty associated with the combined resistance of the resistors in Ω
$\delta R_1 =$ uncertainty associated with resistance of resistor R_1in Ω
$\delta R_2 =$ uncertainty associated with resistance of resistor R_2in Ω
$R_1 =$ the value of the resistance of resistor R_1in Ω
$R_2 =$ the value of the resistance of resistor R_2in Ω

Experiment 3 – Uncertainty in Predicted Time
The uncertainty in the predicted time can be calculated using the following formulae.

$$\delta t_p = \sqrt{\left(\frac{t}{R}\delta R\right)^2 + \left(\frac{t}{C}\delta C\right)^2 + \left(\frac{RC}{V_c}\delta V_c\right)^2 + \left(\frac{RC}{V_0}\delta V_0\right)^2} \qquad \textit{Eqn. 10}$$

where
$\delta t_p =$ uncertainty associated with the predicted time t in s
$\delta R =$ uncertainty associated with resistance of the circuit in Ω
$\delta C =$ uncertainty associated with capacitance of capacitor C in F
δV_C = uncertainty associated with the voltage across the capacitor in V
δV_0 = uncertainty associated with the voltage across the capacitor when $t = 0\ s$ in V
$t_p =$ the value of the predicted time in s
$R =$ the value of the resistnace of the circuit in Ω
$C =$ the value of the capacitanceof capacitor C in F
$V_C =$ the value of the voltage across the capacitor
V_0 = the value of the voltage across the capacitor when $t = 0\ s$ in V

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Additional Formulae

Note you may also need to use the following formulae for calculating the uncertainties in x and y for your graph. If $x = ln\left(\frac{V_c}{V_0}\right)$ then

$$\delta x = \sqrt{\left(\frac{\delta V_c}{V_c}\right)^2 + \left(\frac{\delta V_0}{V_0}\right)^2}$$