**PHYS 101 - Measurement and Uncertainty in Scientific Experiments**

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**Worksheet**

*Complete the worksheet as a group and turn in a single document with your names.*

Miranda Johnston Nico Gorhau

Samin Latif

*Show all work and calculations to receive full credit! You may use additional sheets.*

1. Significant Figures
   1. Suppose you are measuring the mass of a pendulum bob on an electronic mass balance. The mass balance reads “10.4 g”. How many significant figures does this reading have?

8/8; don’t forget units in c

**Three significant figures**

* 1. What is the relative uncertainty of this measurement, expressed as a percent error? (recall that the precision of an electronic instrument is usually equal to the smallest difference it can detect, 0.1 g in this case)

0.1 / 10.4 = 0.00962 0.00962 \* 100 = **0.962%**

±  **1%**

* 1. Suppose you measure the mass with a more precise electronic mass balance, that can measure mass with a precision of 0.01 g. If the mass balance reads “10.40 g”, how many significant digits are there? Write this value so that the number of significant digits is not ambiguous.

**Four significant figures**

**1.040 \* 10^1**

1. Propagation of Uncertainty

You are asked to measure the volume of a spherical object. Knowing that the volume, V, is related to the radius, R, by , you measure the radius to be 2.2 cm ± 0.1 cm.

* 1. Convert the measurement of the radius to meters and express the radius in scientific notation.

2/2; but write so only one power of 10 like this: (2.2±0.1)\*10^-2 m

2.2cm ± 0.1 cm = 0.022m ± 0.001m = **2.2 x10^-2 ± 1 x 10^-3 meters**

* 1. Calculate the volume of the sphere (in cubic meters) using the measured radius and determine the **maximum relative uncertainty**.

V = 4/3 piR^3 = 4/3 pi \* (2.2x10^-2)^3 = **4.5x10^-5**

4pi/3(3r^2) \* delta x1 = 4.188(3 \* 0.000484) \* 0.001 = **6.1 x 10^-6**

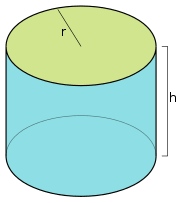
* 1. You now calculate the volume of a cylindrical object. The height is measured to be 5.2 cm ± 0.05 cm and the radius is measured to be 2.5 cm ± 0.05 cm. Calculate the volume and the **maximum relative uncertainty** of the volume calculation.

Volume = pi r^2 h = pi\* 2.5^2 \* 5.2 = 102.1 = **1.0 \* 10^2 cm^3**

8/10 for b+c: compute the max relative uncertainty ∆V/V

Max relative uncertainty = [2pi r h]\*delta r + [pi r^2]\*delta h

= [2pi \* 2.5 \* 5.2] \* 0.05 + [pi \* 2.5^2] \* 0.05 = **5.1 cm^3**



1. Statistical Errors

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*Watch “Video 4 – Ramp Experiment” before doing these exercises*

Your use a compressed spring to launch a wheeled cart up an inclined ramp (see video). We wish to know how far the cart is launched up the ramp, and this displacement can be measured using the ramp’s built-in ruler. The starting position of the cart is measured, and the displacement is then the difference between the starting and ending positions. To determine the precision of this measurement, you repeat and record your measurements 10 times.

Use the data to report an **average value** of the displacement and calculate the **standard deviation** and **standard error** in this value. Convert your standard error to a **percent error.** If you use Excel or some other program to automate these calculations, please include the Excel file or a screenshot of your work.

Spreadsheet:

Table

Description automatically generated

DATA:

|  |  |  |
| --- | --- | --- |
| Trial | End position (cm) | Displacement (cm) |
| 1 | 44.1 | 10.9 |
| 2 | 44.5 | 11.3 |
| 3 | 44.4 | 11.2 |
| 4 | 44.9 | 11.7 |
| 5 | 43.8 | 10.6 |
| 6 | 44.2 | 11.0 |
| 7 | 46.9 | 13.7 |
| 8 | 44.1 | 10.9 |
| 9 | 44.8 | 11.6 |
| 10 | 44.4 | 11.2 |

Average Value = 11.4

Standard Deviation = 0.870

Standard Error = 0.275

Percent Error = 27.5

* 1. Comment on the “spread” of the data and what it says about the precision of your measurements.

The standard deviation is 0.870 cm, which is almost 10 percent of the average displacement. This shows that we were not collecting data with a great amount of precision.

* 1. Identify specific sources of uncertainty in this experiment. Then, suggest some ways to reduce uncertainty and improve the precision.

The spring launch might have been inconsistent. The measurements were also made with bare eyes while the car was in motion, this made it difficult to determine exactly where it stopped. In the future, the car could be videoed and analyzed to collect more accurate data. The spring launch could also be automated to control for variation in the string pull.