Lab 1

34/34, great job

PHYS 101 - Measurement and Uncertainty in Scientific Experiments
Worksheet

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

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

1. Significant Figures
   a. 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?

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   3 sig figs

   b. 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)

   $$10.4 \text{ g} \pm 0.1 \text{ g}$$

   $$\frac{0.1}{10.4} = .0096$$

   $$0.0096 \cdot 100 = .96\%$$

   $$\boxed{1\%}$$

c. 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.

4 sig fig

$$1.040 \cdot 10 \, g$$

2. 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 $V = \left(\frac{4}{3}\right) \pi R^3$, you measure the radius to be 2.2 cm ± 0.1 cm.

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

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$$2.2 \, cm \cdot \frac{1m}{100cm} = 0.022 \, m$$

$$.1 \, cm \cdot \frac{1m}{100cm} = 0.001 \, m$$

$$(2.2 \pm 0.1) \cdot 10^{-2} \, m$$

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

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$$V = \frac{4}{3} \pi R^3$$

$$\frac{\partial V}{\partial R} = 3R^2 \left(\frac{4}{3}\right) \pi = 4\pi R^2$$

$$\Delta V = \frac{\partial V}{\partial R} \Delta R = \left(4\pi R^2\right)\left(\Delta R\right)$$

$$\Delta V = 4\pi \left(2.2 \cdot 10^{-2}\right)^2 \left(1 \cdot 10^{-3}\right)$$

$$\Delta V = 6.08 \cdot 10^{-6} m^3$$

$$V = \frac{4}{3} \pi R^3 = \frac{4}{3} \pi \left(2.2 \cdot 10^{-2}\right)^3 = 4.46 \cdot 10^{-5} m^3$$

$$\frac{\Delta V}{V} = \frac{6.08 \cdot 10^{-6}}{4.46 \cdot 10^{-5}} = 0.136$$

$$Volume = \left(4.5 \quad \pm 0.6 \quad\right) \cdot 10^{-5} m^3$$
maximum relative uncertainty = 0.1

c. 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.

$h = 5.2\,cm \pm .05cm$

$r = 2.5cm \pm .05cm$

$$V = \pi r^2 h$$

$$\Delta V = \frac{\partial V}{\partial r}\Delta r + \frac{\partial V}{\partial h}\Delta h$$
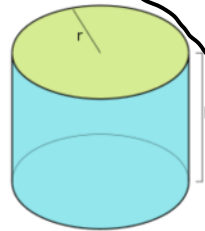
$$\Delta V = 2\pi r h (\Delta r) + \pi r^2 (\Delta h)$$

$$\Delta V = 2\pi (2.5)(5.2)(.05) + \pi (2.5)^2 (.05)$$

$$\Delta V = 5.066\,cm^3$$

$$V = \pi r^2 h = \pi (2.5)^2 (5.2) = 102.1\,cm^3$$

$$\frac{\Delta V}{V} = 0.05$$

$volume = (1.0 \pm .05) \cdot 10^2\,cm$

maximum relative uncertainty $= 0.05$

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3. <u>Statistical Errors</u>

   Watch "Video 4 – Ramp Experiment" before doing these exercises

   14/14 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.** <u>If you use Excel or some other program to automate these calculations, please include the Excel file or a screenshot of your work.</u>

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 cm

Standard Deviation = 0.9 cm

Standard Error = 0.3 cm

Percent Error = 2 %

a. Comment on the "spread" of the data and what it says about the precision of your measurements.

Generally the data is fairly tightly clumped except for a single trial with a displacement of 13.7 cm.

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

Specific source	reduction
① use of incremented measuring tool	① more precise measuring increment
② inconsistent form of measuring (eye)	② mechanized form of tracking (photogate) (video)
	③ add more trials