32.5/34

PHYS 101 - Measurement and Uncertainty in Scientific Experiments

Worksheet

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

David Lu Jackson Xu

Andrew Rodebaugh

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?
      i. **The reading has 3 significant figures.**

2/2

   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)
      i. 0.1/10.4=0.009=0.9% **The relative uncertainty of this measurement can be expressed as 0.9%**

3/3

   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.
      i. **If the mass balance reads “10.40g” there is 4 significant digits.**

1.5/3; write in scientific notation so not ambiguous: 1.040 * 10^1 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.

   i. 2.2/100 = 0.022 meters

   ii. R = 2.2x10^-2m +- 1.0x10^3m

2/2; but write as (2.2±0.1)*10^2 m

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

   i. V = (4/3)pi(0.022)^3

   ii. V = 4.5 x 10^-5 (m^3)

   iii. Dv/dr = 4piR^3

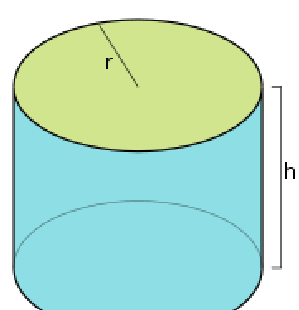
   iv. 4pi(0.022)^2 (.001)= 6.08 x 10^-6 m^3

   v. 6.08 x 10^-6 m^3 /4.5 x 10^-5 (m^3)

   vi. Maximum relative uncertainty = 1.36 x 10^-1m^3

5/5

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.



- V = pi r^2 h
- h = 5.2cm +- 0.05cm
- r = 2.5cm +- 0.05cm
- V = pi(2.5)^2(5.2)
- V = 102.1
- dv/dr = 2pih(deltaR)
- 2pi(2.5)(5.2)(0.05) = 4.08 cm
- dv/dh = (pi)r^2(deltaH)
- (pi)(2.5)^2(0.05) = 0.982 cm
- 4.08 + 0.982 = 5.062
- 5.062/102.1 = 0.05 cm
- **MAXIMUM RELATIVE UNCERTAINTY = 0.05 CM**

5/5

3. Statistical Errors

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

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

C12 fx =AVERAGE(C2:C11)

	A	B	C
1	Trial	End position	Displacement (cr
2	1	44.1	10.9
3	2	44.5	11.3
4	3	44.4	11.2
5	4	44.9	11.7
6	5	43.8	10.6
7	6	44.2	11
8	7	46.9	13.7
9	8	44.1	10.9
10	9	44.8	11.6
11	10	44.4	11.2
12	Average		11.41

Standard Deviation = 0.870

C13 =STDEV(C2:C11)

	A	B	C
1	Trial	End position	Displacement (
2	1	44.1	10.9
3	2	44.5	11.3
4	3	44.4	11.2
5	4	44.9	11.7
6	5	43.8	10.6
7	6	44.2	11
8	7	46.9	13.7
9	8	44.1	10.9
10	9	44.8	11.6
11	10	44.4	11.2
12	Average		11.41
13	Standard Deveation		0.86980202

Standard Error = 0.275

C14 =C13/SQRT(COUNT(C2:C11))

	A	B	C	D
1	Trial	End position	Displacement (cm)	
2	1	44.1	10.9	
3	2	44.5	11.3	
4	3	44.4	11.2	
5	4	44.9	11.7	
6	5	43.8	10.6	
7	6	44.2	11	
8	7	46.9	13.7	
9	8	44.1	10.9	
10	9	44.8	11.6	
11	10	44.4	11.2	
12	Average		11.41	
13	Standard Deveation		0.86980202	
14	Standard Error		0.27505555	

Percent Error = 2.41%

C15 | fx =(C14/C12)*100

	A	B	C
1	Trial	End position	Displacement (cm
2	1	44.1	10.9
3	2	44.5	11.3
4	3	44.4	11.2
5	4	44.9	11.7
6	5	43.8	10.6
7	6	44.2	11
8	7	46.9	13.7
9	8	44.1	10.9
10	9	44.8	11.6
11	10	44.4	11.2
12	Average		11.41
13	Standard Deveation		0.86980202
14	Standard Error		0.27505555
15	Percent Error		2.41065337
16			

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

   In the data 60% of the displacement numbers are >= 11.0m and < 12.0m along with the average for these numbers. Trial 7 is the largest outlier at 13.7m (2.3m greater than the average). In general the precision could be higher but that outlier in the data may be throwing off the accuracy a bit.

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

   Trial 7 being an outlier may have had some errors in data collection especially with it being so far off from the rest of the data. Potentially retesting/throwing out large outliers may help with uncertainty especially if they cannot really return back to the conclusion. Along with increasing the number of tests done may create more precise tests.