Experimental Uncertainty

Name_____ ID_____ TA_____

Partners_____

Date_____ Section_____

Use "grams" and "centimeters" for this experiment so that you can easily compare with the reference values.

- **Measurements of densities**

➢ Description of object 1

Object 1: Material ⇨_____ & Shape ⇨ _____

➢ Reference value of density: ⇒ _____ g/cm^3

Please label the dimensions, such as height, radius, width, etc.

	Mass (g)	Dimension 1 (cm)	Dimension 2 (cm)	Dimension 3 (cm)
Measurement 1				
Measurement 2				
Measurement 3				
Average				
Standard Deviation				

Average Volume of the Object (Use the average values): V = _____

Average Density [average value of mass ÷ average volume]: D = _____

➢ Error propagation

S_1 = _____; S_2 = _____;

S_3 = _____; S_4 = _____

S_D (Uncertainty of density) = _____

Experimental data for the density: [D (average)± S_D (uncertainty)]:_____ ± _____ ( )

Units for density ⇗

Question: Is the reference value of the density satisfied within the standard deviation?

➢ Description of object 2

Object 2: Material ⇨_____ & Shape ⇨ _____

➢ Reference value of density: ⇒ _____ g/cm^3

Please label the dimensions, such as height, radius, width, etc.

	Mass (g)	Dimension 1 (cm)	Dimension 2 (cm)	Dimension 3 (cm)
Measurement 1				
Measurement 2				
Measurement 3				
Average				
Standard Deviation				

Average Volume of the Object (Use the average values): V = _____

Average Density [average value of mass ÷ average volume]: D = _____

➢ Error propagation

S_1 = _____; S_2 = _____;

S_3 = _____; S_4 = _____

S_D (Uncertainty of density) = _____

Experimental data for the density: [D (average)± S_D (uncertainty)]:_____ ± _____ ( )

Units for density ⇗

Question: Is the reference value of the density satisfied within the standard deviation?

➢ Description of object 3

Object 3: Material ⇨_____ & Shape ⇨ _____

➢ Reference value of density: ⇒ _____ g/cm^3

Please label the dimensions, such as height, radius, width, etc.

	Mass (g)	Dimension 1 (cm)	Dimension 2 (cm)	Dimension 3 (cm)
Measurement 1				
Measurement 2				
Measurement 3				
Average				
Standard Deviation				

Average Volume of the Object (Use the average values): V = _____

Average Density [average value of mass ÷ average volume]: D = _____

➢ Error propagation

S_1 = _____; S_2 = _____;

S_3 = _____; S_4 = _____

S_D (Uncertainty of density) = _____

Experimental data for the density: [D (average)± S_D (uncertainty)]: _____ ± _____ ( )

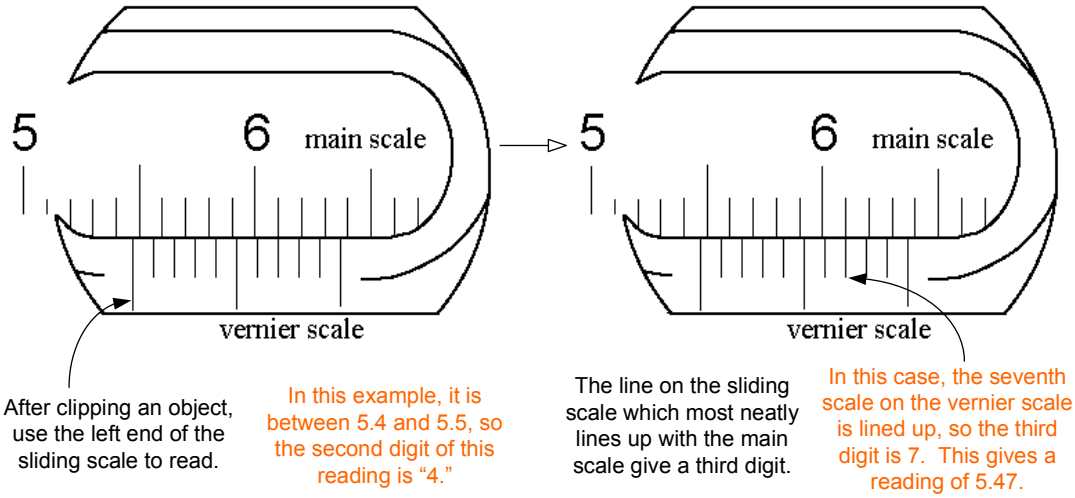
Units for density ⇗

Question: Is the reference value of the density satisfied within the standard deviation?

Reference values of densities	
Copper: 8.93 g/cm^3	Lead: 11.3 g/cm^3
Nickel: 8.8 g/cm^3	Wood: (0.25 – 1.0) g/cm^3
Iron (Steel): 7.8 g/cm^3	Aluminum: 2.7 g/cm^3
Brass: (7.5 – 8.5) g/cm^3	Silver: 10.5 g/cm^3

Appendices

- **How to use a caliper**



- **How to use the formula of Standard Deviation**

The equation of standard deviation is given as

$$\text{Standard Deviation} = \sqrt{\frac{1}{N-1}\sum_i (x_i - x_m)^2}$$

where N is the number of data, x_i is the i-th datum, and x_m is the average value of data. For example, here is a set of data.

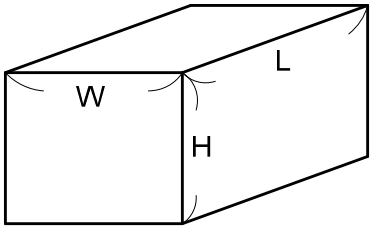
x_i	x_1	x_2	x_3
Values of data	4.56	4.37	4.61

In this case, the number of data is 3, so N = **3**. The average is (4.56 + 4.37 + 4.61)/3 = 4.51. Namely, x_m = **4.51**. Now, if we calculate the standard deviation, we have

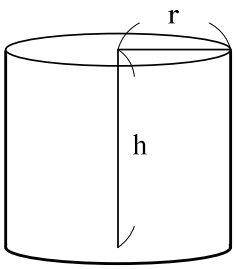
$$SD = \sqrt{\frac{1}{3-1}\left[(4.56-4.51)^2 + (4.37-4.51)^2 + (4.61-4.51)^2\right]} = 0.126 \Rightarrow 0.13.$$

The final format of this data is: **4.51** ± **0.13** [units].

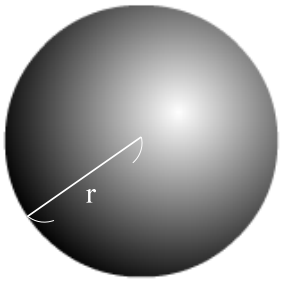
- **How to calculate volumes**



$$V = L \times W \times H$$



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



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

- **How to calculate the error propagations**

S_M, S_L, S_W, S_H, S_h, and S_r are the standard deviation of each dimension. M, L, W, H, h, r, and D are the average value of each dimension.

Cube or rectangular solid

$$S_1 = \frac{(M + S_M)}{L \times W \times H} - D$$ (Uncertainty of the density with standard deviation of the mass)

$$S_2 = \frac{M}{(L + S_L) \times W \times H} - D$$ (Uncertainty of the density with SD of the length)

$$S_3 = \frac{M}{L \times (W + S_W) \times H} - D$$ (Uncertainty of the density with SD of the width)

$$S_4 = \frac{M}{L \times W \times (H + S_H)} - D$$ (Uncertainty of the density with SD of the height)

$$S_D = \sqrt{S_1^2 + S_2^2 + S_3^2 + S_4^2}$$ (Total uncertainty of the density)

Cylinder

$$S_1 = \frac{(M + S_M)}{\pi r^2 h} - D \qquad S_2 = \frac{M}{\pi (r + S_r)^2 h} - D \qquad S_3 = \frac{M}{\pi r^2 (h + S_h)} - D$$

$$S_D = \sqrt{S_1^2 + S_2^2 + S_3^2}$$

Sphere

$$S_1 = \frac{(M + S_M)}{\frac{4}{3}\pi r^3} - D \qquad S_2 = \frac{M}{\frac{4}{3}\pi (r + S_r)^3} - D$$

$$S_D = \sqrt{S_1^2 + S_2^2}$$