Uncertainty

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The experimental uncertainty in a measurement is the best estimate of the total of all inaccuracies present in that measurement. The uncertainty can be expressed in two different ways.

Absolute uncertainty: the size of the uncertainty is expressed, (in only one digit), using units with no indication of its importance.
e.g. $\pm$ 2 cm $\pm$ 0.01 g $\pm$ 0.05 cm $\pm$ 0.001 mL

Relative uncertainty: the absolute uncertainty is expressed as a fraction or as a percent of the measured value, and has no units.

$$\text{Relative uncertainty} = \frac{\text{absolute uncertainty}}{\text{measured value}}$$

$$\text{percentage uncertainty} = \text{relative uncertainty} \times 100\ \% = \frac{\text{absolute uncertainty}}{\text{measured value}} \times 100\ \%$$

Performing calculations with measured values and their uncertainties

For Addition and / or Subtraction
1. Simply add or subtract the measured values as described by the operation sign.
2. Then add together the sizes of all the absolute uncertainties in each measurement to find the total uncertainty.

For Multiplication and /or Division
1. Multiply and /or divide the measured values as described by the operation sign.
2. Add together the sizes of all the relative or the % relative uncertainties for each measurements being multiplied/divided..
3. The absolute error is then the fraction or the percentage of the answer.

All uncertainty / error values have only one significant figure.

Practice Calculations

1. What is the relative uncertainty for the following:
a. 178.3 $\pm$ 0.01 g b. 2.08 $\pm$ 0.01 cm^3 c. 45.001 $\pm$ 0.001 m^2 d. 35.15 $\pm$ 0.02 mL

2. Calculate the percentage uncertainty for question 1.

3. Change the percentage error to absolute error for the following:
a. 1.098 $\pm$ 0.1 % b. 43.00 $\pm$ 0.2 % c. 8.35 $\pm$ 3% d. 11.26 $\pm$ 2%

4. Change the absolute error in the following measurement to % error:
a. 5.23 $\pm$ 0.02 b. 4.1 $\pm$ 0.1 c. 34.02 $\pm$ 0.04 d. 92.38 $\pm$ 0.01

5. Propagate the error in the following calculations:

a. 43.02 ± 0.02 — 8.21 ± 0.03

b. 92.3 ± 0.1 — 4.01 ± 0.02

c. 5.203 ± 0.002 + 4.145 ± 0.002 + 1.12 ± 0.01

d. 2.45 ± 0.01 g + 1.22 ± 0.01 g

e. 3.04 ± 0.02 cm — 1.32 ± 0.02 cm

f. 4.3 ± 0.1 cm X 1.2 ± 0.1 cm

g. 8.42 ± 0.01 g ÷ 4.0 ± 0.1 cm

h. 2.08 ± 0.01 cm X 0.21 ± 0.01 cm

i. 5.5 ± 0.5 m X 12.5 ± 0.5 m

j. 45.001 ± 0.001 m^2 ÷ 9.00 ± 0.01 m

k. 1.2 ± 0.1 m X 3.6 ± 0.1 m

6. A sculpture whose mass is 48.6 ± 0.1 kg rests on a floor measuring 1.2 ± 0.1 m by 3.6 ± 0.1 m.

a. What is the area of the floor ? (Area = l x w)

b. What pressure is the sculpture exerting on the floor? (Pressure = force / area, kg / m^2)

7. A sample of aluminium is found to have a mass of 11.25 ± 0.05 g and a volume of 4.32 ± 0.1 mL

a. What are the relative uncertainties in the mass and the volume ?

b. What is the experimental value for the density of aluminium?

c. What are the relative and absolute uncertainties in the experimental density ?

d. The literature value for the density of aluminium is 2.71 g mL^{-1}.

i. What is the experimental error?

ii. Comment on the experimental result .

9. Calculate the density of an object whose volume is 25.55 ± 0.01 mL and a mass of 20.26 ± 0.02 g.

10. A triangle has the following dimensions:

length = 5.72 ± 0.05 cm width = 3.51 ± 0.05 cm height = 4.03 ± 0.05 cm

a. Calculate the absolute and relative uncertainties in the perimeter of the triangle.

b. Calculate the absolute and relative uncertainties in the area of the triangle.