

# Checking units, uncertainties and vector components

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab answers

The sample data give a density near  $647 \text{ kg/m}^3$ . Your own values will differ with the wood you use, but the method, the order of the uncertainties and the conclusion about the squared diameter should be the same.

**Level:** Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 1, IB A

## Question 1 Mean diameter

Sum =  $3.20 + 3.18 + 3.22 + 3.19 + 3.21 = 16.00 \text{ cm}$ , mean =  $3.20 \text{ cm}$ . Range =  $3.22 - 3.18 = 0.04 \text{ cm}$ , so uncertainty =  $0.02 \text{ cm}$ .  **$d = 3.20 \pm 0.02 \text{ cm}$ .**

## Question 2 Percentage uncertainties

m:  $0.1 \div 62.4 = 0.16 \%$ . l:  $0.1 \div 12.0 = 0.83 \%$ . d:  $0.02 \div 3.20 = 0.63 \%$ .  **$0.16 \%$ ,  $0.83 \%$  and  $0.63 \%$ .**

## Question 3 Volume

$V = \pi \times 3.20^2 \times 12.0 \div 4 = \pi \times 10.24 \times 12.0 \div 4 = 96.5 \text{ cm}^3$ .  **$V = 96.5 \text{ cm}^3$ .**

## Question 4 Density and uncertainty

$\rho = 62.4 \div 96.5 = 0.647 \text{ g/cm}^3$ . The diameter is squared, so its contribution is  $2 \times 0.63 = 1.25 \%$ . Total =  $0.16 + 0.83 + 1.25 = 2.24 \%$ , and  $0.0224 \times 0.647 = 0.0145 \text{ g/cm}^3$ .  **$\rho = 0.647 \pm 0.015 \text{ g/cm}^3$  ( $647 \pm 15 \text{ kg/m}^3$ ).**

## Question 5 Largest contribution

The diameter contributes  $1.25 \%$ , the length  $0.83 \%$  and the mass only  $0.16 \%$ . **The diameter dominates because it is squared.**

## Question 6 Float or sink

$647 \text{ kg/m}^3$  is below  $1000 \text{ kg/m}^3$ , so it floats. When floating, fraction submerged = density of dowel  $\div$  density of water =  $647 \div 1000 = 0.647$ . **It floats with about  $65 \%$  of its volume under water.**

### Question 7 Unit check

$\rho = m \div V$ , so the unit is  $\text{kg} \div \text{m}^3 = \text{kg m}^{-3}$ . Conversion:  $0.647 \text{ g/cm}^3 = 0.647 \times 10^3 \text{ kg/m}^3 =$   
**647 kg m<sup>-3</sup>.**

### Question 8 Improvement

Measure the diameter with vernier callipers ( $\pm 0.01 \text{ cm}$  or better) instead of a ruler. **This reduces the largest contribution, the squared diameter.**