1 Physical quantities and units – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary

Write each word three times.

English	**Write it 3 times** (English)		
measurement			
uncertainty			
systematic error			
zero error			
accuracy			
random error			
mean			
precision			
absolute uncertainty			
perpendicular			
components			

Recall

In **Part 1** you wrote quantities in SI base units, checked an equation is homogeneous, and added two perpendicular vectors. Keep ready:

- Every quantity is a number **and** a unit; a vector has size **and** direction.
- Two perpendicular vectors add to a resultant of size $\sqrt{X^2 + Y^2}$.

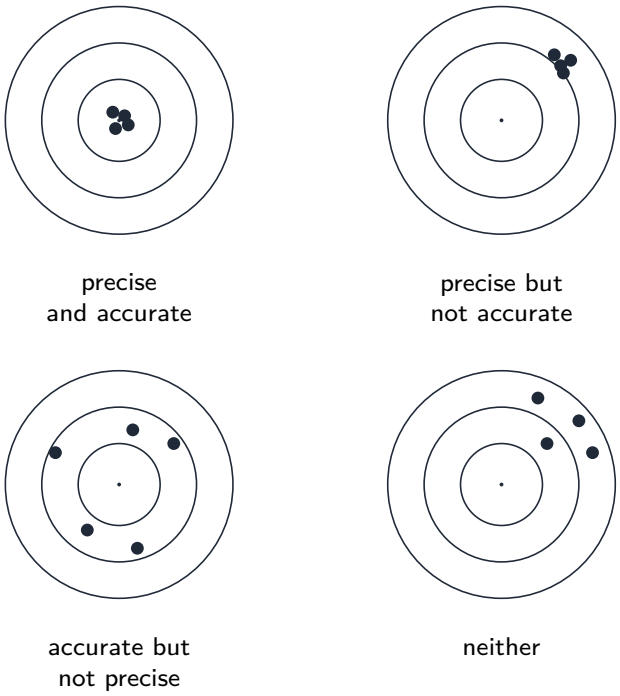
Part 2 looks at how *sure* we are of a measurement (uncertainty), and at splitting a vector into parts.

New ideas

1 Systematic and random errors

Every **measurement** has some **uncertainty** – we are never perfectly sure of the value. Errors come in two kinds:

- a **systematic error** shifts every reading the same way (e.g. a **zero error** – the scale doesn't read zero at the start). Repeating does **not** remove it; it harms the **accuracy**.
- a **random error** scatters readings above and below the true value. Taking the **mean** of many repeats reduces it; it harms the **precision**.



Precise = readings close together; *accurate* = readings near the true value.

Watch out: repeating a measurement reduces *random* error but never a *systematic* one – a zero error stays however many times you repeat.

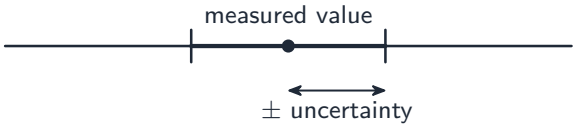
2 Absolute and percentage uncertainty

A measurement is written $x \pm \Delta x$, where Δx is the **absolute uncertainty**. The

$$\text{percentage uncertainty} = \frac{\Delta x}{|x|} \times 100\%.$$

To combine uncertainties in a calculated value: **add or subtract** → add the *absolute* uncertainties; **multiply or divide** → add the *percentage* uncertainties; a **power** n → multiply the percentage by n.

Worked example. A diameter is $d = 5.0 \pm 0.1$ cm, so its percentage uncertainty is $\frac{0.1}{5.0} \times 100\% = 2\%$. An area $A \propto d^2$, so the percentage uncertainty in A is $2 \times 2\% = 4\%$.

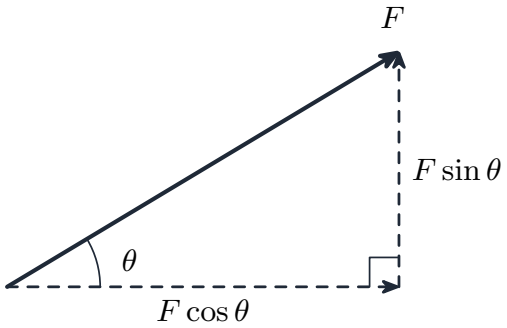


$$\%\ \text{uncertainty} = \frac{\text{uncertainty}}{\text{value}} \times 100\%$$

3 Resolving a vector into components

Any vector can be split into two **perpendicular components**. For a vector of size v at angle θ to the horizontal:

$$v_{\mathrm{H}} = v\cos\theta, \qquad v_{\mathrm{V}} = v\sin\theta.$$



Worked example. A force of 50 N acts at 30° above the horizontal: $v_{\mathrm{H}} = 50\cos 30° = 43$ N, $v_{\mathrm{V}} = 50\sin 30° = 25$ N.

Practice

1.1 State whether each is a systematic or a random error: (a) a balance that reads 2 g with nothing on it; (b) readings that scatter each time you repeat them. [2]

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1.2 A set of readings is grouped very close together but far from the true value. State whether they are (a) precise, (b) accurate. [2]

1.3 A length is measured as 20.0 ± 0.5 cm. Find its percentage uncertainty. [2]

1.4 A quantity $y = ab$, where a has a percentage uncertainty of 2% and b of 3%. Find the percentage uncertainty in y. [1]

1.5 A force of 12 N acts at 60° to the horizontal. Find its horizontal and vertical components. [3]

1.6 Challenge. The side of a cube is measured with a percentage uncertainty of 1%. State the percentage uncertainty in its volume, and explain why. [2]

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