A-LEVEL PHYSICS • EXERCISE SHEET

1.3 Errors and uncertainties

Name: ______________ Class: __________ Date: ____________ **Total: 16 marks**

Objective

Build the skills to answer exam questions on **errors and uncertainties** —error types, precision vs accuracy, and combining uncertainties.

You must be able to:

- explain **systematic** (incl. **zero**) and **random** errors
- distinguish **precision** 精密度 from **accuracy** 准确度
- combine **absolute** and **percentage** uncertainties in a derived quantity

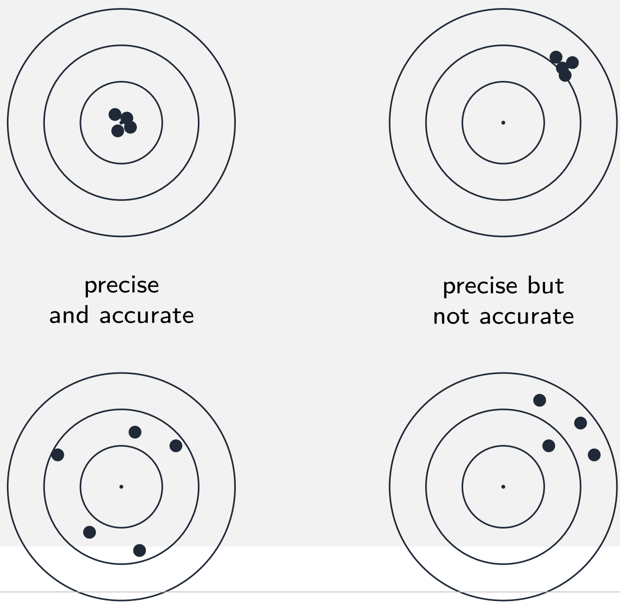
1 Worked examples

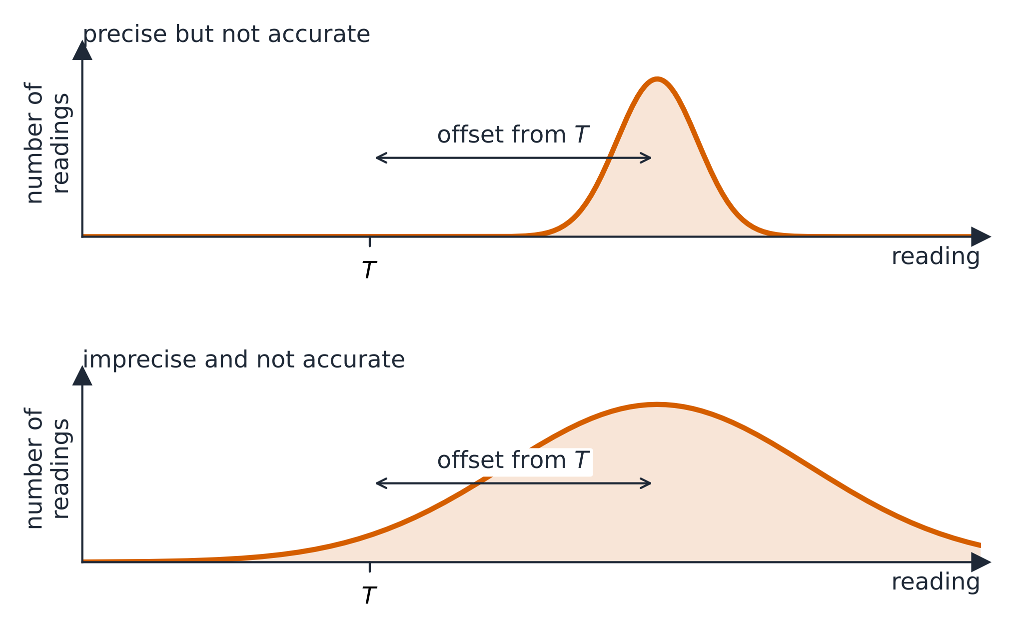
Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ Errors, precision and accuracy

- A **systematic error** shifts every reading the **same way** (a **zero error**, a wrong calibration). Repeating does not reveal it; it harms **accuracy**.
- A **random error** scatters readings **both ways**. Taking the **mean** of many repeats reduces it; it harms **precision**.

Precision = how close repeats are to each other; **accuracy** = how close they are to the true value:





Precision contrasted with accuracy

Uncertainty in one quantity

Write a measurement as $x \pm \Delta x$. The **percentage uncertainty** is $\dfrac{\Delta x}{|x|} \times 100\%$. E.g. (2.50 ± 0.05) m $\to \dfrac{0.05}{2.50} \times 100 = 2\%$.

Combining uncertainties

- **Add / subtract** $\to$ add the **absolute** uncertainties: $y = a \pm b \Rightarrow \Delta y = \Delta a + \Delta b$.
- **Multiply / divide** $\to$ add the **percentage** uncertainties.
- **Power** $y = a^n$ $\to$ **multiply** the percentage by $|n|$.

Worked example. $R = V/I$ with $V = (6.0 \pm 0.1)$ V, $I = (2.0 \pm 0.1)$ A: $R = 3.0\ \Omega$; $\%V = 1.7\%$, $\%I = 5.0\%$, so $\%R = 6.7\%$, i.e. $R = (3.0 \pm 0.2)\ \Omega$.

2 Practice

Now apply the methods above.

2.1 State the difference between a **systematic** error and a **random** error. [2]

2.2 A balance reads 0.3 g with **nothing** on it. Name this error and state how to correct a reading. [2]

2.3 A length is (2.50 ± 0.05) m. Find its **percentage uncertainty**. [1]

2.4 State the difference between **precision** and **accuracy**. [2]

3 Exam-style questions

3.1 Repeated readings are **close together** but **far from** the true value. They are: [1]

- **A** accurate but not precise
- **B** precise but not accurate
- **C** both accurate and precise
- **D** neither

3.2 Two lengths are $a = (40 \pm 1)$ mm and $b = (25 \pm 1)$ mm. Find $a - b$ with its **absolute uncertainty**. [2]

3.3 A resistance is found from $R = V/I$, with $V = (6.0 \pm 0.1)$ V and $I = (2.0 \pm 0.1)$ A. Find R and its **absolute uncertainty**. [4]

3.4 A cube has side $L = (2.00 \pm 0.02)$ cm. Its volume is $V = L^3$. Find the **percentage**

uncertainty in V. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **1.3 Errors and uncertainties** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/22 N25 —Q1 (combining uncertainties)
- 9702/24 N25 —Q5 (uncertainty in a result)
- 9702/12 N25 —Q4 (precision and accuracy)
- 9702/11 N25 —Q2 (uncertainties)

Solutions

2.1 A **systematic** error shifts every reading the **same amount/direction** (not reduced by repeating); a **random** error scatters readings **both ways** and is reduced by taking the **mean** of repeats.

2.2 A **zero error** (systematic); **subtract** the 0.3 g from every reading.

2.3 $\dfrac{0.05}{2.50} \times 100 = 2\%$.

2.4 **Precision** —how close repeated readings are to **each other**; **accuracy** —how close a reading (or the mean) is to the **true value**.

3.1 **B** —precise but not accurate.

3.2 $a - b = 40 - 25 = 15$ mm; $\Delta = 1 + 1 = 2$ mm, so (15 ± 2) mm.

3.3 $R = 6.0/2.0 = 3.0\ \Omega$; $\%V = \frac{0.1}{6.0} \times 100 = 1.7\%$, $\%I = \frac{0.1}{2.0} \times 100 = 5.0\%$; $\%R = 1.7 + 5.0 = 6.7\%$; $\Delta R = 0.067 \times 3.0 = 0.2\ \Omega$, so $R = (3.0 \pm 0.2)\ \Omega$.

3.4 $\%L = \frac{0.02}{2.00} \times 100 = 1\%$; $V = L^3$ so $\%V = 3 \times 1\% = 3\%$.