1. Physical Quantities and Units

1.3 Errors and uncertainties

Paper 1

Question Paper

1 A thermometer can be read to an accuracy of ± 0.5 °C. This thermometer is used to measure a temperature rise from 40 °C to 100 °C.

What is the percentage uncertainty in the measurement of the temperature rise?

A 0.5% **B** 0.8% **C** 1.3% **D** 1.7%

2 The value of quantity X has a percentage uncertainty of 2%.

The value of quantity Y has a percentage uncertainty of 4%.

The value of a quantity W is calculated from the values of X and Y.

The value of W has a percentage uncertainty of 8%.

What could be the relationship between W, X and Y?

A $W = XY$ **B** $W = 2XY$ **C** $W = \frac{X}{Y^2}$ **D** $W = \frac{Y}{X^2}$

3 The density of the material of a rectangular block is determined by measuring the mass and linear dimensions of the block. The list shows the results obtained, together with their uncertainties.

$$\text{mass} = (25.0 \pm 0.1)\,\text{g}$$
$$\text{length} = (5.00 \pm 0.01)\,\text{cm}$$
$$\text{width} = (2.00 \pm 0.01)\,\text{cm}$$
$$\text{height} = (1.00 \pm 0.01)\,\text{cm}$$

The density is calculated to be 2.50 g cm^{-3}.

What is the uncertainty in this result?

A ± 0.01 g cm^{-3} **B** ± 0.02 g cm^{-3} **C** ± 0.05 g cm^{-3} **D** ± 0.13 g cm^{-3}

4 A solid bar has a square cross-section. Its length is measured as 50.0 ± 0.2 cm and its width is measured as 2.00 ± 0.01 cm.

These values are used to calculate the volume of the bar.

What is the percentage uncertainty in the calculated volume?

A $\pm 0.21\%$ **B** $\pm 0.22\%$ **C** $\pm 0.90\%$ **D** $\pm 1.4\%$

5 A copper pipe has a true diameter of 42.03 mm.

A builder measures the diameter of the pipe five times using digital calipers. The measurements are shown.

diameter / mm
48.01
47.99
48.01
48.00
47.99

What describes the builder's measurements?

A accurate and precise

B accurate but not precise

C not precise and not accurate

D precise but not accurate

6 Two measurements for a solid sphere are shown.

$$\text{mass} = (32.5 \pm 0.1)\,\text{g}$$

$$\text{diameter} = (1.87 \pm 0.04)\,\text{cm}$$

These values are used to determine the density of the sphere.

What is the percentage uncertainty in the density?

A 2.4% **B** 4.6% **C** 6.1% **D** 6.7%

7 A student takes measurements to determine the constant acceleration of a model car moving from rest in a straight line. The measured values with their absolute uncertainties are shown.

quantity	measured value	uncertainty
displacement	16.5 m	± 0.1 m
time	15.0 s	± 1.0 s

The student uses the equation $s = \frac{1}{2}at^2$ to calculate the acceleration of the car.

What is the acceleration and its absolute uncertainty?

A $(0.11 \pm 0.01)\,\text{m s}^{-2}$

B $(0.11 \pm 0.02)\,\text{m s}^{-2}$

C $(0.15 \pm 0.01)\,\text{m s}^{-2}$

D $(0.15 \pm 0.02)\,\text{m s}^{-2}$

8 A value for the acceleration of free fall on Earth is given as $(10 \pm 2)\,\mathrm{m\,s^{-2}}$.

Which statement is correct?

A The value is accurate but not precise.

B The value is both precise and accurate.

C The value is neither precise nor accurate.

D The value is precise but not accurate.

9 Which statement about systematic errors is **not** correct?

A A systematic error can be caused by using an incorrectly calibrated instrument.

B One particular type of systematic error can affect all the measurements by the same amount.

C The effect of a systematic error can be reduced by repeating and averaging the measurements.

D Zero error is a type of systematic error.

10 In an experiment to determine the acceleration of free fall g, the time t taken for a ball to fall through distance s is measured. The percentage uncertainty in the measurement of s is 2%. The percentage uncertainty in the measurement of t is 3%.

The value of g is determined using the equation shown.

$$g = \frac{2s}{t^2}$$

What is the percentage uncertainty in the calculated value of g?

A 1% **B** 5% **C** 8% **D** 11%

11 A spring is suspended from a fixed point and a force is applied. The position of a pointer attached to the bottom of the spring against a vertical ruler is recorded.

Before the force is applied, the position of the pointer is (225 ± 2) mm.

After the force is applied, the position of the pointer is (250 ± 2) mm.

The extension of the spring is determined.

What is the percentage uncertainty in the extension?

A 1.6% **B** 1.8% **C** 8.0% **D** 16%

12 A micrometer screw gauge is used to measure the diameter of a wire.

The reading on the micrometer with the jaws closed is (-0.05 ± 0.02) mm.

The reading with the wire in position between the two jaws is $(+1.03 \pm 0.02)$ mm.

What is the diameter of the wire?

A (0.98 ± 0.02) mm

B (1.08 ± 0.02) mm

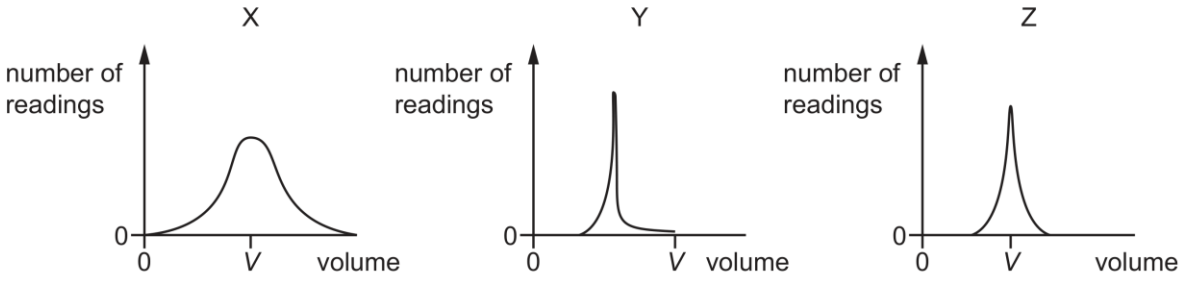
C (0.98 ± 0.04) mm

D (1.08 ± 0.04) mm

13 Students take readings of the volume of a liquid using three different pieces of measuring equipment X, Y and Z.

The true value of the volume of the liquid is *V*.

The students' results are shown.



How many pieces of equipment are precise and how many are accurate?

	number of precise pieces of equipment	number of accurate pieces of equipment
A	1	1
B	1	2
C	2	1
D	2	2

14 Four possible sources of error in a series of measurements are listed.

1 an analogue meter whose scale is read from different angles

2 a meter which always measures 5% too high

3 a meter with a needle that is not frictionless, so the needle sometimes sticks slightly

4 a meter with a zero error

Which errors are random and which are systematic?

	random error	systematic error
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	3 and 4	1 and 2

15 A student measures the time T for one complete oscillation of a pendulum of length l.

Her results are shown in the table.

l / m	T / s
0.420 ± 0.001	1.3 ± 0.1

She uses the formula

$$T = 2\pi\sqrt{\frac{l}{g}}$$

to calculate the acceleration of free fall g.

What is the best estimate of the percentage uncertainty in the value of g?

A 0.02% **B** 4% **C** 8% **D** 16%

16 A measurement is taken correctly but with a ruler at a significantly higher temperature than that at which the ruler was calibrated. The higher temperature causes the ruler to expand.

What describes the effect on the measurement caused by the higher temperature and how the measurement may be improved?

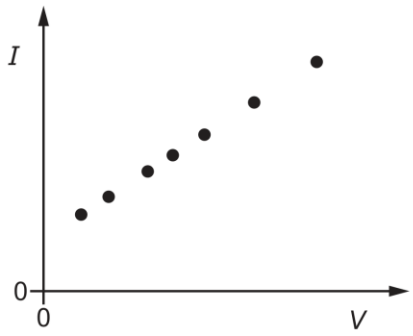
A The measurement will be subject to a random error. The measurement can be made more accurate by taking the average of several repeated measurements.

B The measurement will be subject to a random error. The measurement can be made more precise by taking the average of several repeated measurements.

C The measurement will be subject to a systematic error. The measurement can be made more accurate by taking the average of several repeated measurements.

D The measurement will be subject to a systematic error. The measurement can be made more precise by taking the average of several repeated measurements.

17 Readings are made of the current I for different voltages V across a fixed resistor. The results are plotted on a graph to show the variation of I with V.



What is the best description of the errors in the readings?

A both systematic and random

B neither systematic nor random

C random only

D systematic only

18 The diameter of a spherical golf ball is measured with calipers and found to be $(4.11 \pm 0.01)\,\text{cm}$.

The volume of a sphere is $V = \frac{1}{6}\pi d^3$, where d is the diameter of the sphere.

What is the volume of the golf ball?

A $(36.35 \pm 0.01)\,\text{cm}^3$

B $(36.35 \pm 0.03)\,\text{cm}^3$

C $(36.35 \pm 0.09)\,\text{cm}^3$

D $(36.4 \pm 0.3)\,\text{cm}^3$

19 A steel ball is dropped and falls through a vertical height h. The time t taken to fall is measured using light gates.

The results are given in the table.

h	(4.05 ± 0.01) m
t	(0.91 ± 0.02) s

The acceleration of free fall g is calculated using the equation shown.

$$h = \tfrac{1}{2}gt^2$$

What is the percentage uncertainty in the value of g?

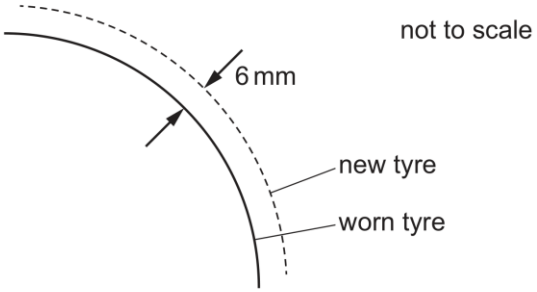
A 2.4% **B** 4.6% **C** 5.1% **D** 9.3%

20 The speed shown on a car's speedometer is proportional to the rate of rotation of the tyres.

The variation of the diameter of a tyre as it wears introduces an error in the speed shown on the speedometer.

A car has new tyres of diameter 600 mm. The speedometer is accurately calibrated for this diameter.

The tyres wear as shown, with 6 mm of material being removed from the outer surface.



What is the error in the speed shown on the speedometer after this wear has taken place?

A The speed shown is too high by 1%.

B The speed shown is too high by 2%.

C The speed shown is too low by 1%.

D The speed shown is too low by 2%.

21 A student wishes to determine the density ρ of lead. She measures the mass and diameter of a small sphere of lead:

$$\text{mass} = (0.506 \pm 0.005)\,\text{g}$$

$$\text{diameter} = (2.20 \pm 0.02)\,\text{mm}.$$

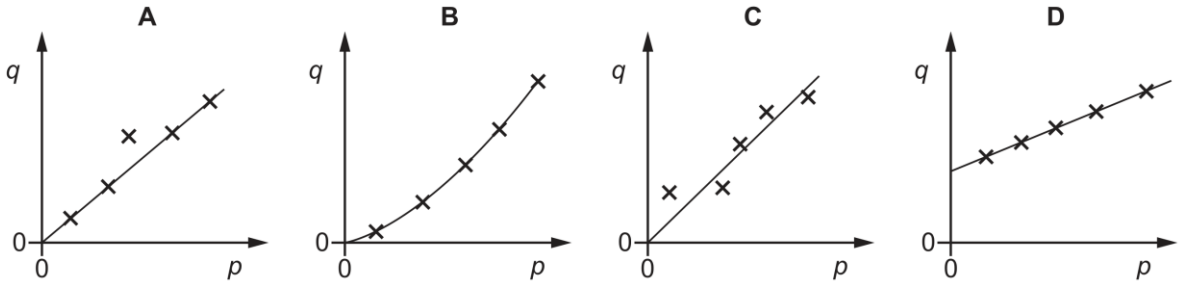
What is the best estimate of the percentage uncertainty in her calculated value of ρ?

A 1.7% **B** 1.9% **C** 2.8% **D** 3.7%

22 Two quantities p and q are directly proportional to each other.

Experimental results are taken and plotted in a graph of q against p.

Which graph shows there were random errors in the measurements of p and q?



23 A man of mass 75.2 kg uses a set of weighing scales to measure his mass three times. He obtains the following readings.

	mass / kg
reading 1	80.2
reading 2	80.1
reading 3	80.2

Which statement best describes the precision and accuracy of the weighing scales?

A not precise to $\pm$ 0.1 kg and accurate to $\pm$ 0.1 kg

B not precise to $\pm$ 0.1 kg and not accurate to $\pm$ 0.1 kg

C precise to $\pm$ 0.1 kg and accurate to $\pm$ 0.1 kg

D precise to $\pm$ 0.1 kg and not accurate to $\pm$ 0.1 kg

24 The power P dissipated in a resistor of resistance R is calculated using the expression

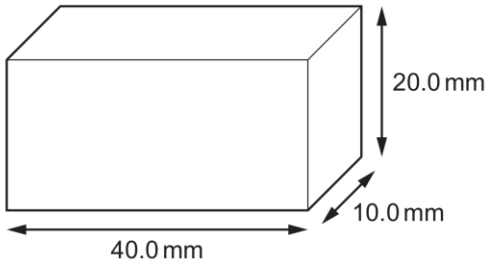
$$P = \frac{V^2}{R}$$

where V is the potential difference (p.d.) across the resistor. The percentage uncertainty in V is 5% and in R is 2%.

What is the percentage uncertainty in P?

A 3% **B** 7% **C** 8% **D** 12%

25 The sides of a wooden block are measured with calipers. The lengths of the sides are measured as 20.0 mm, 40.0 mm and 10.0 mm.



The calipers can measure with an absolute uncertainty of ±0.1 mm.

What is the percentage uncertainty in the calculated volume of the block?

A 0.3% **B** 1.8% **C** 3.8% **D** 30%

26 The sides of a cube are measured with calipers.

The measured length of each side is (30.0 ± 0.1) mm.

The measurements are used to calculate the volume of the cube.

What is the percentage uncertainty in the calculated value of the volume?

A 0.01% **B** 0.3% **C** 1% **D** 3%

27 A student measures the current through a resistor and the potential difference (p.d.) across it. There is a 4% uncertainty in the current reading and a 1% uncertainty in the p.d. reading. The student calculates the resistance of the resistor.

What is the percentage uncertainty in the calculated resistance?

A 0.25% **B** 3% **C** 4% **D** 5%

28 A student applies a potential difference V of $(4.0 \pm 0.1)\,\text{V}$ across a resistor of resistance R of $(10.0 \pm 0.3)\,\Omega$ for a time t of $(50 \pm 1)\,\text{s}$.

The student calculates the energy E dissipated using the equation below.

$$E = \frac{V^2 t}{R} = \frac{4.0^2 \times 50}{10.0} = 80\,\text{J}$$

What is the absolute uncertainty in the calculated energy value?

A 1.5 J **B** 3 J **C** 6 J **D** 8 J

29 A digital meter has an accuracy of ±1%.

The meter is used to measure the current in an electrical circuit.

The reading on the meter varies between 3.04 A and 3.08 A.

What is the value of the current, with its uncertainty?

A $(3.06 \pm 0.02)\,\text{A}$

B $(3.06 \pm 0.04)\,\text{A}$

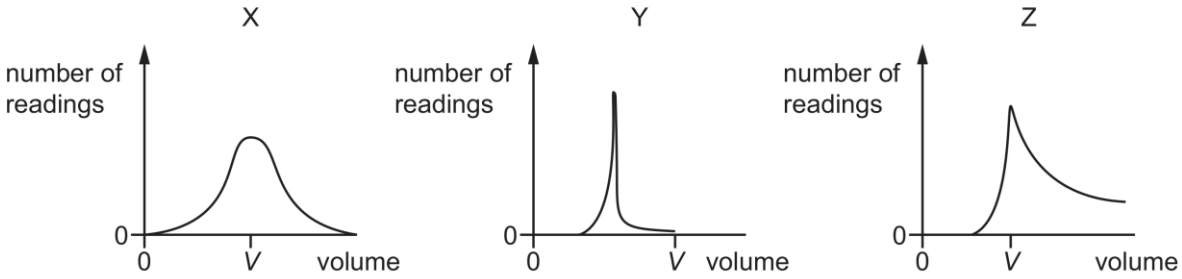
C $(3.06 \pm 0.05)\,\text{A}$

D $(3.06 \pm 0.07)\,\text{A}$

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