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PEARSON EDEXCEL A LEVEL PHYSICS (9PH0) — ORIGINAL PRACTICE QUESTIONS

Topic 1.1: Measurements & Uncertainties

A Level Physics — Original Practice Set

Written by GuideMyGrades — original questions in the style of Pearson Edexcel A Level Physics

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Contents

This booklet contains original practice questions written by GuideMyGrades for A Level Physics Topic 1.1 (Measurements & Uncertainties), modelled on the style, structure, command words and difficulty of genuine Pearson Edexcel papers. Each section opens with a fully worked example, followed by two or more practice questions of increasing difficulty. None of the questions are taken from or adapted from any real past paper — the content, numbers and contexts are original.

Question Paper

- A. SI Base Units, Prefixes & Deriving Units**
- B. Precision, Accuracy & Types of Error**
- C. Reading Instruments: Absolute & Percentage Uncertainty**
- D. Uncertainty from Two Readings**
- E. Uncertainty from Multiple Readings**
- F. Combining Uncertainties in a Calculated Quantity**
- G. Graphical Uncertainty & Systematic vs Random Error**
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Mark Scheme

Topic 1.1: Measurements & Uncertainties

A Level Physics — Original Practice Set



Topic 1.1: Measurements & Uncertainties — Question Paper

Original questions written by GuideMyGrades in the style of Pearson Edexcel A Level Physics (9PH0). Not from a real past paper. Click ANSWER (top right of each question) to jump to its mark scheme.

A. SI Base Units, Prefixes & Deriving Units

Every physical quantity can be built from the seven SI base units. Learning the base units table, the standard prefixes, and how to derive units from an equation will help throughout this course.

MEMORISE THIS

SI Base Quantities & Units

“Length” covers any distance, displacement, or wavelength — it is always measured in metres. Luminosity (candela) is not required at A Level.

Base Quantity	Unit	Unit Symbol
Length	Metre	m
Time	Second	s
Mass	Kilogram	kg
Electric Current	Ampere	A
Temperature	Kelvin	K
Amount of Substance	Mole	mol
Luminosity (not at A Level)	Candela	cd

MEMORISE THIS

Standard Prefixes & Multipliers

Prefix	Symbol	Multiplier
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}
peta	P	10^{15}



WORKED EXAMPLE**Deriving Units From an Equation**

Use the equations $\text{Force} = \text{mass} \times \text{acceleration}$, $\text{Work done} = \text{Force} \times \text{distance}$, and $\text{Power} = \text{Energy} / \text{time}$ to derive the SI base units of the watt (W).

■ mass ■ acceleration ■ distance ■ time ■ force (derived) ■ energy (derived)

Solution

1. Acceleration has units m s^{-2} (it is a rate of change of velocity, itself a rate of change of a length).
2. $\text{Force} = \text{mass} \times \text{acceleration}$, so the units of force = $\text{kg} \times \text{m s}^{-2} = \text{kg m s}^{-2}$.
3. $\text{Work done (energy)} = \text{force} \times \text{distance}$, so the units of energy = $(\text{kg m s}^{-2}) \times \text{m} = \text{kg m}^2 \text{s}^{-2}$.
4. $\text{Power} = \text{energy} / \text{time}$, so the units of power = $(\text{kg m}^2 \text{s}^{-2}) / \text{s}$. Dividing by seconds is the same as multiplying by s^{-1} , so the s^{-2} becomes s^{-3} .

$$1 \text{ W} = 1 \text{ kg m}^2 \text{s}^{-3}$$

1.**ANSWER >**

Choose the correct answer to each of the following. Write the letter of your chosen answer on the line provided.

(a) Which of the following is the SI base unit for mass?

[1]

- A. gram
- B. kilogram
- C. tonne
- D. newton

(b) The prefix 'micro' (μ) represents a multiplying factor of:

[1]

- A. 10^{-3}
- B. 10^{-6}
- C. 10^{-9}
- D. 10^6

(c) A current of 25 mA, written in amps using standard form, is:

[1]

- A. $25 \times 10^3 \text{ A}$
- B. $2.5 \times 10^{-2} \text{ A}$
- C. $2.5 \times 10^2 \text{ A}$
- D. $2.5 \times 10^{-5} \text{ A}$

(Total for Question 1 = 3 marks)



2.

ANSWER ›

The Hooke's law equation is $F = kx$, where F is force and x is extension.

(a) Which of the following gives the base units of the spring constant k ? [1]

- A. kg s^{-2}
- B. kg m s^{-2}
- C. N m
- D. N m^{-1}

(b) The equation for gravitational potential energy is $E_p = mgh$. Show that the base units of E_p are $\text{kg m}^2 \text{s}^{-2}$. [3]

(Total for Question 2 = 4 marks)

3.

ANSWER ›

Choose the correct answer to each of the following. Write the letter of your chosen answer on the line provided. Some questions use equations from the A Level Physics data & formulae sheet.

(a) Which of the following is one of the seven SI base quantities? [1]

- A. Force
- B. Energy
- C. Electric current
- D. Velocity

(b) Which of the following is a derived unit, not a base unit? [1]

- A. Kilogram
- B. Second
- C. Ampere
- D. Newton

(c) Using $W = mg$ (weight = mass $\times$ gravitational field strength), which combination of SI base units is equivalent to the newton (N)? [1]

- A. kg m s^{-2}
- B. $\text{kg m}^2 \text{s}^{-2}$
- C. kg s^{-2}
- D. kg m s^{-1}



- (d) Using $E_k = \frac{1}{2}mv^2$, which of the following gives the base units of the joule (J)? [1]
- A. kg m s^{-2}
 - B. $\text{kg m}^2 \text{s}^{-1}$
 - C. $\text{kg m}^2 \text{s}^{-2}$
 - D. $\text{kg}^{-1} \text{m}^2 \text{s}^{-2}$

- (e) Using stress $\sigma = F/A$, which combination of SI base units is equivalent to the pascal (Pa)? [1]
- A. $\text{kg m}^{-1} \text{s}^{-2}$
 - B. kg m s^{-2}
 - C. $\text{kg m}^2 \text{s}^{-2}$
 - D. $\text{kg m}^{-2} \text{s}^{-1}$

(Total for Question 3 = 5 marks)

4.

ANSWER ›

Choose the correct answer to each of the following. Write the letter of your chosen answer on the line provided.

- (a) A current of $4.7 \mu\text{A}$, written in standard form in amps, is: [1]
- A. $4.7 \times 10^{-6} \text{ A}$
 - B. $4.7 \times 10^{-3} \text{ A}$
 - C. $4.7 \times 10^6 \text{ A}$
 - D. $47 \times 10^{-6} \text{ A}$

- (b) A resistance of $2.2 \text{ M}\Omega$ is equivalent to: [1]
- A. $2.2 \times 10^6 \Omega$
 - B. $2.2 \times 10^3 \Omega$
 - C. $22 \times 10^6 \Omega$
 - D. $2.2 \times 10^{-6} \Omega$

(Total for Question 4 = 2 marks)



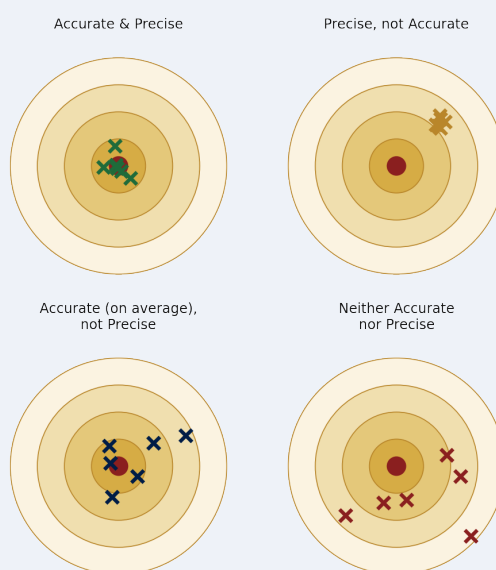
B. Precision, Accuracy & Types of Error

Precision, accuracy, and the difference between random and systematic errors are key ideas that apply throughout every practical measurement in this course.

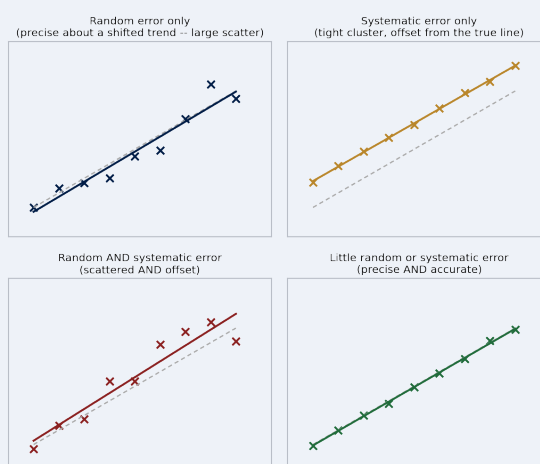
MEMORISE THIS

Precision vs Accuracy

Precision describes how close repeated readings are to EACH OTHER (the spread of the results). Accuracy describes how close a reading is to the TRUE value. The two are independent — a measurement can be precise without being accurate, or accurate (on average) without being precise.



the four combinations, as darts on a dartboard



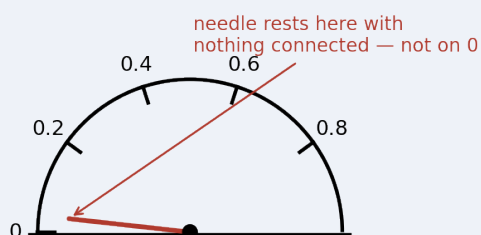
the same four combinations, as repeated-reading graphs

MEMORISE THIS**Random Errors vs Systematic Errors**

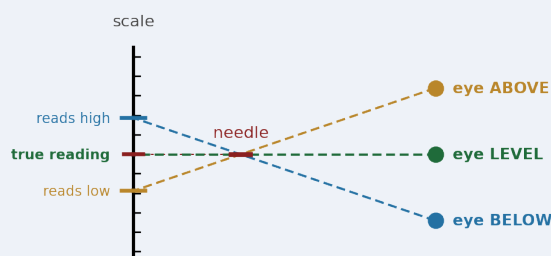
Examples:

- i. e.g. *Zero Error* — a systematic error where an instrument does not read zero when it should, so every reading is offset by the same fixed amount.
- ii. e.g. *Parallax Error* — a human (observational) error caused by viewing a scale from the wrong angle. This is generally systematic, but could be random if the angle between the observer and the measurement varies between readings.

Error type	What it does	How to reduce it
Random	Causes unpredictable variation in each reading (due to uncontrollable factors) — increases the spread of results around the mean and reduces precision.	Repeat the reading several times and calculate a mean.
Systematic	Shifts every reading by the same amount, in the same direction (e.g. faulty equipment or a flaw in the method) — reduces accuracy.	Recalibrate the equipment, or correct the method (e.g. account for a zero error).



Zero Error — the needle isn't on 0 with nothing connected

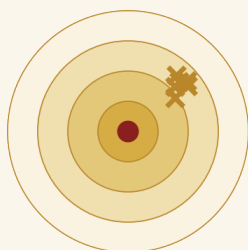


Parallax Error — the apparent reading depends on eye level



WORKED EXAMPLE

A student repeats a measurement of the diameter of a ball bearing five times using a micrometer, obtaining five very similar values. However, the micrometer had not been zeroed correctly before use, so every reading is offset from the true value by the same fixed amount. Discuss the precision and accuracy of this measurement.



tight cluster, offset from the bullseye — precise, not accurate

Solution

1. Precision describes how close repeated readings are to EACH OTHER (the spread of the results). Since the readings are all very similar, this measurement is precise.
2. Accuracy describes how close a reading is to the TRUE value. Because the micrometer has a zero error, every reading is shifted by the same fixed amount away from the true value, so the measurement is not accurate.
3. A zero error is a systematic error: it affects every reading consistently, in the same direction, so it reduces accuracy without increasing the spread of the results (precision is unaffected).

The measurement is precise but not accurate, because of a systematic (zero) error.

5.

ANSWER ›

A student uses a stopwatch to time one oscillation of a pendulum, repeating the measurement 5 times and obtaining a wide spread of values. She suspects this is due to her own reaction time when starting and stopping the stopwatch.

- (a) State whether the error caused by her reaction time is a random error or a systematic error. [1]

- (b) Explain your answer to part (a). [2]

- (c) Suggest one way the student could reduce the effect of this error on her final result. [1]

(Total for Question 5 = 4 marks)



6.

ANSWER ›

A student uses a ruler to measure the length of a wire. State, giving a reason, whether each situation below is a random error or a systematic error.

- (a) The ruler has a worn end, so its '0 mm' mark is actually 2 mm from the true zero position. [2]
Every length measured with this ruler is therefore too short by 2 mm.

- (b) The student reads the ruler from a different angle each time — sometimes from the left, [2]
sometimes from the right — introducing a parallax error that varies unpredictably between
readings.

- (c) State one difference between how random errors and systematic errors affect a set of [2]
repeated readings.

(Total for Question 6 = 6 marks)

7.

ANSWER ›

A student measures the current through a resistor five times using an ammeter, obtaining (in A): 1.24, 1.26, 1.23, 1.25, 1.24. State, giving a reason, whether each situation below would introduce a random error or a systematic error into this set of repeated readings.

- (a) The ammeter has not been zeroed correctly, so it reads 0.02 A even when no current is [2]
flowing.

- (b) The student's eye is not always exactly level with the ammeter's needle when taking each [2]
reading, introducing a parallax error that varies between readings.



(c) Explain why repeating the measurement and taking a mean reduces the effect of the error in (b), but not the error in (a). [2]

(Total for Question 7 = 6 marks)

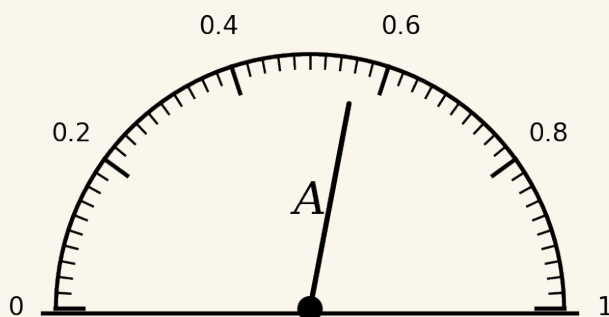


C. Reading Instruments: Absolute & Percentage Uncertainty

WORKED EXAMPLE

Reading a Single Instrument

The diagram shows an analogue ammeter. State the absolute uncertainty in the reading shown, and use it to calculate the percentage uncertainty.



■ resolution ■ reading ■ absolute uncertainty

Solution

- Resolution (the interval the scale goes up in) = 0.02 A .
- Absolute uncertainty (half the resolution) = $0.02 \div 2 = \pm 0.01 \text{ A}$. This applies to any single reading, analogue or digital.
- The reading is 0.56 A , so $I = (0.56 \pm 0.01) \text{ A}$.
- Percentage uncertainty = $(\text{absolute uncertainty} \div \text{reading}) \times 100 = (0.01 / 0.56) \times 100 = 1.8\%$ (2 s.f.).

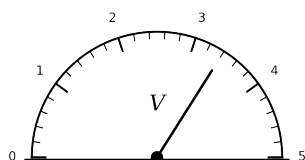
$I = (0.56 \pm 0.01) \text{ A} \rightarrow \text{percentage uncertainty} \approx 1.8\%$

8.

ANSWER ›

For each instrument below, state (i) its resolution (the interval it goes up in) and (ii) its absolute uncertainty (half the resolution) in the reading shown.

(a) An analogue voltmeter.



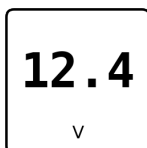
(i) Resolution (the interval it goes up in) of the voltmeter.

[1]

(ii) Absolute uncertainty (half the resolution) in the reading shown.

[1]





(b) A digital voltmeter.

(i) Resolution (the interval it goes up in) of the voltmeter.

[1]

(ii) Absolute uncertainty (half the resolution) in the reading shown.

[1]

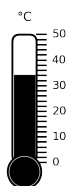
(Total for Question 8 = 4 marks)

9.

ANSWER ›

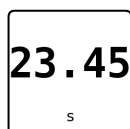
For each instrument below, state the absolute uncertainty (half the resolution) in the reading shown, and calculate the percentage uncertainty.

(a) A liquid-in-glass thermometer.



Absolute uncertainty and percentage uncertainty.

[2]



(b) A digital stopwatch, showing a single time reading.

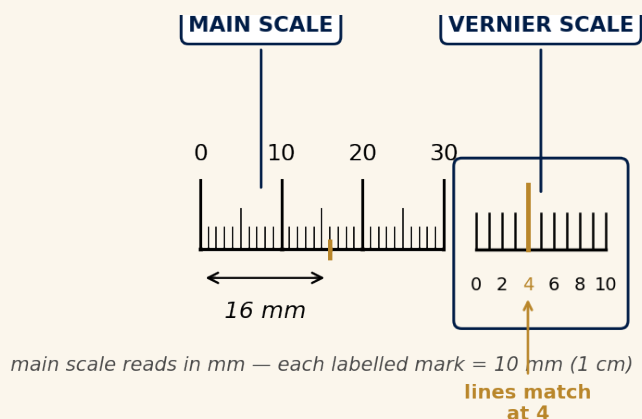
Absolute uncertainty and percentage uncertainty.

[2]

(Total for Question 9 = 4 marks)

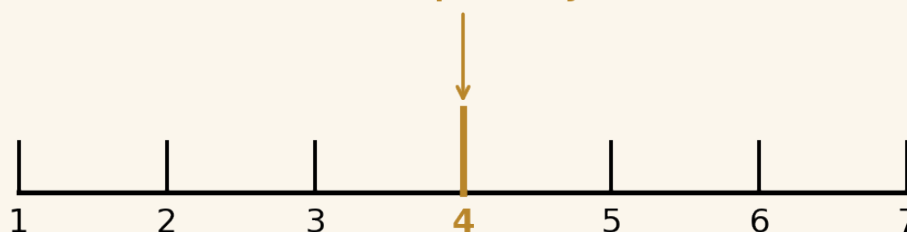
WORKED EXAMPLE**How to Read a Vernier Caliper**

The vernier calipers below are being used to measure the external diameter of a small ball bearing. Read the scale to find the diameter.



main scale + vernier scale

these two lines line up exactly



zoomed-in view of the vernier scale

zoomed-in: where the two lines line up exactly

■ main scale reading ■ vernier reading ■ resolution ■ absolute uncertainty

Solution

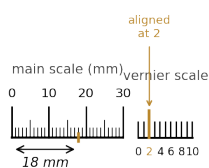
1. Read the main scale at the position just before the vernier scale's zero mark: this gives 16 mm.
2. Now look along the vernier (sliding) scale to find the one division that lines up exactly with a mark on the main scale — the zoomed-in view shows this is division 4.
3. This vernier scale has a resolution of 0.1 mm, so division 4 adds $4 \times 0.1 = 0.4$ mm.
4. Add the two readings together: $16 + 0.4 = 16.4$ mm.

diameter = 16.4 mm (resolution 0.1 mm, so absolute uncertainty = half the resolution = ± 0.05 mm)

10.

ANSWER ›

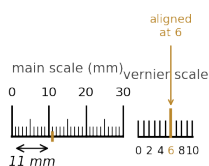
The vernier calipers below are used for two separate measurements, each aligning exactly with a division. State each reading, to the resolution of the instrument.



(a) First measurement.

State the reading shown.

[2]



(b) Second measurement, using the same calipers.

State the reading shown.

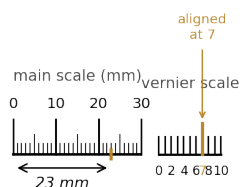
[2]

(Total for Question 10 = 4 marks)

11.

ANSWER ›

The vernier calipers below are used to measure a different object.



State the absolute uncertainty in the reading shown, and use it to calculate the percentage uncertainty.

Absolute uncertainty and percentage uncertainty.

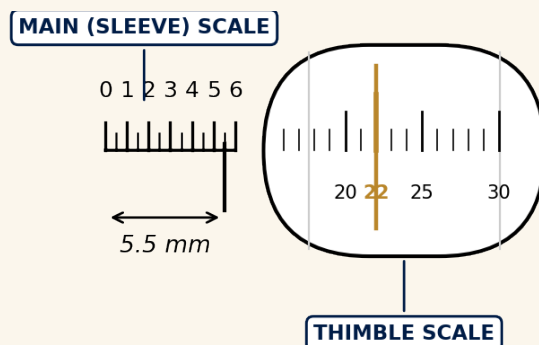
[2]

(Total for Question 11 = 2 marks)



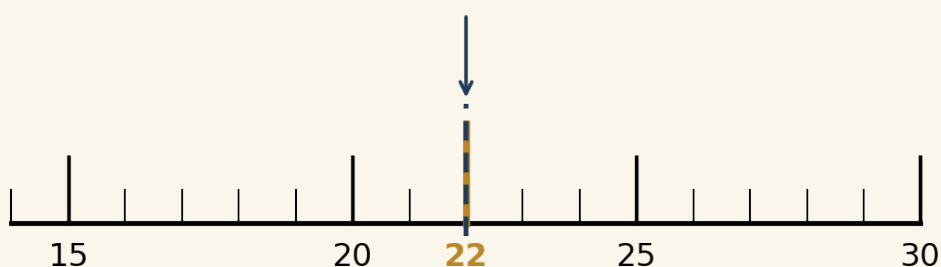
WORKED EXAMPLE**How to Read a Micrometer Screw Gauge**

The micrometer screw gauge below is being used to measure the diameter of a thin wire. Read the scale to find the diameter.



main (sleeve) scale + thimble scale

**fixed datum line
reads here**



zoomed-in view of the thimble scale

zoomed-in: the thimble scale at the datum line

■ main (sleeve) reading ■ thimble reading ■ resolution ■ absolute uncertainty

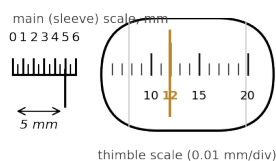
Solution

1. Read the main (sleeve) scale at the edge of the thimble: here it shows 5.5 mm.
2. Now read the thimble scale at the fixed datum line — the zoomed-in view shows this lines up at graduation 22.
3. The thimble scale has a resolution of 0.01 mm, so this adds $22 \times 0.01 = 0.22$ mm.
4. Add the two readings together: $5.5 + 0.22 = 5.72$ mm.

diameter = 5.72 mm (resolution 0.01 mm, so absolute uncertainty = half the resolution = ± 0.005 mm)

12.**ANSWER ›**

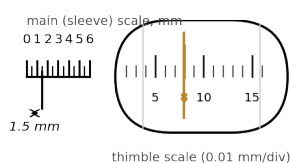
The micrometer screw gauge below is used for two separate measurements, each aligning exactly with a division. State each reading, to the resolution of the instrument.



(a) First measurement.

State the reading shown.

[2]



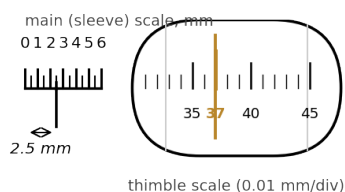
(b) Second measurement, using the same micrometer.

State the reading shown.

[2]

(Total for Question 12 = 4 marks)**13.****ANSWER ›**

The micrometer screw gauge below is used to measure a different wire.



State the absolute uncertainty in the reading shown, and use it to calculate the percentage uncertainty.

Absolute uncertainty and percentage uncertainty.

[2]

(Total for Question 13 = 2 marks)

14.**ANSWER ›**

For each measurement task below, state which instrument from the list would be most appropriate, and justify your choice by comparing resolutions. Instruments available: metre ruler (resolution 1 mm), vernier calipers (resolution 0.1 mm), micrometer screw gauge (resolution 0.01 mm).

(a) The external diameter of a test tube, approximately 18 mm. [2]

(b) The diameter of a thin copper wire, approximately 0.5 mm. [2]

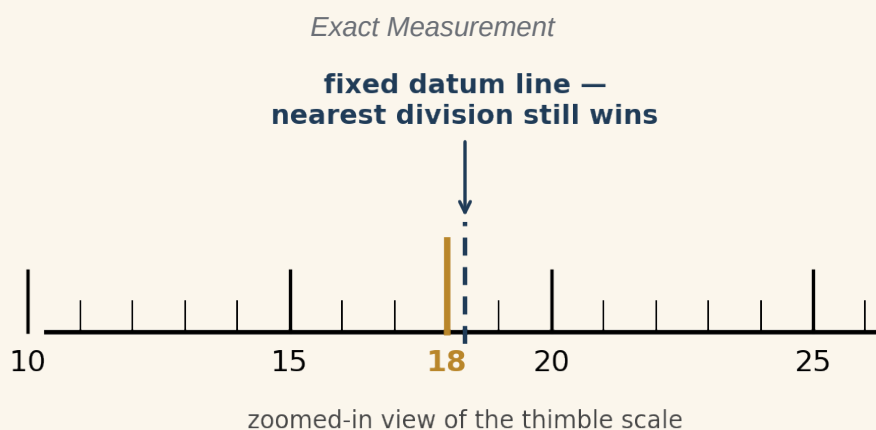
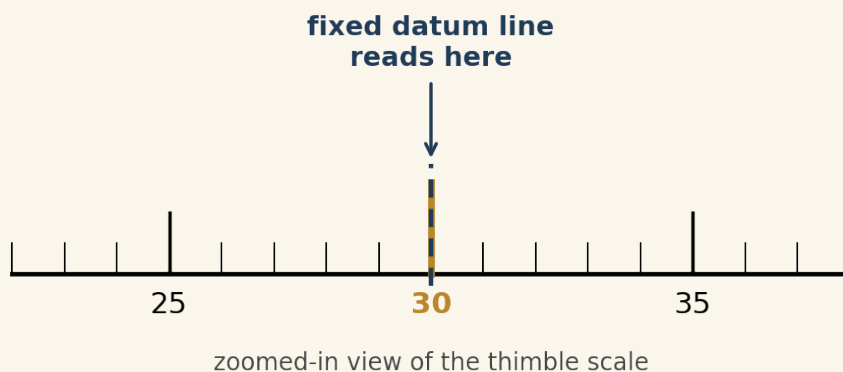
(c) The length of a pencil, approximately 150 mm. [2]

(Total for Question 14 = 6 marks)



WORKED EXAMPLE**Reading a Scale That Isn't Perfectly Aligned**

The alignment mark often falls just before or after a graduation, not exactly on one. Compare the two situations below.



Not at an Exact Measurement

■ thimble reading ■ fixed datum line

Solution

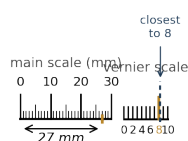
- Exact Measurement:** the datum line falls exactly on graduation 30, so the reading is $30 \times 0.01 = 0.30$ mm.
- Not at an Exact Measurement:** the datum line falls between two graduations, but is clearly closest to 18. The reading is still $18 \times 0.01 = 0.18$ mm — the nearest division, never an estimated in-between value like "18.3".
- This applies to any graduated scale read against a fixed line — ruler, vernier, or micrometer: always round to the nearest division.

Both are valid, fully-resolved readings — the uncertainty is still $\pm$ half the resolution (± 0.005 mm here) either way.

15.

ANSWER ›

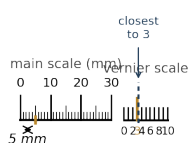
The vernier calipers below are used for two separate measurements, and in each case the vernier scale's aligned division doesn't line up exactly. State each reading, and explain how you decided on it.



(a) First measurement.

State the reading shown, and explain how you decided on it.

[2]



(b) Second measurement, using the same calipers.

State the reading shown, and explain how you decided on it.

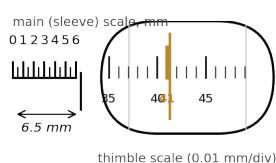
[2]

(Total for Question 15 = 4 marks)

16.

ANSWER ›

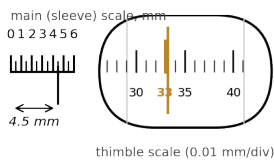
The micrometer screw gauge below is used for two separate measurements, and in each case the thimble scale doesn't line up exactly with the fixed datum line. State each reading, and explain how you decided on it.



(a) First measurement.

State the reading shown, and explain how you decided on it.

[2]



(b) Second measurement, using the same micrometer.

State the reading shown, and explain how you decided on it.

[2]

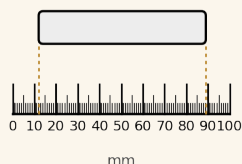
(Total for Question 16 = 4 marks)



D. Uncertainty from Two Readings

WORKED EXAMPLE

A student uses the ruler below to measure the length of a rod, taking a reading at each end. Calculate the length of the rod, its absolute uncertainty and its percentage uncertainty.



■ start reading ■ end reading ■ resolution ■ absolute uncertainty

Solution

1. Reading at the left-hand end of the rod = 12 mm; reading at the right-hand end = 89 mm.
2. Length = 89 – 12 = 77 mm.
3. Resolution = 1 mm, so each reading's own uncertainty is half that: ± 0.5 mm.
4. Two independent readings are subtracted, so their uncertainties add: $0.5 + 0.5 = \pm 1.0$ mm (the full resolution — not a different rule, just two halves added).
5. Percentage uncertainty = $(1.0 / 77) \times 100 = 1.3\%$.

length = (77 ± 1) mm $\rightarrow$ percentage uncertainty $\approx 1.3\%$

17.

ANSWER ›

A student measures the natural length of a spring using a ruler of resolution 1 mm, reading 15 mm at one end and 62 mm at the other.

(a) Calculate the length of the spring.

[1]

(b) State the absolute uncertainty in this length.

[2]

(Total for Question 17 = 3 marks)

18.

ANSWER ›

A student measures the diameter of a coin using a ruler of resolution 0.5 mm, reading 3.0 mm at one edge and 24.6 mm at the other.

(a) Calculate the diameter of the coin.

[1]



(b) State the absolute uncertainty in this diameter.

[2]

(c) Calculate the percentage uncertainty in this diameter.

[2]

(Total for Question 18 = 5 marks)



E. Uncertainty from Multiple Readings

WORKED EXAMPLE

A student measures the diameter of a wire five times, obtaining (in mm): 0.72, 0.75, 0.73, 0.76, 0.74. Calculate the mean diameter, its absolute uncertainty and its percentage uncertainty.

■ maximum reading ■ minimum reading ■ mean ■ absolute uncertainty

Solution

- Mean = $(0.72 + 0.75 + 0.73 + 0.76 + 0.74) / 5 = 0.740 \text{ mm}$.
- Method 1 (half the range): range = maximum – minimum = $0.76 - 0.72 = 0.04 \text{ mm}$. Absolute uncertainty = range / 2 = $0.04 / 2 = \pm 0.020 \text{ mm}$.
- Method 2 (furthest from the mean): the reading furthest from the mean is 0.76 mm (or 0.72 mm), so absolute uncertainty = $|0.76 - 0.740| = \pm 0.020 \text{ mm}$.
- Both methods are accepted by Edexcel mark schemes, and normally give the same (or a very similar) answer. Give your final answer as mean $\pm$ range/2.
- Percentage uncertainty = $(0.020 / 0.740) \times 100 = 2.7\%$.

diameter = $(0.740 \pm 0.020) \text{ mm}$ → percentage uncertainty $\approx 2.7\%$

19.

ANSWER ›

A student measures the resistance of a resistor four times, obtaining (in Ω): 12.1, 12.4, 12.2, 12.3.

- (a) Calculate the mean resistance. [1]

- (b) Calculate the absolute uncertainty in the mean resistance, using range/2 = (maximum – minimum)/2. [2]

(Total for Question 19 = 3 marks)

20.

ANSWER ›

A student times 10 oscillations of a pendulum five times, obtaining (in s): 20.1, 20.4, 20.2, 20.5, 20.3.

- (a) Calculate the mean time for 10 oscillations. [1]

- (b) Calculate the absolute uncertainty in this mean time, using range/2 = (maximum – minimum)/2. [2]



(c) Calculate the percentage uncertainty in this mean time.

[2]

(d) State one advantage of taking repeated readings and calculating a mean, compared with using a single reading.

[1]

(Total for Question 20 = 6 marks)



WORKED EXAMPLE**Identifying and Excluding an Anomalous Result**

A student measures the diameter of a ball bearing five times, obtaining (in mm): 4.52, 4.55, 4.53, 5.98, 4.54. Identify the anomalous reading, and calculate the mean diameter and its absolute uncertainty using the remaining readings.

■ anomalous reading ■ remaining readings

Solution

1. Compare the readings: 4.52, 4.55, 4.53, 4.54 all lie within 0.03 mm of each other, but 5.98 is far outside this spread — this is the anomalous result.
2. An anomalous result comes from a one-off mistake (e.g. misreading the scale), not normal random variation. Exclude it before calculating the mean — never keep it, and never discard a value just because it's inconvenient.
3. Mean of the remaining four = $(4.52 + 4.55 + 4.53 + 4.54) / 4 = 4.535$ mm.
4. Absolute uncertainty = range/2 of the remaining readings = $(4.55 - 4.52) / 2 = \pm 0.015$ mm.

diameter = (4.535 ± 0.015) mm — the anomalous 5.98 mm reading is excluded and stated as such

21.**ANSWER ›**

A student times one oscillation of a pendulum five times, obtaining (in s): 1.98, 2.01, 2.85, 1.99, 2.00.

- (a) Identify the anomalous reading, and suggest why it should not be included when calculating the mean. [2]

- (b) Calculate the mean time, excluding the anomalous reading. [1]

- (c) Calculate the absolute uncertainty in this mean, using range/2 of the remaining readings. [2]

(Total for Question 21 = 5 marks)

22.**ANSWER ›**

A student measures the voltage across a resistor five times, obtaining (in V): 2.34, 2.36, 3.90, 2.35, 2.33.

- (a) Identify the anomalous reading, and suggest why it should not be included when calculating the mean. [2]



(b) Calculate the mean voltage, excluding the anomalous reading. [1]

(c) Calculate the absolute uncertainty in this mean, using range/2 of the remaining readings. [2]

(d) Calculate the percentage uncertainty in this mean voltage. [2]

(Total for Question 22 = 7 marks)



F. Combining Uncertainties in a Calculated Quantity

WORKED EXAMPLE

Percentage Uncertainty in an Area — From Radius or From Diameter

Coin 1: radius $r = (0.60 \pm 0.10)$ cm, $A = \pi r^2$. Coin 2: diameter $d = (1.40 \pm 0.10)$ cm, $A = \pi d^2/4$. Find the percentage uncertainty in each area.

■ radius, r ■ diameter, d

Solution

1. Radius: % unc in $r = (0.10/0.60) \times 100 = 16.7\%$. $A \propto r^2$, so double it: % unc in $A = 33.3\%$.
2. Diameter: % unc in $d = (0.10/1.40) \times 100 = 7.1\%$. $A \propto d^2$ too ($\pi/4$ has no uncertainty), so double it: % unc in $A = 14.3\%$.
3. Same rule either way: find the % uncertainty of whichever length you were given, then double it. Radius and diameter are used interchangeably — never convert between them first.

% uncertainty in area = $2 \times$ (% uncertainty in the measured length), whether that length is a radius or a diameter

23.

ANSWER ›

A student measures the radius of a circular disc as $r = (4.0 \pm 0.1)$ cm and calculates its area using $A = \pi r^2$.

- (a) Calculate the percentage uncertainty in r . [1]

- (b) Hence calculate the percentage uncertainty in the area, A . [2]

(Total for Question 23 = 3 marks)

24.

ANSWER ›

A student measures the diameter of a ball bearing as $d = (25.0 \pm 0.5)$ mm and calculates its area using $A = \pi d^2/4$.

- (a) Calculate the percentage uncertainty in d . [1]

- (b) Hence calculate the percentage uncertainty in the area, A . [2]



(c) Calculate the area of the ball bearing's cross-section, in mm^2 , and hence state its absolute uncertainty. [2]

(Total for Question 24 = 5 marks)



WORKED EXAMPLE**Combining Uncertainties: Multiplying & Raising to a Power**

The current through a resistor is $I = (2.50 \pm 0.05) \text{ A}$ and its resistance is $R = (15.0 \pm 0.3) \Omega$. The power dissipated is $P = I^2 R$. Calculate the percentage uncertainty in the power.

■ current, I ■ resistance, R

Solution

1. % uncertainty in $I = (0.05 / 2.50) \times 100 = 2.0\%$.
2. % uncertainty in $R = (0.3 / 15.0) \times 100 = 2.0\%$.
3. For $P = I^2 R$, the percentage uncertainty in I is doubled (because I is squared) and added to the percentage uncertainty in R : % unc(P) = $2 \times \%$ unc(I) + % unc(R).
4. % uncertainty in $P = (2 \times 2.0) + 2.0 = 6.0\%$.

percentage uncertainty in $P \approx 6.0\%$

25.**ANSWER ›**

A potential difference $V = (6.0 \pm 0.1) \text{ V}$ drives a current $I = (0.40 \pm 0.01) \text{ A}$ through a resistor, where $R = V / I$.

(a) Calculate the percentage uncertainty in V . [1]

(b) Calculate the percentage uncertainty in I . [1]

(c) Hence calculate the percentage uncertainty in R . [1]

(Total for Question 25 = 3 marks)

26.**ANSWER ›**

A student determines the density of a sample of wire using the following measurements.

mass, $m = (0.895 \pm 0.005) \text{ g}$

length, $L = (200 \pm 1) \text{ mm}$

diameter, $d = (0.800 \pm 0.005) \text{ mm}$

(a) Calculate the percentage uncertainty in each of the three measurements. [3]



(b) Given that the density of the wire is $\rho = m / (\pi(d/2)^2 L)$, calculate the percentage uncertainty in the density of the wire. [3]

(c) Calculate the density of the wire, in kg m^{-3} , and hence state its absolute uncertainty. [4]

(Total for Question 26 = 10 marks)



G. Graphical Uncertainty & Systematic vs Random Error

WORKED EXAMPLE

A student plots a graph of force against extension for a spring. The gradient of the best-fit line is 24.5 N m^{-1} . The steepest and shallowest lines that are still consistent with the data give gradients of 26.0 N m^{-1} and 23.0 N m^{-1} . Calculate the percentage uncertainty in the gradient.

■ steepest line ■ shallowest line

Solution

- Uncertainty in the gradient = (steepest – shallowest) / 2 = $(26.0 - 23.0) / 2 = \pm 1.5 \text{ N m}^{-1}$.
- Percentage uncertainty = $(1.5 / 24.5) \times 100 = 6.1\%$.

percentage uncertainty in the gradient $\approx 6.1\%$

27.

ANSWER ›

For a different graph, the best-fit line has a gradient of 10.0 units, and the steepest and shallowest acceptable lines have gradients of 10.8 and 9.4 units respectively.

- (a) Calculate the absolute uncertainty in the gradient. [1]

.....

- (b) Calculate the percentage uncertainty in the gradient. [2]

.....

(Total for Question 27 = 3 marks)

28.

ANSWER ›

A student investigating a spring finds a best-fit gradient of 45.2 N m^{-1} , with steepest and shallowest acceptable lines of 47.0 N m^{-1} and 43.5 N m^{-1} . The spring balance used to apply the force had not been correctly zeroed before the experiment.

- (a) Calculate the percentage uncertainty in the gradient. [3]

.....

.....

- (b) State and explain whether the zero error introduces a random error or a systematic error. [2]

.....

.....

(Total for Question 28 = 5 marks)



H. Orders of Magnitude, Significant Figures & Estimation

WORKED EXAMPLE

The mass of a single aluminium atom is 4.48×10^{-26} kg, and the density of aluminium is 2700 kg m^{-3} . Estimate the diameter of a single aluminium atom.

■ mass of one atom ■ density

Solution

1. Number of atoms in $1.00 \text{ kg} = 1.00 / 4.48 \times 10^{-26} = 2.23 \times 10^{25} \approx 2 \times 10^{25}$.
2. Volume of 1.00 kg of aluminium = mass / density = $1.00 / 2700 = 3.70 \times 10^{-4} \text{ m}^3$.
3. Volume per atom = $3.70 \times 10^{-4} / 2.23 \times 10^{25} = 1.66 \times 10^{-29} \text{ m}^3$.
4. Treating the atom as a sphere, $r^3 = 3V / 4\pi$, so $r = (3 \times 1.66 \times 10^{-29} / 4\pi)^{1/3} = 1.58 \times 10^{-10} \text{ m}$.

diameter = $2r \approx 3.2 \times 10^{-10} \text{ m}$

29.

ANSWER ›

A calculation of the speed of a trolley gives a result of 4.8371 m s^{-1} . The data used in the calculation was measured to 2 significant figures.

- (a) State the speed of the trolley to an appropriate number of significant figures. [1]

- (b) Explain your choice of the number of significant figures. [1]

(Total for Question 29 = 2 marks)

30.

ANSWER ›

Estimate the number of times a person's heart beats in an average lifetime. Show your working clearly and state any assumptions you make. [4]

(Total for Question 30 = 4 marks)



Topic 1.1: Measurements & Uncertainties — Mark Scheme

Mark scheme for the original questions above, written by GuideMyGrades. Click [QUESTION](#) to jump back.

A. SI Base Units, Prefixes & Deriving Units

Question 1

[QUESTION](#)

Question Number	Answer	Mark
1(a)	B — kilogram (the SI base unit of mass)	B1
1(b)	B — 10^{-6}	B1
1(c)	B — 2.5×10^{-2} A ($25 \text{ mA} = 25 \times 10^{-3} \text{ A} = 2.5 \times 10^{-2} \text{ A}$)	B1
	Total for Question 1	3

Question 2

[QUESTION](#)

Question Number	Answer	Mark
2(a)	A — kg s^{-2} ($k = F / x = \text{kg m s}^{-2} \div \text{m}$)	B1
	Incorrect answers: B is the base units of force (N), not k; C is correct units but not written in base units; D is an incorrect combination	
2(b)	Units of m, g and h are kg, m s^{-2} and m respectively	M1
	$E_p = mgh \rightarrow \text{units} = \text{kg} \times \text{m s}^{-2} \times \text{m}$	M1
	$= \text{kg m}^2 \text{ s}^{-2}$ ✓ (matches the base units given in the question)	A1
	Total for Question 2	4

Question 3

[QUESTION](#)

Question Number	Answer	Mark
3(a)	C — electric current (the other three are all derived quantities, built from combinations of the seven base quantities)	B1
3(b)	D — newton (kilogram, second and ampere are base units; the newton is derived: kg m s^{-2})	B1
3(c)	A — kg m s^{-2} (g has units m s^{-2} , so $W = mg \rightarrow \text{kg} \times \text{m s}^{-2}$)	B1
3(d)	C — $\text{kg m}^2 \text{ s}^{-2}$ ($E_k = \frac{1}{2}mv^2 \rightarrow \text{kg} \times (\text{m s}^{-1})^2 = \text{kg m}^2 \text{ s}^{-2}$; $\frac{1}{2}$ is a pure number and carries no units)	B1
3(e)	A — $\text{kg m}^{-1} \text{ s}^{-2}$ ($\sigma = F/A \rightarrow (\text{kg m s}^{-2}) \div \text{m}^2 = \text{kg m}^{-1} \text{ s}^{-2}$)	B1



	Total for Question 3	5
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Question 4[◀ QUESTION](#)

Question Number	Answer	Mark
4(a)	A — 4.7×10^{-6} A (micro = 10^{-6} , so $4.7 \mu\text{A} = 4.7 \times 10^{-6}$ A)	B1
4(b)	A — $2.2 \times 10^6 \Omega$ (mega = 10^6 , so $2.2 \text{ M}\Omega = 2.2 \times 10^6 \Omega$; C gives the same value but is not correctly written in standard form, since 22 is not between 1 and 10)	B1
	Total for Question 4	2

B. Precision, Accuracy & Types of Error**Question 5**[◀ QUESTION](#)

Question Number	Answer	Mark
5(a)	Random error	B1
5(b)	Reaction time varies unpredictably from one attempt to the next (sometimes a little early, sometimes a little late), rather than shifting every reading by the same amount in the same direction	B2 (allow 1 mark for a partial answer)
5(c)	Repeat the timing and calculate a mean (or time multiple oscillations, e.g. 10, and divide by the number of oscillations)	B1
	Total for Question 5	4

Question 6[◀ QUESTION](#)

Question Number	Answer	Mark
6(a)	Systematic error	B1
	because the 2 mm offset shifts every reading by the same amount in the same direction — it does not increase the spread of repeat readings, but does move them all away from the true value	B1
6(b)	Random error	B1
	because the size and direction of the parallax error introduced this way changes unpredictably between readings, rather than shifting every reading consistently	B1



6(c)	Random errors change the spread (precision) of repeated readings and are reduced by repeating and averaging; systematic errors shift every reading consistently in one direction (reducing accuracy) and are not removed by averaging — only by recalibrating the equipment or correcting the method	B2 (allow 1 mark for a partial answer)
	Total for Question 6	6

Question 7

◀ QUESTION

Question Number	Answer	Mark
7(a)	Systematic error	B1
	because the 0.02 A offset shifts every reading by the same fixed amount in the same direction, rather than increasing the spread of the repeated readings	B1
7(b)	Random error	B1
	because the parallax error varies unpredictably from one reading to the next (as the angle of the student's eye changes), causing the readings to scatter around the true value rather than all being shifted the same way	B1
7(c)	Taking a mean averages out unpredictable, random variation (like the changing parallax angle in (b)), so it partly cancels out and improves precision	B1
	but a systematic error (like the zero error in (a)) shifts every single reading by the same amount, so it is still present in the mean and cannot be removed by averaging — only by recalibrating the ammeter	B1
	Total for Question 7	6

C. Reading Instruments: Absolute & Percentage Uncertainty

Question 8

◀ QUESTION

Question Number	Answer	Mark
8(a)(i)	Resolution = 0.2 V (the interval the scale goes up in)	B1
8(a)(ii)	Absolute uncertainty = half the resolution = ± 0.1 V. (± 0.1 V for full marks; ± 0.2 V — the full resolution, not halved — caps the mark at partial credit.)	B1
8(b)(i)	Resolution = 0.1 V (the interval the display goes up in)	B1
8(b)(ii)	Absolute uncertainty = half the resolution = ± 0.05 V. (± 0.05 V for full marks; ± 0.1 V — the full resolution, not halved — caps the mark at partial credit.)	B1



	Total for Question 8	4
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Question 9[◀ QUESTION](#)

Question Number	Answer	Mark
9(a)	Reading = 34 °C. Resolution = 2 °C, so absolute uncertainty = half the resolution = ± 1 °C. (± 1 °C for full marks; ± 2 °C — the full resolution, not halved — caps the mark.)	M1
	% uncertainty = $(1 / 34) \times 100 = 2.9\%$	A1
9(b)	Reading = 23.45 s. Resolution = 0.01 s, so absolute uncertainty = half the resolution = ± 0.005 s. (± 0.01 s caps the mark.)	M1
	% uncertainty = $(0.005 / 23.45) \times 100 = 0.021\%$	A1
	Total for Question 9	4

Question 10[◀ QUESTION](#)

Question Number	Answer	Mark
10(a)	Reading = $18 + 0.2 = 18.2$ mm	B2
10(b)	Reading = $11 + 0.6 = 11.6$ mm	B2
	Total for Question 10	4

Question 11[◀ QUESTION](#)

Question Number	Answer	Mark
	Reading = 23.7 mm. Resolution = 0.1 mm, so absolute uncertainty = half the resolution = ± 0.05 mm. (± 0.1 mm caps the mark.)	M1
	% uncertainty = $(0.05 / 23.7) \times 100 = 0.21\%$	A1
	Total for Question 11	2

Question 12[◀ QUESTION](#)

Question Number	Answer	Mark
12(a)	Reading = $5.0 + 0.12 = 5.12$ mm	B2
12(b)	Reading = $1.5 + 0.08 = 1.58$ mm	B2



	Total for Question 12	4
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Question 13[◀ QUESTION](#)

Question Number	Answer	Mark
	Reading = 2.87 mm. Resolution = 0.01 mm, so absolute uncertainty = half the resolution = ± 0.005 mm. (± 0.01 mm caps the mark.)	M1
	% uncertainty = $(0.005 / 2.87) \times 100 = 0.17\%$	A1
	Total for Question 13	2

Question 14[◀ QUESTION](#)

Question Number	Answer	Mark
14(a)	Vernier calipers	B1
	the object (≈ 18 mm) is too large to fit in a micrometer's jaws, and a plain ruler's 1 mm resolution is too coarse to measure a diameter this precisely; the calipers' jaws are also designed to grip round objects like this	B1
14(b)	Micrometer screw gauge	B1
	at only ≈ 0.5 mm, the wire is too thin to grip precisely in the calipers' jaws, and both the ruler's 1 mm and the calipers' 0.1 mm resolution are too coarse relative to the wire's own size; the micrometer's 0.01 mm resolution is needed	B1
14(c)	Metre ruler	B1
	the pencil (≈ 150 mm) is far too long to fit in the jaws of a micrometer or vernier calipers, and a plain ruler's 1 mm resolution is perfectly adequate for a measurement of this size	B1
	Total for Question 14	6

Question 15[◀ QUESTION](#)

Question Number	Answer	Mark
15(a)	Reading = $27 + 0.8 = 27.8$ mm	B1
	because although the vernier and main scale lines don't coincide exactly, division 8 is the closest one to lining up, so that is the division used in the reading	B1
15(b)	Reading = $5 + 0.3 = 5.3$ mm	B1



	because division 3 on the vernier scale is the closest one to lining up, even though it isn't a perfect coincidence, so that is the division used in the reading	B1
	Total for Question 15	4

Question 16[◀ QUESTION](#)

Question Number	Answer	Mark
16(a)	Reading = $6.5 + 0.41 = 6.91$ mm	B1
	because the datum line falls between two graduations but is clearly closest to graduation 41, and a reading is always taken to the nearest division, not estimated between two	B1
16(b)	Reading = $4.5 + 0.33 = 4.83$ mm	B1
	because the datum line is closest to graduation 33 on the thimble scale, even though it doesn't line up perfectly, so that is the division used in the reading	B1
	Total for Question 16	4

D. Uncertainty from Two Readings**Question 17**[◀ QUESTION](#)

Question Number	Answer	Mark
17(a)	Length = $62 - 15 = 47$ mm	B1
17(b)	Uncertainty in each reading = half the smallest division = ± 0.5 mm	M1
	Total uncertainty = $0.5 + 0.5 = \pm 1.0$ mm	A1
	Total for Question 17	3

Question 18[◀ QUESTION](#)

Question Number	Answer	Mark
18(a)	Diameter = $24.6 - 3.0 = 21.6$ mm	B1
18(b)	Uncertainty in each reading = half the smallest division = ± 0.25 mm	M1
	Total uncertainty = $0.25 + 0.25 = \pm 0.5$ mm	A1
18(c)	% uncertainty = $(0.5 / 21.6) \times 100$	M1



	= 2.3%	A1
	Total for Question 18	5

E. Uncertainty from Multiple Readings

Question 19

[◀ QUESTION](#)

Question Number	Answer	Mark
19(a)	Mean = $(12.1 + 12.4 + 12.2 + 12.3) / 4 = 12.25 \, \Omega$	B1
19(b)	Uncertainty = range/2 = $(12.4 - 12.1) / 2$	M1
	= $\pm 0.15 \, \Omega$ (the furthest-from-mean method gives the same answer here — both are accepted)	A1
	Total for Question 19	3

Question 20

[◀ QUESTION](#)

Question Number	Answer	Mark
20(a)	Mean = $(20.1 + 20.4 + 20.2 + 20.5 + 20.3) / 5 = 20.3 \, \text{s}$	B1
20(b)	Uncertainty = range/2 = $(20.5 - 20.1) / 2$	M1
	= $\pm 0.2 \, \text{s}$ (the furthest-from-mean method gives the same answer here — both are accepted)	A1
20(c)	% uncertainty = $(0.2 / 20.3) \times 100$	M1
	= 0.99%	A1
20(d)	Repeating readings and taking a mean reduces the effect of random error, giving a more precise value	B1
	Total for Question 20	6

Question 21

[◀ QUESTION](#)

Question Number	Answer	Mark
21(a)	2.85 s — it lies well outside the spread of the other four readings (1.98–2.01 s), suggesting a one-off mistake (e.g. a slip starting/stopping the stopwatch) rather than normal random variation	B2 (allow 1 mark for a partial answer)
21(b)	Mean = $(1.98 + 2.01 + 1.99 + 2.00) / 4 = 1.995 \approx 2.00 \, \text{s}$	B1



21(c)	Uncertainty = range/2 = $(2.01 - 1.98) / 2$	M1
	= ± 0.015 s	A1
	Total for Question 21	5

Question 22

◀ QUESTION

Question Number	Answer	Mark
22(a)	3.90 V — it lies well outside the spread of the other four readings (2.33–2.36 V), suggesting a one-off mistake (e.g. a misread scale or a momentary fault) rather than normal random variation	B2 (allow 1 mark for a partial answer)
22(b)	Mean = $(2.34 + 2.36 + 2.35 + 2.33) / 4 = 2.345$ V	B1
22(c)	Uncertainty = range/2 = $(2.36 - 2.33) / 2$	M1
	= ± 0.015 V	A1
22(d)	% uncertainty = $(0.015 / 2.345) \times 100$	M1
	= 0.64%	A1
	Total for Question 22	7

F. Combining Uncertainties in a Calculated Quantity

Question 23

◀ QUESTION

Question Number	Answer	Mark
23(a)	% uncertainty in $r = (0.1 / 4.0) \times 100 = 2.5\%$	B1
23(b)	% uncertainty in $A = 2 \times 2.5\%$	M1
	= 5.0%	A1
	Total for Question 23	3

Question 24

◀ QUESTION

Question Number	Answer	Mark
24(a)	% uncertainty in $d = (0.5 / 25.0) \times 100 = 2.0\%$	B1
24(b)	% uncertainty in $A = 2 \times 2.0\%$	M1
	= 4.0%	A1



24(c)	$A = \pi(d/2)^2 = \pi \times 12.5^2 = 490.9 \text{ mm}^2 \approx 491 \text{ mm}^2$	M1
	Absolute uncertainty = $4.0\% \times 491 \approx 19.6 \text{ mm}^2 \approx 20 \text{ mm}^2$, so $A = (491 \pm 20) \text{ mm}^2$	A1
	Total for Question 24	5

Question 25

◀ QUESTION

Question Number	Answer	Mark
25(a)	% uncertainty in $V = (0.1 / 6.0) \times 100 = 1.7\%$	B1
25(b)	% uncertainty in $I = (0.01 / 0.40) \times 100 = 2.5\%$	B1
25(c)	% uncertainty in $R = 1.7 + 2.5 = 4.2\%$	B1
	Total for Question 25	3

Question 26

◀ QUESTION

Question Number	Answer	Mark
26(a)	% uncertainty in $m = (0.005 / 0.895) \times 100 = 0.56\%$	B1
	% uncertainty in $L = (1 / 200) \times 100 = 0.5\%$	B1
	% uncertainty in $d = (0.005 / 0.800) \times 100 = 0.63\%$	B1
26(b)	% uncertainty in $\rho = \% \text{unc}(m) + 2 \times \% \text{unc}(d) + \% \text{unc}(L)$	M1
	$= 0.56 + (2 \times 0.63) + 0.5$	M1
	$= 2.3\%$ (allow 2.2–2.4%)	A1
26(c)	$V = \pi(d/2)^2 L = \pi \times (4.00 \times 10^{-4})^2 \times 0.200 = 1.01 \times 10^{-7} \text{ m}^3$	M1
	$\rho = m / V = 8.95 \times 10^{-4} / 1.01 \times 10^{-7} = 8900 \text{ kg m}^{-3}$ (8902 kg m^{-3})	A1
	Absolute uncertainty = $2.3\% \times 8900 = 2.1 \times 10^2 \text{ kg m}^{-3}$	M1
	$\rho = (8900 \pm 200) \text{ kg m}^{-3}$	A1
	Total for Question 26	10

G. Graphical Uncertainty & Systematic vs Random Error

Question 27

◀ QUESTION

Question Number	Answer	Mark
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27(a)	Uncertainty = $(10.8 - 9.4) / 2 = \pm 0.7$	B1
27(b)	% uncertainty = $(0.7 / 10.0) \times 100$	M1
	= 7.0%	A1
	Total for Question 27	3

Question 28[◀ QUESTION](#)

Question Number	Answer	Mark
28(a)	Uncertainty = $(47.0 - 43.5) / 2 = \pm 1.75 \text{ N m}^{-1}$	M1
	% uncertainty = $(1.75 / 45.2) \times 100$	M1
	= 3.9%	A1
28(b)	Systematic error	B1
	because a zero error affects every reading by the same amount in the same direction, shifting all the results consistently rather than causing them to scatter	B1
	Total for Question 28	5

H. Orders of Magnitude, Significant Figures & Estimation**Question 29**[◀ QUESTION](#)

Question Number	Answer	Mark
29(a)	4.8 m s^{-1}	B1
29(b)	A calculated result should not be given to more significant figures than the least precise piece of data used (here, 2 significant figures)	B1
	Total for Question 29	2

Question 30[◀ QUESTION](#)

Question Number	Answer	Mark
	Reasonable assumptions stated, e.g. average resting heart rate ≈ 70 beats per minute; average lifespan ≈ 80 years	B1
	Correct method: number of beats = heart rate $\times$ minutes per day $\times$ days per year $\times$ number of years	M1
	= $70 \times (60 \times 24) \times 365 \times 80$	M1

	$\approx 3 \times 10^9$ beats (accept any answer of the correct order of magnitude consistent with the candidate's own assumptions)	A1
	Total for Question 30	4

