CAMBRIDGE TECHNICALS

Oxford Cambridge and RSA

CAMBRIDGE TECHNICALS LEVEL 3 (2016)

Examiners' report

# APPLIED SCIENCE

05847–05849, 05879, 05874

## Unit 3 January 2024 series

Version 1

# Contents

# Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

# Unit 3 series overview

Unit 3 (Scientific analysis and reporting) is a mandatory unit for the Level 3 Cambridge Technical Foundation Diploma, Diploma, and Extended Diploma in Applied Science. All Learning Outcomes within the specification are assessed in every series through a paper worth a maximum of 100 marks and of two hours duration.

This unit assesses:

- the ability to use mathematical techniques to analyse data;
- the ability to use graphical techniques to analyse data;
- the ability to use keys to classify organisms;
- the ability to critically analyse and evaluate the quality of data;
- the ability to draw justified conclusions from data;
- the ability to record, report on, and review scientific analyses;
- knowledge of the use of modified, extended, or combined laboratory techniques in analytical procedures – building on Unit 2 (Scientific techniques).

Questions are presented to candidates using a range of styles, including short answer, calculation, fill-the-blanks, matching pairs, true/false, and a longer 6-mark level of response question. Questions are presented in a scientific context, which may, however, be a context with which candidates are unfamiliar.

Centres must provide candidates with extensive opportunities for practising those skills detailed in the unit specification as well as exposure to the required experimental techniques and apparatus – this will allow candidates to answer questions in this paper with greater confidence.

Some of the questions in this paper required candidates to answer precisely, applying their knowledge tightly to the context given, and using stimulus material to work out the answer, using skills of observation, analysis, and evaluation. Careful reading of the question, and care in answering the question precisely and in depth was important to gain maximum credit.

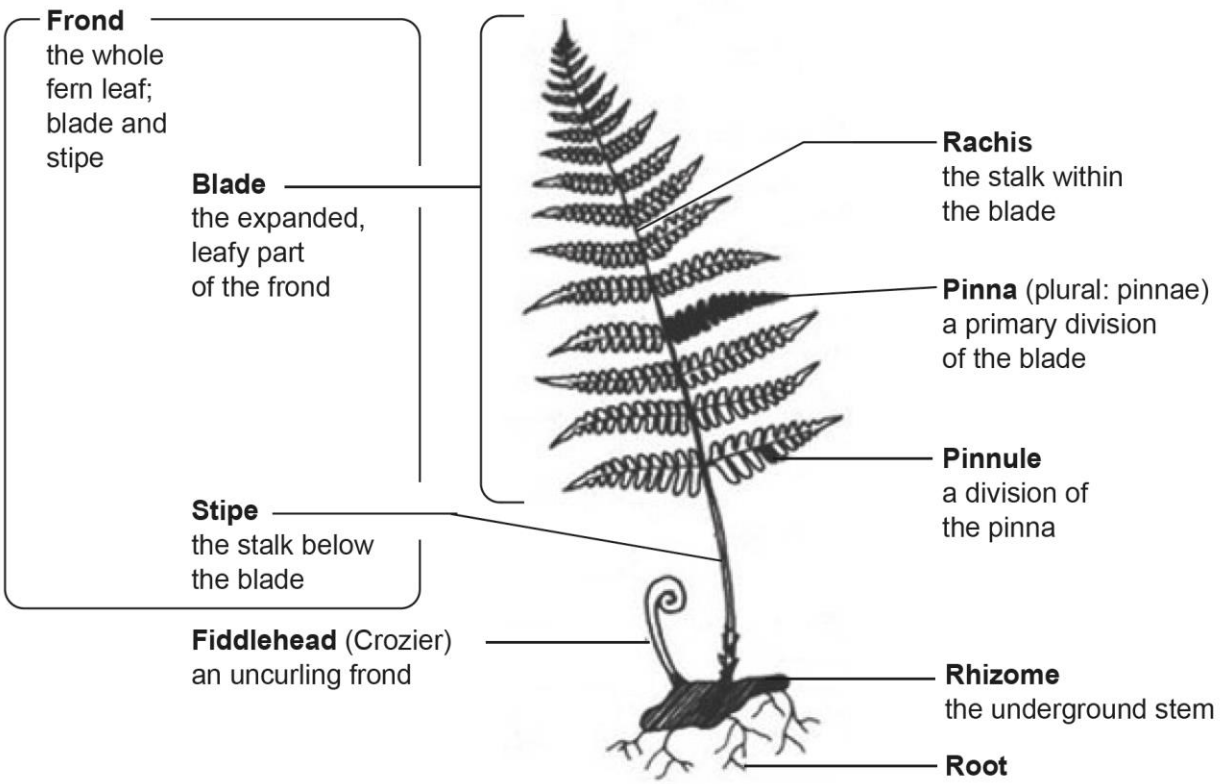
| Candidates who did well on this paper generally: | Candidates who did less well on this paper generally: |
|---|---|
| • understood and applied the conventions to be followed when constructing line graphs and lines-of-best-fit (Question 2 (b))<br>• were able to show, step-by-step, how the gradient of a straight line-of-best-fit is determined (Question 2 (c))<br>• showed working when carrying out calculations and were confident in the use of standard form, significant figures, and units<br>• were able to use knowledge gained from undertaking practical activities to answer Questions 3 and 5<br>• were generally confident in the analysis and evaluation of information and data presented in unfamiliar contexts (Questions 1, 4, and 6). | • struggled with the construction of line graphs and lines-of-best-fit, often transposing axes, choosing awkward scales, not taking enough care when plotting points, and not ensuring even distribution of points above and below a line-of-best-fit (Question 2 (b))<br>• were unable to determine the gradient of a straight line-of-best-fit, failing to draw suitable triangles against the line-of-best-fit, struggling to determine the x/y coordinates of the intercepts, and substituting the intercepts correctly into dy/dx (Question 2 (c))<br>• struggled to work through multi-stage calculations (Question 3 (a) and Question 5 (e))<br>• found difficulty in demonstrating knowledge and understanding of thermal decomposition (Question 3) and complexometric titrations (Question 5) of which they should have had practical experience<br>• experienced difficulty in the analysis and/or evaluation of information and/or data presented in unfamiliar contexts, struggling with the terminology of fern morphology (Question 1), the application of scientific principles in applied contexts (Question 4) and the presentation of unfamiliar data to different target audiences (Question 6). |

## Question 1 (a) (i)

**1** Ferns come in various shapes and sizes, but they all have two major parts – the **fronds** and the **rhizome**.

The fronds are divided into leaf-like structures called pinnae. The pinnae are attached to a central stem called a rachis.

The diagram below shows the key features of a fern.

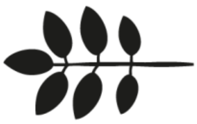



**(a)** Most ferns have divided fronds which resemble feathers. The fronds can be classified as pinnate, bi-pinnate or tri-pinnate.

**(i)** The frond shown in the diagram below is pinnate.

This type of frond may be even-pinnate or odd-pinnate.

**even-pinnate**



**odd-pinnate**

Describe the difference between an even-pinnate frond and an odd-pinnate frond.

.......................................................................................................................................

....................................................................................................................................... **[1]**

A significant number of candidates overlooked the relevance of the terms even-pinnate and odd-pinnate, commenting instead on the relative numbers of pinnae on the two fronds without appreciating that fronds of different ages will be different sizes and have differing numbers of pinnae.

## Question 1 (a) (ii)

**(ii)** Some ferns have divided fronds which can be bi-pinnate or tri-pinnate.

**bi-pinnate**

**tri-pinnate**

Describe the differences between pinnate, bi-pinnate and tri-pinnate fronds.

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....................................................................................................................................... **[5]**

This question proved challenging to candidates of all capabilities. Not only did candidates have great difficulty describing the comparative morphology of pinnate, bi-pinnate, and tri-pinnate fronds clearly and succinctly, they also experienced difficulty in using the terms defined in the first diagram correctly. For example, structures were often named incorrectly, which made nonsense of what were already somewhat confused descriptions. The terms leaf and stem were frequently used inappropriately to describe various parts of the frond by different candidates. Most responses were quite lengthy, but only a handful of candidates gained any marks, usually either MP1 and/or MP2.

## Exemplar 1

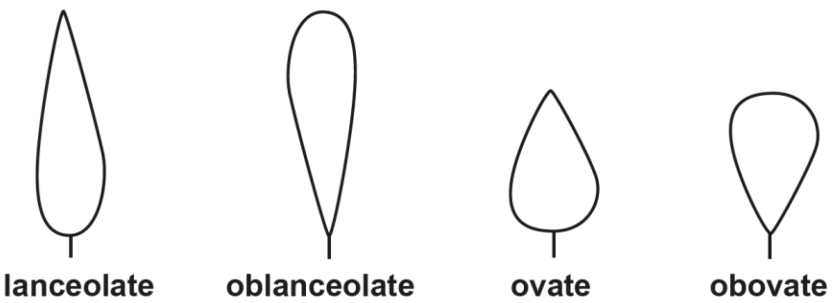
The rachis divide twice for the bipinnate and three times for the tripinnate. The tripinnate contains fewer blades than the bipinnate on each rachis however the pinnate fern only has a singular blade attached to each rachis. The bipinnate blade takes shape of the even-pinnate type however the tripinnate takes the odd-pinnate shape blade.

The response in Exemplar 1 was not given any marks. This candidate has attempted to describe the division of the rachis to form pinnae but has incorrectly identified the number of divisions in each type of frond considered. There is confusion over which part of the frond constitutes the blade, the candidate seemingly confusing blades with pinnae. The final statement about the even-pinnate and odd-pinnate nature of the fronds in the diagram is correct but has been incorrectly linked to blade shape (the identification of even-pinnate and odd-pinnate fronds was not included in the mark scheme as it is not correct in general for bi-pinnate and tri-pinnate fronds, which may be either even-pinnate or odd-pinnate, but would have been given as an AVP since candidates were not being examined on their knowledge of fern morphology).

## Question 1 (b) (i)

**(b)** The part of the frond containing the pinnae is called the blade.

The overall shape of the blade may be described as lanceolate, oblanceolate, ovate or obovate:




Lanceolate is described as long, wider nearer the base and tapering at the tip.

**(i)** Describe the overall shape of oblanceolate.

................................................................................................................................................ **[1]**

Candidates performed well on this question, referring both to the length and the relative shapes of the ends of the blade.

## Question 1 (b) (ii)

**(ii)** Explain why oblanceolate and obovate may be difficult to tell apart.

................................................................................................................................ **[1]**

This question was answered well by the majority of candidates, who identified that the blades have similar shapes with wide tips and narrow bases. Some candidates provided detailed responses which explained that there would be variation in both blade length and width which would blur the distinction between oblanceolate and obovate. Because of the difference in blade length and width, reference to oblanceolate and obovate blades having the same shape was not accepted unless qualified.

## Question 1 (b) (iii)

**(iii)** Suggest how the length and width of the leaf may be used to distinguish between lanceolate and ovate.

................................................................................................................................ **[1]**

This question presented few problems to candidates, with the majority correctly identifying that lanceolate blades are longer and thinner. A minority of candidates stated the reverse alternative for ovate blades.

## Question 1 (c) (i)

**(c)** *Dryopteris filix-mas* is widespread throughout the British Isles. It is commonly known as the male fern.

**(i)** Explain the naming convention used for *Dryopteris filix-mas*.

................................................................................................................................

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................................................................................................................................ **[2]**

The majority of candidates were given 2 marks for identifying the generic and specific names. A disappointingly small number of candidates mentioned binomial nomenclature in their responses.

## Question 1 (c) (ii)

**(ii)** Henry and Sasha are studying *D. filix-mas* for a school project.

In their journal they write a description to help with the identification of *D. filix-mas*.

Firstly, they look at the type of frond to determine whether it is pinnate, bi-pinnate or tri-pinnate.

Suggest **four other** features of the plant that they could consider for identification purposes.

1 ..........................................................................................................................

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2 ..........................................................................................................................

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3 ..........................................................................................................................

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4 ..........................................................................................................................

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**[4]**

Candidates struggled to gain more than 1 or 2 marks on this question. Many candidates were hampered by incorrect use of anatomical terms: pinnae were often confused with pinnules, and blades and fronds both described as leaves. Many candidates suggested that frond divisions could be used, without realising that this feature had been used by the students in the stem of the question and could not be suggested as another feature. Some candidates suggested rhizome shape or length could be used, either not appreciating that this would involve digging out the fern from the soil leading to its destruction or not appreciating that living organisms should not be destroyed in the course of carrying out field-work. One or two candidates referred to habitat as a feature, but this option was rarely seen. References to shape of the blade and number of pinnae were the most commonly seen suggestions, as candidates may have used the references to these features in Questions 1(a)(i) and 1(b). References to number of pinnae were taken as meaning odd-pinnate or even-pinnate, although this was not explicit and there will be variation in the number of pinnae between ferns of the same species due to both genetic and age-related variation.

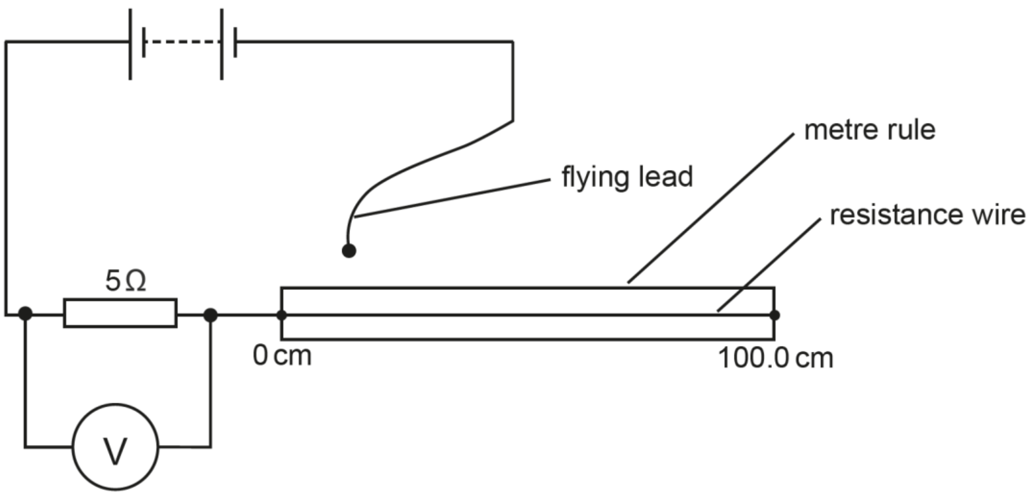
**Examination technique**

Candidates should be taught to write succinctly, stating clearly what they are wanting to convey and avoiding ambiguities. Practising with past questions and peer-marking answers with reference to the published mark scheme is a useful way of developing this skill.

## Question 2 (a)

**2** Tom is a physics student. He is investigating an electrical circuit.

A diagram of the circuit he uses is shown below.




The resistance wire is attached to a metre rule.

A 5 Ω fixed resistor is connected in series with the resistance wire and a battery of cells.

A voltmeter measures the voltage across the fixed resistor.

Tom varies the length *L*, of the resistance wire in the circuit by attaching a flying lead to the wire at different positions along its length.

**Table 2.1** shows Tom's measurements and calculations.

**Table 2.1**

| **Length *L* (cm)** | **Voltage *V* (V)** | **Current *I* (A)** | **1/*I* ($A^{-1}$)** |
|---|---|---|---|
| 100 | 1.8 | 0.35 | 2.8 |
| 80 | 2.0 | 0.40 | 2.5 |
| 60 | 2.3 | 0.46 | 2.2 |
| 40 | 2.7 | 0.54 | 1.9 |
| 20 | 3.2 | | |

**(a)** Complete **Table 2.1** by calculating:

- the value of $I$ using the equation: $V = I R$ where *R* is the resistance of the fixed resistor
- the value of $1/I$.

Record both of your calculations in **Table 2.1** to a suitable number of significant figures.

**[3]**

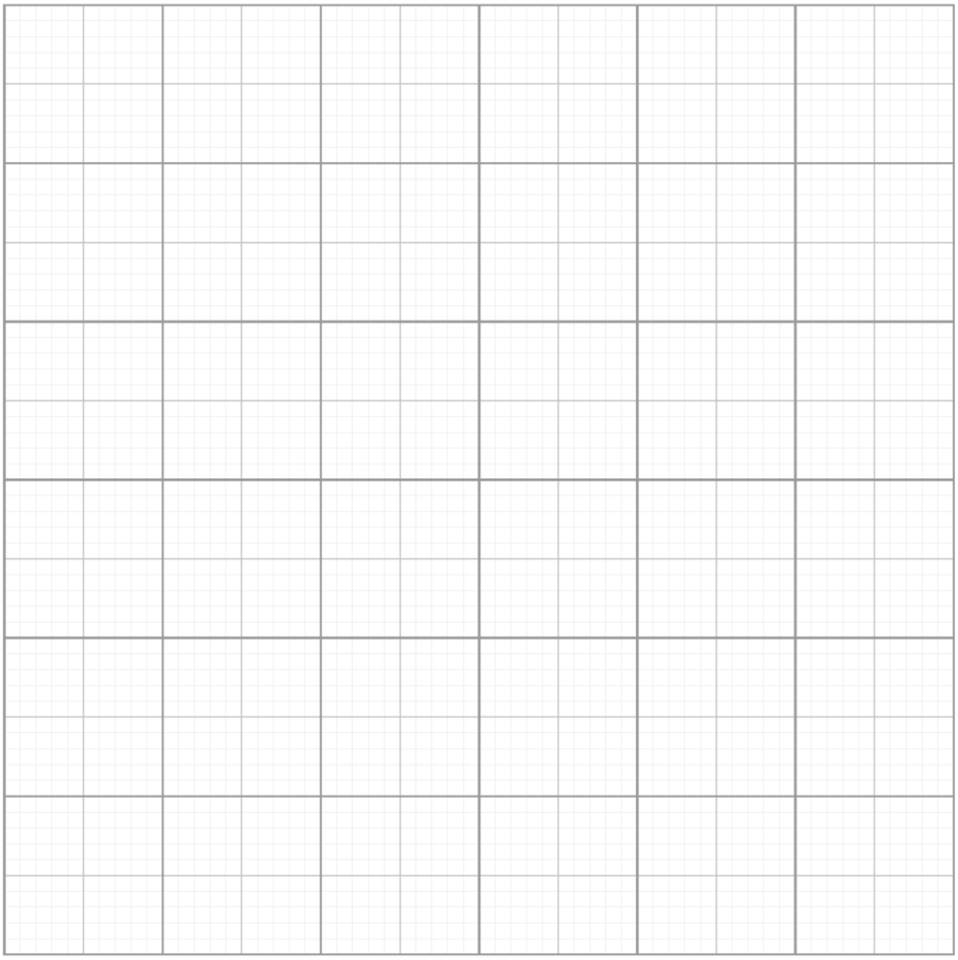
Nearly all candidates scored 3 marks on this question. Even where marks had been lost in the calculation of $I$ and $1/I$ the values calculated were both quoted to two significant figures. No ECF was allowed for correct calculation of $1/I$ from an incorrectly calculated value of $I$ in this simple calculation.

## Question 2 (b)

**(b)** Plot a graph of $1/I$ ($A^{-1}$) on the vertical axis against $L$ (cm) on the horizontal axis.

Start both axes at the origin (0, 0).

Draw the straight line of best fit. Extend this line to intercept the y-axis.



**[5]**

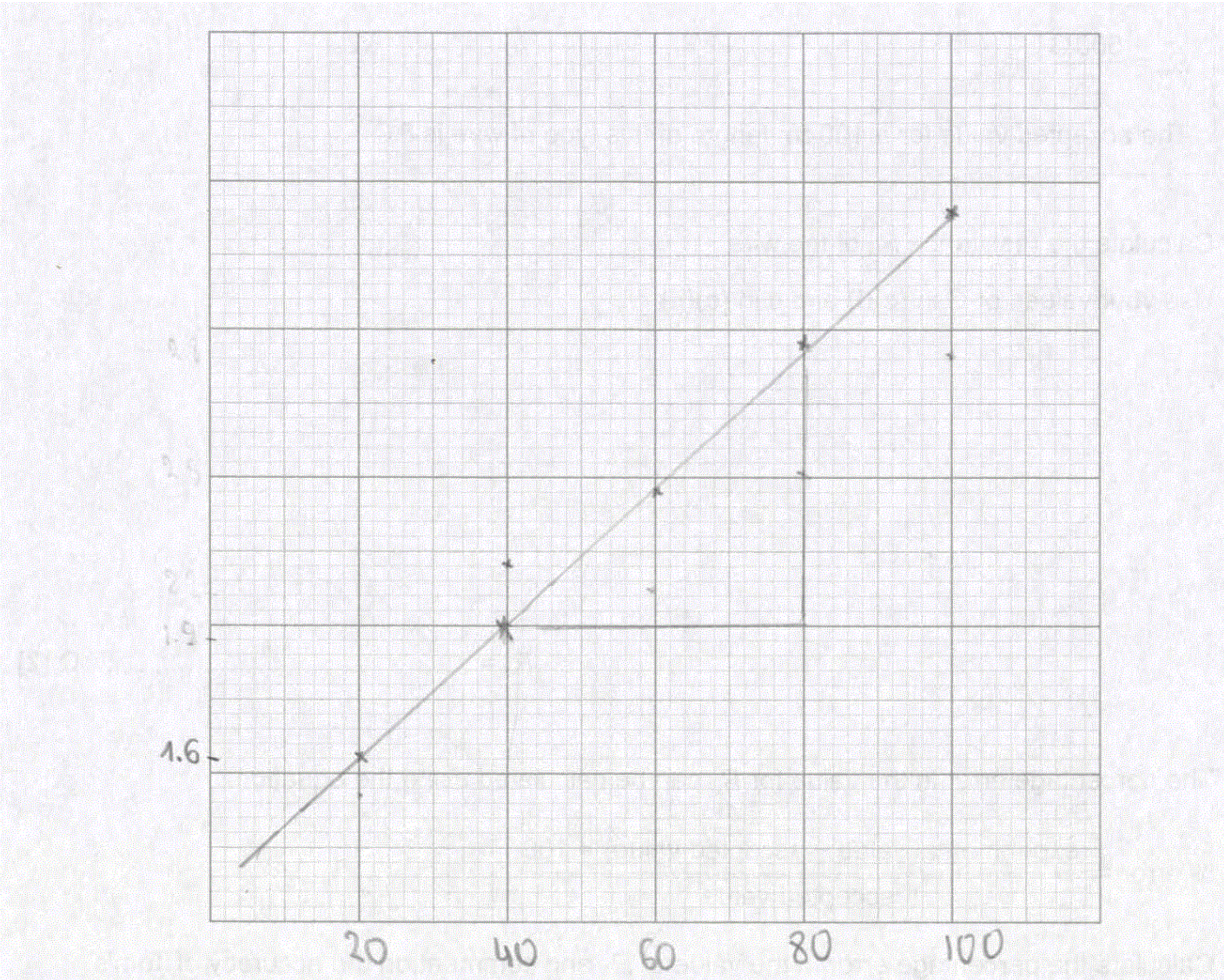
Nearly all candidates placed the axes in the correct orientation and labelled the axes with units included. In one or two cases the y-axis was labelled incorrectly as 1/*A* – but it was, nevertheless, to the candidates' credit that they had included units as part of the labelling.

Nearly all candidates selected scales for the y- and x- axes that were appropriate for the size of grid and ranges of values; in just one or two cases the scales selected were awkward or impractical when it came to the plotting of points and reading off values – in such cases this led to the loss of subsequent marks.

Nearly all candidates managed to plot points correctly to the nearest half small square, although candidates who had selected inappropriate scales for the y- and x- axes struggled. Crosses or points should be sharp and no more than one small square in size; many candidates draw thick and/or excessively large crosses/points.

The majority of candidates drew correct lines-of-best-fit which were sharp and continuous without feathering/sketching and which extended to the y-axis. There were, however, too many candidates who produced lines which were too thick – this was the most common error. Despite being prompted in the question stem, and again in Question (c)(ii), there were a handful of candidates who did not extend their line-of-best-fit to intercept the y-axis.

## Exemplar 2




This is a 1-mark exemplar. The candidate was given MP4 for having drawn a good line-of-best fit through the plotted points. The axes have not been labelled, neither are units stated, so MP1 cannot be given. A suitable scale has been constructed for the x-axis, but there is no scale constructed for the y-axis so MP2 cannot be given. In the absence of a scale on the y-axis MP3 cannot be given as the tolerance of the plotting of the points cannot be determined. Unfortunately, the line-of-best fit was not extended to intercept the y-axis, so MP5 cannot be given.

A triangle to the line-of-best fit has been drawn to determine its gradient for (c)(i), but it is not half the length of the drawn line required for the award of (c)(i) MP1.

## Question 2 (c) (i)

**(c)**
**(i)** On your graph show how to determine the gradient of the line of best fit.

Calculate the gradient *G* and its units.

Show your working.

*G* = ……………………………………… units …………………… **[4]**

As in previous series, determination of the gradient of a line-of-best-fit proved challenging for many candidates.

The points of the triangle (or in the case of a curve-of-best-fit, tangent) drawn should be at least half of the drawn-line-of-best-fit apart – many candidates chose to work with miniscule triangles.

Only a handful of candidates stated the x and y coordinates of the selected points (on this occasion, MP2 was given where the coordinates were stated in dy/dx).

In nearly all cases where triangles had been constructed candidates were able to calculate the relevant dy and dx values and substitute them into dy/dx accordingly. There were, however, a small number of candidates who instead of reading off dy and dx values as change in $1/I$ and change in L read them off in terms of number of small squares.

Derivation of the correct unit proved problematical for a number of candidates – a number of candidates who had correctly calculated the gradient did not gain MP4 because they stated an incorrect unit. No ECF was allowed for a gradient calculated correctly from an inaccurately drawn line, as MP4 was regarded as an accuracy mark.

## Question 2 (c) (ii)

**(ii)** Determine the value of the y-intercept, *c*, of your line of best fit.

*c* = ……………………………………… units …………………… **[1]**

This question presented few problems to candidates. The only candidates who struggled to read the y-intercept correctly were those who had chosen an awkward/impractical scale. Despite being instructed to do so previously in part (b), there were one or two candidates who had null responses for this question because they had not extended their line-of-best-fit to intercept the y-axis.

## Question 2 (d) (i)

**(d)** Tom's teacher says:

> You can calculate the resistance $R_w$ of the wire using the equation:
>
> $$R_w = \frac{500\,G}{c}$$
>
> The accepted value for a 100 cm length of this type of wire is 8 Ω.

**(i)** Calculate the resistance $R_w$ of the wire.

Use your values of *G* in **(c)(i)** and *c* in **(c)(ii)**.

$R_w$ = ………………………………………… Ω **[2]**

This simple substitution proved difficult for a number of candidates, who were unable to substitute their calculated values of G and c into the equation provided.

## Question 2 (d) (ii)

**(ii)** The percentage error in the value for $R_w$ can be calculated using the equation:

$$\% \text{ error} = \frac{(\text{experimental value} - \text{accepted value}) \times 100}{\text{accepted value}}$$

Calculate the percentage error in the value of $R_w$ and comment on the accuracy of Tom's results.

Percentage error = ………….…………............. %

Comment on accuracy ..........................................................................................................

.................................................................................................................................... **[2]**

The majority of candidates gained MP1 for substituting their calculated value of *R*w from (d)(i) into the equation provided, but a significant number of candidates variously rearranged the provided equation when substituting *R*w. Most candidates made a comment on the accuracy of the results, but only one or two justified their comment against a criterion (where a criterion was provided it was in nearly all cases within suitable limits).

## Question 2 (e)

**(e)** Use the data in **Table 2.1** to describe the relationship between *L* and *V*.

....................................................................................................................................

.................................................................................................................................... **[2]**

Nearly all candidates gained MP1 for identifying that as length decreased the voltage increased. A surprisingly small number referred to this relationship as a negative correlation. MP2 was not seen.

## Question 2 (f) (i)

**(f)** Tom says that the total supply voltage stayed the same during the investigation.

**(i)** What further evidence would make Tom's conclusion more secure?

................................................................................................................................ **[1]**

Only one or two candidates correctly referred to measuring the voltage drop potential difference across the battery/cell. Many candidates referred to measuring the voltage after the battery/cell.

## Question 2 (f) (ii)

**(ii)** Assuming that the total supply voltage remains constant, suggest an explanation for the trend in *V* in **Table 2.1**.

................................................................................................................................

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................................................................................................................................ **[2]**

Only one or two candidates understood that total voltage remains constant because as the voltage drop across the resistor increases the voltage drop across the wire decreases.

**Subject knowledge**

Candidates' knowledge of Unit 1, LO 6.1, "electrical properties", was not demonstrated. Unit 3 requires a secure underpinning knowledge of both Unit 1 and Unit 2 content.

## Question 3 (a) (i)

**3**

**(a)** Zac is a chemistry student investigating the thermal decomposition of iron(II) sulfate, $FeSO_4$.

When iron(II) sulfate is heated strongly it decomposes as shown in the following equation:

$$2FeSO_4(s) \longrightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

Zac does an experiment to determine the percentage yield of iron(III) oxide, $Fe_2O_3$ in this reaction.

He uses a data book to find the relevant molar masses.

| **Compound** | **Molar mass (g mol$^{-1}$)** |
|---|---|
| $FeSO_4$ | 152 |
| $Fe_2O_3$ | 160 |

Zac uses the following steps in his experiment:

1. Measure and record the mass of an empty crucible.
2. Put three spatula-fulls of iron(II) sulfate into the crucible.
3. Measure and record the mass of the crucible and its contents.
4. In a fume cupboard, heat the crucible using a Bunsen burner.
5. After ten minutes turn off the Bunsen burner and allow the crucible to cool down.
6. Measure and record the mass of the crucible and its contents.

He obtains the following results:

- Mass of empty crucible (step 1) = 50.32 g.
- Mass of crucible and iron(II) sulfate before heating (step 3) = 56.40 g.
- Mass of crucible and iron(III) oxide after heating (step 6) = 52.54 g.

**(i)** Calculate the mass of iron(II) sulfate used by Zac.

............................................................................................................................ **[1]**

Nearly all candidates selected the correct values provided to calculate the mass of iron (II) sulfate used, but many candidates then omitted to include the required unit (g). Some candidates included the molar mass of iron (II) sulfate in their calculation and/or mass of crucible and iron (III) oxide after heating, suggesting that they did not have practical experience of investigating thermal decomposition.

## Question 3 (a) (ii)

**(ii)** Zac calculates that 304 g of iron(II) sulfate should produce 160 g of iron(III) oxide.

Use the chemical equation and the molar masses to show that he is correct.

.......................................................................................................................................................

....................................................................................................................................................... **[1]**

This question proved challenging to candidates of all capabilities. Many candidates clearly understood the stoichiometry of the reaction, but struggled to construct an explanation that conveyed their knowledge.

## Question 3 (a) (iii)

**(iii)** Use your answer to **(a)(i)** and the information in **(a)(ii)** to calculate the mass of $Fe_2O_3$ that Zac should expect to produce in his experiment.

Expected mass = ................................................ g **[1]**

There were a significant number of null responses to this question, which led to null responses for Question 3(a)(v). Candidates who did attempt the question generally understood the proportionality involved and were able to use this knowledge to correctly calculate the expected mass of iron (III) oxide.

## Question 3 (a) (iv)

**(iv)** Use his experimental results to calculate the actual mass of $Fe_2O_3$ produced.

....................................................................................................................................................... **[1]**

There were a significant number of null responses to this question, which led to null responses for (a)(v). Candidates who had correctly answered (a)(i) generally answered this question correctly, whereas candidates who had experienced difficulty with (a)(i) also experienced similar difficulties with this question. As with (a)(i), many candidates who correctly calculated the mass of iron (III) oxide produced omitted to include the required units (g).

## Question 3 (a) (v)

**(v)** Use the following equation to calculate the percentage yield of $Fe_2O_3$.

$$\% \text{ yield} = \frac{\text{mass of product obtained} \times 100}{\text{expected mass of product}}$$

Percentage yield = ............................................ % **[1]**

There were a significant number of null responses to this question, invariably as a consequence of null responses to (a)(iii) and/or (a)(iv). Nearly all candidates who did attempt this question were able to correctly substitute their calculated expected mass of product and mass of product obtained into the equation to correctly calculate percentage yield.

## Question 3 (a) (vi)

**(vi)** Suggest how Zac could improve his experiment to make sure that the reaction had finished.

........................................................................................................................................ **[1]**

The vast majority of candidates did suggest that Zac should continue heating the crucible, but a significant number did not provide any indication as to when he should stop heating. A number of candidates were clearly thinking about other practical investigations and lost sight of the thermal investigation concerned as they referred to heating until bubbles no longer being produced.

## Question 3 (a) (vii)

**(vii)** Zac uses these definitions of experimental analysis to evaluate the investigation.

| Letter | Definition |
|---|---|
| **A** | Error due to measurements differing from the true value by a consistent amount. |
| **B** | Error due to measurements varying in an unpredictable way. |
| **C** | The closeness of agreement between measured values obtained by repeated measurements. |
| **D** | The closeness of a measurement to the true value. |
| **E** | The difference between a measured value and the true value. |

Write down which letter, **A**, **B**, **C**, **D** or **E** describes:

- Accuracy .....................
- Measurement error .....................
- Precision .....................
- Random error .....................
- Systematic error .....................

**[5]**

All but one or two candidates linked every definition with a term. Very few candidates selected five correct answers, the majority selecting two or three correctly. The majority of candidates were able to correctly define accuracy, with a smaller number correctly defining precision. Correct identification of the different types of error proved more problematic for candidates.

## Question 3 (b) (i)

**(b)** Jamila is a chemistry student investigating the rate of reaction between magnesium carbonate powder and hydrochloric acid.

She measures the volume of carbon dioxide produced at regular time intervals.

The table shows Jamila's measurements.

| **Time (s)** | 0 | 20 | 40 | 60 | 80 | 100 | 120 | 140 | 160 | 180 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Volume of $CO_2$ produced ($cm^3$)** | 0 | 24 | 44 | 56 | 68 | 74 | 82 | 87 | 91 | 93 | 95 |

**(i)** Describe the interval and range of Jamila's independent variable.

interval ....................................................

range ....................................................

**[2]**

Many candidates lost marks by omitting the required units (s/sec) from otherwise correct answers. A significant number of candidates were not given MP2 because they stated the range as 200 rather than 0–200.

## Question 3 (b) (ii)

**(ii)** Suggest why Jamila's range was **not** suitable.

.................................................................................................................................. **[1]**

A common response seen suggested that Jamila's time range was not suitable because it started at zero. A significant number of candidates did correctly identify that at 200 s the volume of carbon dioxide being produced was still increasing – candidates referred variously to the reaction not having finished or carbon dioxide/gas still being produced.

## Question 3 (b) (iii)

**(iii)** Jamila's experimental method is used by another student.

Suggest **three** pieces of information the student will need to know in order to obtain repeatable results.

1 ..............................................................................................................................

2 ..............................................................................................................................

3 ..............................................................................................................................

**[3]**

Candidates generally understood the information that would be needed to repeat the experiment. Unfortunately, many candidates referred to the amount [sic] of magnesium carbonate and/or hydrochloric acid or the strength of hydrochloric acid used, rather than mass, volume, or concentration as appropriate. Candidates who referred to the collection and measurement of the volume of carbon dioxide invariably only referred to one aspect, and many also referred to the amount of carbon dioxide collected.

## Question 3 (b) (iv)

**(iv)** Explain how Jamila will know whether the method is repeatable.

.............................................................................................................................. **[1]**

Nearly all candidates correctly stated that when repeated the method should produce the same/similar results.

## Question 3 (b) (v)

**(v)** Jamila uses the results to determine how the rate of reaction changes over time.

Using the data in the table:

- describe the trend in the rate of the reaction.

  ……………………………………………………………………………………………………

- justify your answer by determining the mean rate of reaction:
  - between 0 and 20 s.

    Rate = ……………………………………… $cm^3\ s^{-1}$

  - between 180 and 200 s.

    Rate = ……………………………………… $cm^3\ s^{-1}$

**[3]**

Only a small number of candidates correctly identified that the rate of reaction decreased with time; many candidates did not refer to the rate of reaction at all in their response but instead stated that the volume/amount (again) of carbon dioxide increased with time.

Calculation of the mean rates of reaction proved problematical for many candidates. A value of 12 $cm^3\ s^{-1}$ was commonly quoted for 0–20 s, while 94 $cm^3\ s^{-1}$ was commonly quoted for 180–-200 s.

### Assessment for learning

Centres should provide candidates with as many opportunities as possible to gain experience with the practical techniques specified within the Unit specifications for both this unit and Unit 2 (Laboratory techniques).

Centres should make sure that the correct equipment is used and the correct procedures are followed when conducting investigations, and that candidates understand why particular equipment is used and specific procedures followed.

## Question 4 (a) (i)

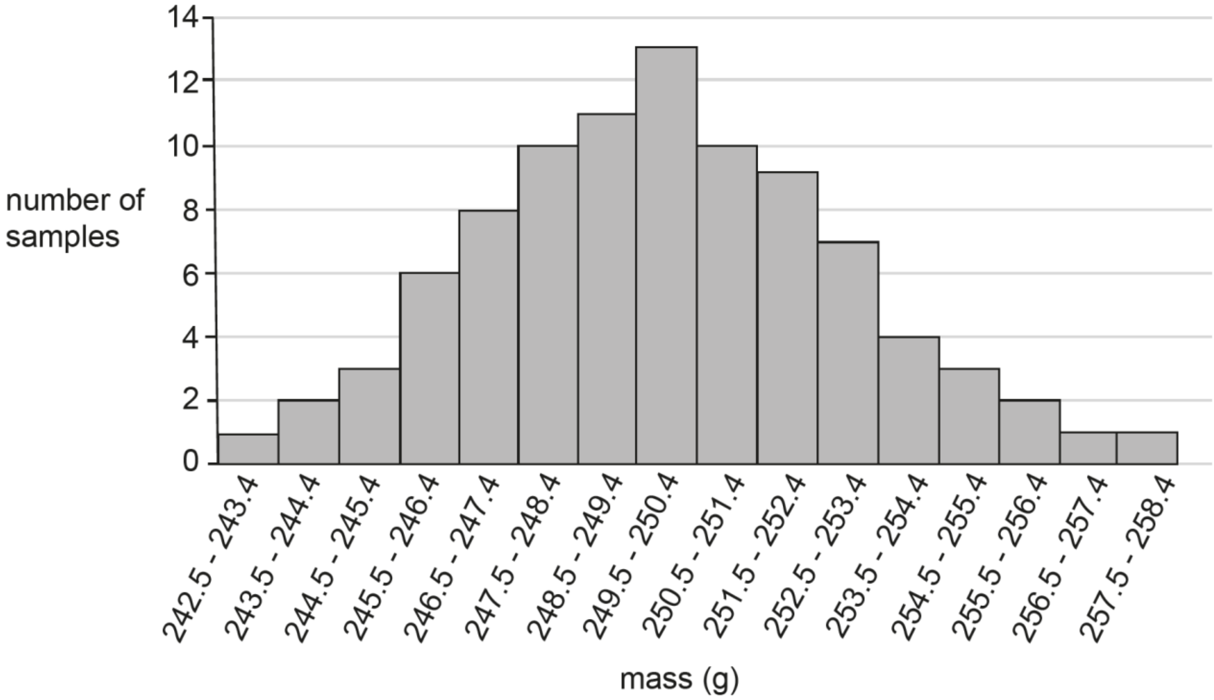
**4** Sara is an engineer working for a company in the food industry. She works on a production line which dispenses cocoa powder into tins.

She needs to ensure that the filling machine is delivering the correct amount of cocoa powder into each tin. She does this using a sampling technique.

She randomly removes a tin of cocoa from the production line and weighs it. She subtracts the mass of the empty tin and records the mass of cocoa powder to one decimal place. She repeats this process at regular intervals.

**(a)** Sara groups the masses into ranges and counts how many samples fall into each mass range. She then displays her results as shown in **Fig. 4.1**.

**Fig. 4.1**



**(i)** From the list below choose the type of graph shown in **Fig. 4.1** and explain why it is appropriate for this data.

Tick (✓) **one** box.

| | |
|---|---|
| Bar chart | ☐ |
| Histogram | ☐ |
| Kite diagram | ☐ |
| Pie graph | ☐ |
| Scatter graph | ☐ |

Explanation ..............................................................................................................................

.............................................................................................................................................. **[2]**

The majority of candidates correctly identified Fig. 4.1 as a histogram, but a significant number thought it was a bar chart – no candidates selected the other alternatives. Candidates who had incorrectly identified the graph as a bar chart were consequently unable to gain MP2 as the justification required would have been incorrect for their selection. Many candidates did not justify the use of a histogram in terms of the data presented, but instead described how a histogram differs from a bar chart in its appearance.

## Question 4 (a) (ii)

**(ii)** Suggest why there is a variation in the mass of the samples.

..............................................................................................................................................

.............................................................................................................................................. **[1]**

A range of responses was seen to this question, but the majority of candidates answered in terms of accuracy or precision within the context of the question.

## Question 4 (a) (iii)

**(iii)** Sara planned to determine the mass of 90 samples, but on this occasion she weighed 91 samples.

Use the data displayed in **Fig. 4.1** to show how she knew that she had weighed 91 samples.

..........................................................................................................................................

.......................................................................................................................................... **[2]**

This question proved straightforward to nearly all candidates who identified that the sum of all the samples added up to 91. Nearly all candidates gained both marks.

## Question 4 (b) (i)

**(b)** Sara must test the reliability of the production process. She assumes that the data in **Fig. 4.1** is normally distributed and uses her data to calculate the 95% confidence interval for the mean mass.

The 95% confidence interval is the range of values that she would expect the mean mass to fall between 95% of the time.

The 95% confidence interval can be calculated using the following equation:

$$95\% \text{ confidence interval} = \bar{x} \pm \frac{1.96\,s}{\sqrt{n}}$$

where n is the number of samples = 91

s is the standard deviation = 3.07

$\bar{x}$ is the mean mass of cocoa = 250 g

**(i)** Use these values to determine the 95% confidence interval.

95% confidence interval = ……………….. g ± ……………….. g **[1]**

Despite being directed on the answer line to state the 95% confidence interval and being provided with a specific answer space, a number of candidates stated the lower and upper limits of the 95% confidence range even though the values made little sense in the answer space provided (and the same information was then requested in (b)(ii)). However, the majority of candidates did correctly state the mean mass of cocoa dispensed and the correct interval.

## Question 4 (b) (ii)

**(ii)** Calculate the lower and upper limits of the mean masses within the 95% confidence limit.

Give your answers to **one** decimal place.

Lower limit = ………………………………………… g

Upper limit = ………………………………………… g
**[2]**

The majority of candidates were able to use their answers from (b)(i) to correctly calculate the lower and upper limits of the 95% confidence limit, although a small number overlooked the instruction to state the values to one decimal place – where values were quoted to one decimal place they were invariably rounded correctly.

## Question 4 (b) (iii)

**(iii)** To comply with the company's regulations, the mean mass of cocoa in the tins must lie between 249.5 and 250.5 g.

Suggest **two** reasons why the company specifies an upper and lower limit.

1 ……………………………………………………………………………………………………

2 ……………………………………………………………………………………………………
**[2]**

This question proved challenging for nearly all candidates. Many candidates referred to tins being overfilled without explaining how this would affect profits or suggesting that overfilling might lead to overspill. Many candidates referred vaguely to tins of varying weight/content being unfair on customers. Only one or two candidates considered the consequences to the business of customers receiving under-filled tins.

## Question 4 (b) (iv)

**(iv)** Sara looks at her calculations and concludes that she cannot be sufficiently confident that the mean mass of cocoa is between 249.5 g and 250.5 g.

Explain why you think Sara's conclusion is correct.

.......................................................................................................................................

....................................................................................................................................... **[1]**

A significant number of responses referred variously to masses of cocoa/tins being outside the range quoted in the question, only a minority of candidates appreciated the relationship between the quoted range and the 95% confidence interval and answered appropriately.

## Question 4 (b) (v)

**(v)** Calculate the smallest value of s (the standard deviation) which would be needed to give a mean mass range of 250 ± 0.5 g with a sample size of 91 and a confidence level of 95%.

Use the formula:

$$\frac{1.96\,s}{\sqrt{n}} = 0.5$$

**[1]**

The majority of candidates were able to rearrange the equation provided and substitute the correct value of n to calculate the standard deviation. Nearly all candidates did correctly substitute 91 for n. The principal cause of errors was incorrect rearrangement of the equation to determine s.

## Question 4 (b) (vi)

**(vi)** Suggest how the production process could be modified to reduce the value of s from 3.07 to the value you have calculated in **(b)(v)**.

.......................................................................................................................................

....................................................................................................................................... **[1]**

A significant number of candidates referred vaguely to using a different/better machine without mentioning the need for better accuracy/consistency/precision. A number of candidates referred to (re)calibration of the machine, not appreciating that it would have no effect on an inherently inconsistent/unreliable dispenser.

## Questions 5 (a) and (b)

**5** Ali and Ryan keep pet chickens. Sometimes the chickens lay eggs with soft shells.

Ali and Ryan use a titration technique to determine whether chicken eggs with soft shells contain less calcium carbonate than chicken eggs with normal shells.

They decide to extract the calcium ions, $Ca^{2+}$, from eggshells by dissolving the shell in acid and then titrating the solution with EDTA.

They use the following steps:

**Step 1** Determine the mass of a soft eggshell.

**Step 2** Break up the eggshell into small pieces and add excess dilute nitric acid.

**Step 3** When all the eggshell has dissolved, neutralise the solution from **Step 2** with dilute sodium hydroxide.

**Step 4** Transfer the solution from **Step 3** to a 250 $cm^3$ volumetric flask and make up to the mark with distilled water. This is **solution 1**.

**Step 5** Transfer 10.0 $cm^3$ of **solution 1** into a conical flask, add 5 $cm^3$ of ammonia buffer solution and then add a few drops of Eriochrome Black T indicator.

**Step 6** Titrate against 0.050 mol $dm^{-3}$ of EDTA solution.

**Step 7** Repeat **Steps 5** and **6** until concordant titres are obtained.

**(a)** Put a (ring) around the word that describes this type of titration.

**complexometric** **neutralisation** **precipitation** **redox**

**[1]**

**(b)** Tick (✓) the box that shows the colour change of the indicator at the end point of this reaction.

Blue to red ☐

Colourless to red ☐

Red to blue ☐

Red to colourless ☐

**[1]**

The whole range of options for both (a) and (b) was selected by candidates. It was evident that candidates' knowledge and understanding of titrations in general, not just complexometric titrations, was poor and that many candidates had only limited practical experience of performing titrations.

## Question 5 (c)

**(c)** State what **concordant titres** means.

........................................................................................................................ $cm^3$ **[1]**

A significant number of candidates referred to similar values or values being close to each other without stating a volume, even those candidates who specified volumes within 0.1 $cm^3$ very often overlooked the fact that it is two titres that are concordant – invariably the volume specified was correct. There were a number of responses where a seemingly random volume had been selected and stated without any explanation.

## Question 5 (d)

**(d)** Describe how the EDTA solution should be added to ensure accurate titre values are achieved.

........................................................................................................................

........................................................................................................................

........................................................................................................................ **[2]**

The majority of candidates understood that the titrant should be added dropwise while the analyte is swirled within the flask, although some candidates overlooked the second mark-point (just one or two candidates referred to the use of a magnetic stirrer as an alternative to swirling the flask). The idea of using deionised water to wash the titrant into the analyte was not seen.

## Questions 5 (e) (i), (ii), (iii), (iv) and (v)

**(e)** Ali and Ryan obtained the following results:

- Mass of one eggshell = 5.18 g.
- 27.05 $cm^3$ of 0.050 mol $dm^{-3}$ EDTA was required to react with 10.0 $cm^3$ of **solution 1**.

You will need to use the following equations in your calculations:

- Number of moles of a solution = $\frac{\text{concentration (mol dm}^{-3}\text{)} \times \text{volume (cm}^3\text{).}}{1000}$
- Number of moles of a solid = $\frac{\text{mass (g)}}{\text{molar mass (g mol}^{-1}\text{).}}$

**(i)** Calculate the number of moles of EDTA needed to reach the end point.

Number of moles EDTA = ……………………………………… mol **[1]**

**(ii)** One mole of $Ca^{2+}$ ions reacts with one mole of EDTA.

Deduce the number of moles of $Ca^{2+}$ ions in 10.0 $cm^3$ of **solution 1**.

Number of moles $Ca^{2+}$ = ……………………………………… mol **[1]**

**(iii)** The number of moles of $Ca^{2+}$ ions in 250.0 $cm^3$ of **solution 1** is equal to the number of moles of $CaCO_3$ in the eggshell.

Calculate the number of moles $CaCO_3$ in the eggshell.

Number of moles $CaCO_3$ = ……………………………………… mol **[1]**

**(iv)** The molar mass of $CaCO_3$ is 100.1 g $mol^{-1}$.

Calculate the mass of $CaCO_3$ in the eggshell.

Mass of $CaCO_3$ = ……………………………............. g **[1]**

**(v)** Calculate the percentage by mass of $CaCO_3$ in the eggshell.

Give your answer to **three** significant figures.

Percentage by mass = ……………………………............. % **[2]**

Many candidates found this series of calculations challenging; there were a significant number of candidates who did not attempt any of the calculations, while other candidates did not progress beyond (e)(i) or (e)(ii). Some candidates who progressed through the various calculations did not appreciate that their responses were obviously incorrect and should be checked, but, nevertheless, persisted and were able to gain marks through ECF, although it was evident that they had little understanding of how the calculations linked together or of what was being calculated.

A significant number of candidates did not appreciate the simple 1:1 stoichiometry in the reaction between calcium ions and EDTA in (e)(ii) and calculated wide range of values for the number of moles of calcium ions in solution 1. This was a principal source of error being introduced into subsequent calculations.

## Question 5 (f)

**(f)** Ali and Ryan read that the percentage by mass of $CaCO_3$ in a normal eggshell should be between 95 and 97%.

Evaluate whether Ali and Ryan's titration proves that soft-shelled eggs contain less $CaCO_3$ than normal eggshells.

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

........................................................................................................................................ **[3]**

Candidates who had not calculated the percentage by mass of calcium carbonate in the eggshell were unable to access MP1 as the evaluation was required to be based on their answer in (e)(v), although MP2 and MP3 were still accessible.

All candidates who calculated a percentage by mass in (e)(v) made the correct assessment about the calcium carbonate content of soft-shelled eggs based on their calculation.

No candidates commented on the fact that only one egg had been tested nor that the experiment should be repeated on other eggs.

**Assessment for learning**

Centres should provide candidates with as many opportunities as possible to gain experience with the practical techniques specified within the Unit specifications for both this unit and Unit 2 (Laboratory techniques).

Centres should make sure that the correct equipment is used and the correct procedures are followed when conducting investigations, and that candidates understand why particular equipment is used and specific procedures followed.

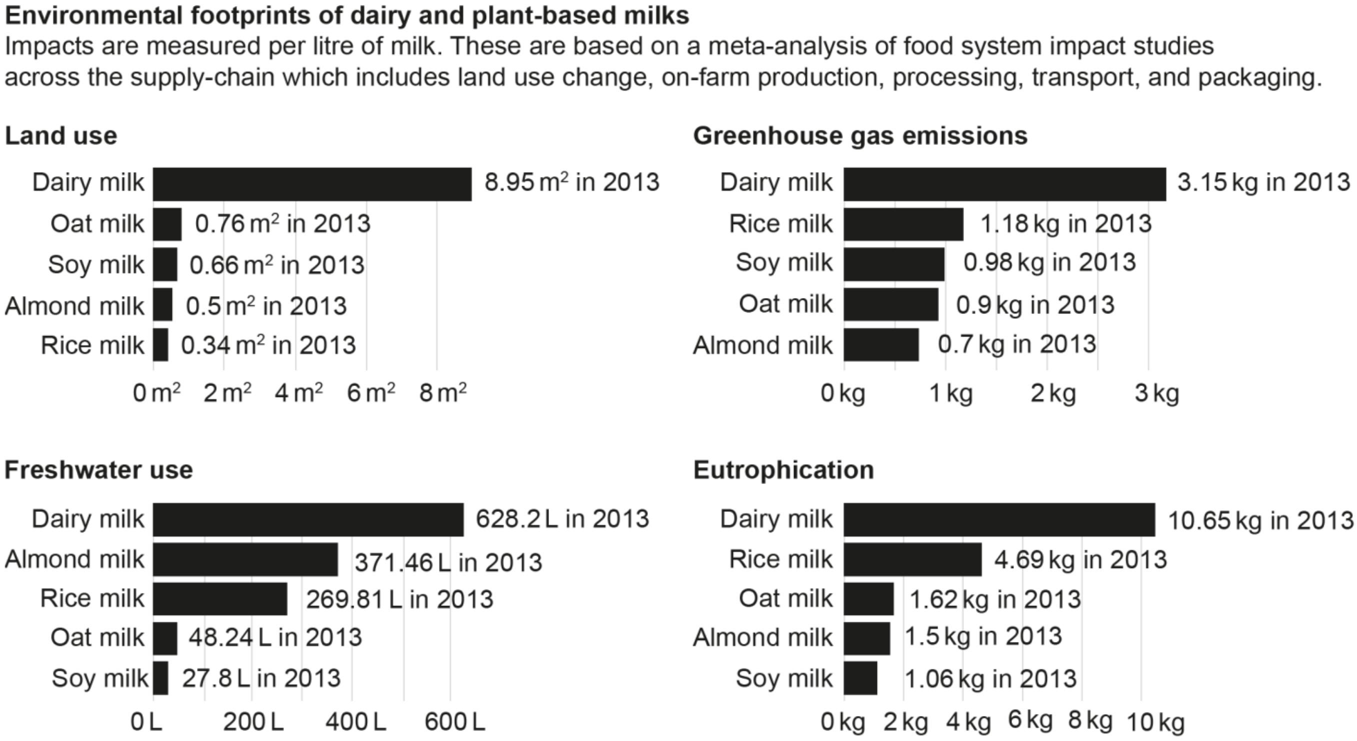
## Question 6 (a) (i)

**6** Some students are studying climate change.

As part of their investigation, they decide to compare the environmental impact of dairy and plant-based milks.

They found the graph shown in **Fig. 6.1**. It is part of a web page from a University of Oxford research group who collate global data from many sources. This page shows the environmental footprints of dairy and a range of plant-based milks.

**Fig. 6.1**




**Source:**
Poore, J & Nemecek, T (2018). Reducing food's environmental impacts through producers and consumers. Science, <https://OurWorldInData.org/environmental-impacts-of-food>

**(a)** The students say that the graph is secondary data.

**(i)** Describe what **secondary data** means.

............................................................................................................................................ **[1]**

This question proved to be straightforward, nearly all candidates understood that secondary data is data collected by another person/group.

## Question 6 (a) (ii)

**(ii)** Explain how the web page confirms that the data is secondary.

....................................................................................................................................

.................................................................................................................................. **[1]**

Nearly all candidates identified the source/reference in Fig. 6.1 as evidence of the secondary nature of the data displayed.

## Question 6 (a) (iii)

**(iii)** Explain why the students might think that the data has a high validity.

....................................................................................................................................

.................................................................................................................................. **[1]**

The overwhelming majority of candidates identified the fact that the data was from the University of Oxford as providing it with high validity, but it was rarely stated explicitly why data from the University of Oxford might have high validity. A small number of candidates referred in general terms to the data having been produced by academics or a research group in a trusted institution.

## Question 6 (b) (i)

**(b)** One of the intended audiences for the website is the public.

**(i)** Suggest **two other** audiences that would be interested in the data in the graph.

1 ..................................................................................................................................

2 ..................................................................................................................................
**[2]**

Nearly all candidates made two valid suggestions, with the whole range of options being seen. Some candidates offered "students" or "(general) public", overlooking the fact the question required them to suggest two audiences other than the public and that it was students studying climate change that were using the data.

## Question 6 (b) (ii)

**(ii)** Explain how and why the public might use the information in the graph.

........................................................................................................................................

........................................................................................................................................ **[2]**

This question proved to be a little more challenging for candidates. Many candidates did gain full marks, some candidates gained all three mark-points, but a significant number of candidates only gained one mark-point because they did not expand on their explanation.

### Exemplar 3

They can choose to stop buying dairy and plant-based milks or continue to buy them. **[2]**

This 1-mark response was given MP2 for the idea that the information provided in the graph would allow consumers to decide which milk to drink. However, the candidate has not expanded on the point made to explain that the choice would be based on an understanding of the environmental impact of milk production, nor that that the consequence of changing the preferred milk would be a reduction in environmental footprint.

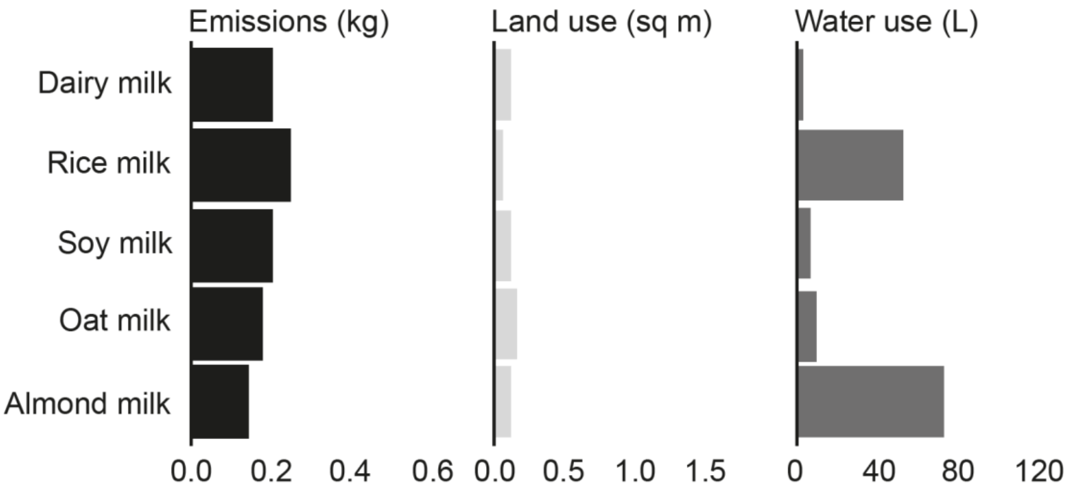
## Question 6 (c)

**(c)** The graph in **Fig. 6.2** is on a website published by the New Zealand dairy industry.

It uses the data shown in **Fig. 6.1** but has been amended using their own calculations.

**Fig. 6.2**

**Environmental impact of one glass (200 ml) of different milks**




**Source:**

Poore & Nemecek (2018), Science. Additional calculations, Poore, J <http://www.stuff.co.nz/national/2457029/1L-milk-creates-1kg-of-CO2> <https://www.dairynznewslink.co.nz/wp-content/uploads/2018/12/Dairy-sector-quick-facts-2017-18_Farms-and-herds_newslink-002_LATEST-VERSION-061218-1.pdf> <https://www.dairynz.co.nz/news/latest-news/how-now-new-zealand-cow/> <https://www.dairynz.co.nz/environment/water-use/water-use-calculator>

Suggest **two** reasons why the students might challenge the validity of the data in **Fig. 6.2**.

1 ..........................................................................................................................

2 ..........................................................................................................................

**[2]**

This question proved challenging for many candidates. There were many unqualified references to the data being biased or being from the dairy industry without explaining why the data might be biased or why data produced by the dairy industry might be suspect. A small number of candidates identified that the references provided were from the internet, but only one or two developed the point that online sources are not necessarily subject to peer review. No candidate compared the data displayed in Fig. 6.2 with that in Fig. 6.1 to make the point that the data in Fig. 6.2 makes the dairy industry appear a lot more environmentally friendly.

## Exemplar 4

1 Most likely not peer reviewed

2 They have bias (amended it themselves)

**[2]**

In this 1-mark exemplar, the candidate has made two statements about why the students might question the validity of the data in Fig. 6.2. MP3 was given for statement 1, although the candidate has not stated what it is about the source that suggests it might not have been peer reviewed – this was felt to be credit-worthy, but candidates should always justify their reasoning when responding to questions in which the command verb is "suggest". No credit was given for statement 2 as the reference to the data being biased was unqualified and did not explain that the nature of the bias was to make dairy milk appear more environmentally friendly (MP1). The candidate did not address the fact that the data was produced by an organisation with a vested interest in dairy farming.

## Question 6 (d)*

**(d)*** Discuss the scientific data in **Fig. 6.1** and **Fig. 6.2** considering the quality of the reporting in terms of clarity, conciseness and appropriateness for the intended audience.

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.................................................................................................................................. **[6]**

It was evident from the number of null responses and somewhat truncated answers to this question that a significant number of candidates had not allowed sufficient time for this level of response question.

This question proved challenging to candidates of all abilities, with only a handful of candidates managing to progress into Level 2. There were a significant number of candidates who did not progress beyond Level 0.

Marks within Level 1 were invariably gained from a simple comparison of the relative clarity of the two figures – a simple comparative statement about the relative clarity was worthy of 1 mark; 2 marks were given if some justification (use of units, utility of numbers, identification of year) was provided.

Those candidates who progressed to Level 2 provided some comments about the conciseness or, more usually, the appropriateness of the data. Comments about the appropriateness of the data invariably focused on the use of values per 200 ml in Fig. 6.2, which candidates identified as being equivalent to one glass of milk and, therefore, relevant to/understandable by the general public.

In general responses lacked clarity and succinctness and tended to be repetitive, with some candidates writing at great length for very little credit.

## Exemplar 5

In fig 6.1 it provides the public with clarity
with precise units and data along with the
year it took place in. With the variety of milk
used in food production/packaging helping
potential customers to gain conciseness and
appropriateness of the situation. Unlike 6.2
the lack of detail of key dates, key values
of how it impacts the environment within a
space of a year, losing clients/customer
with lack of clarity and conciseness.

This response was given 2 marks within Level 1. The candidate has included two valid points within the response to justify the award of Level 1 – this is the comparison between the relative clarity of Fig 6.1 and the lack of detail in Fig. 6.2. The award of the higher mark within Level 1 is justified because the candidate has qualified their comments about the clarity of the reporting by referring to the provision of dates and clear values and units in Fig. 6.1 when compared to Fig. 6.2. The candidate has made no comments about either the conciseness or appropriateness of the presentation of the data and so the response is limited to Level 1.

The award of marks for consideration of conciseness and/or appropriateness was made on a similar basis: the lower mark within the level for a simple comparison of the presentation of the data in the two figures, the higher mark within the level for a qualifying statement about the presentation of the data in the two figures. One level was given for each characteristic on which a valid comment was made.

In their response the candidate has referred to "the public" as the audience for Fig. 6.1. The audience is not relevant when considering clarity and can be ignored. When considering the appropriateness of the presentation of the data "the public" would be too vague a term as the intended audience for Fig. 6.1, unless subsequently qualified as being at least the scientific community with possible reference to a wider – informed – public.

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